USDA-ARS Developed Technologies for Recovering Manure Phosphorus

Ariel A. Szogi

AGRICULTURAL RESEARCH SERVICE
Coastal Plains Soil, Water and Plant research Center
Florence, SC

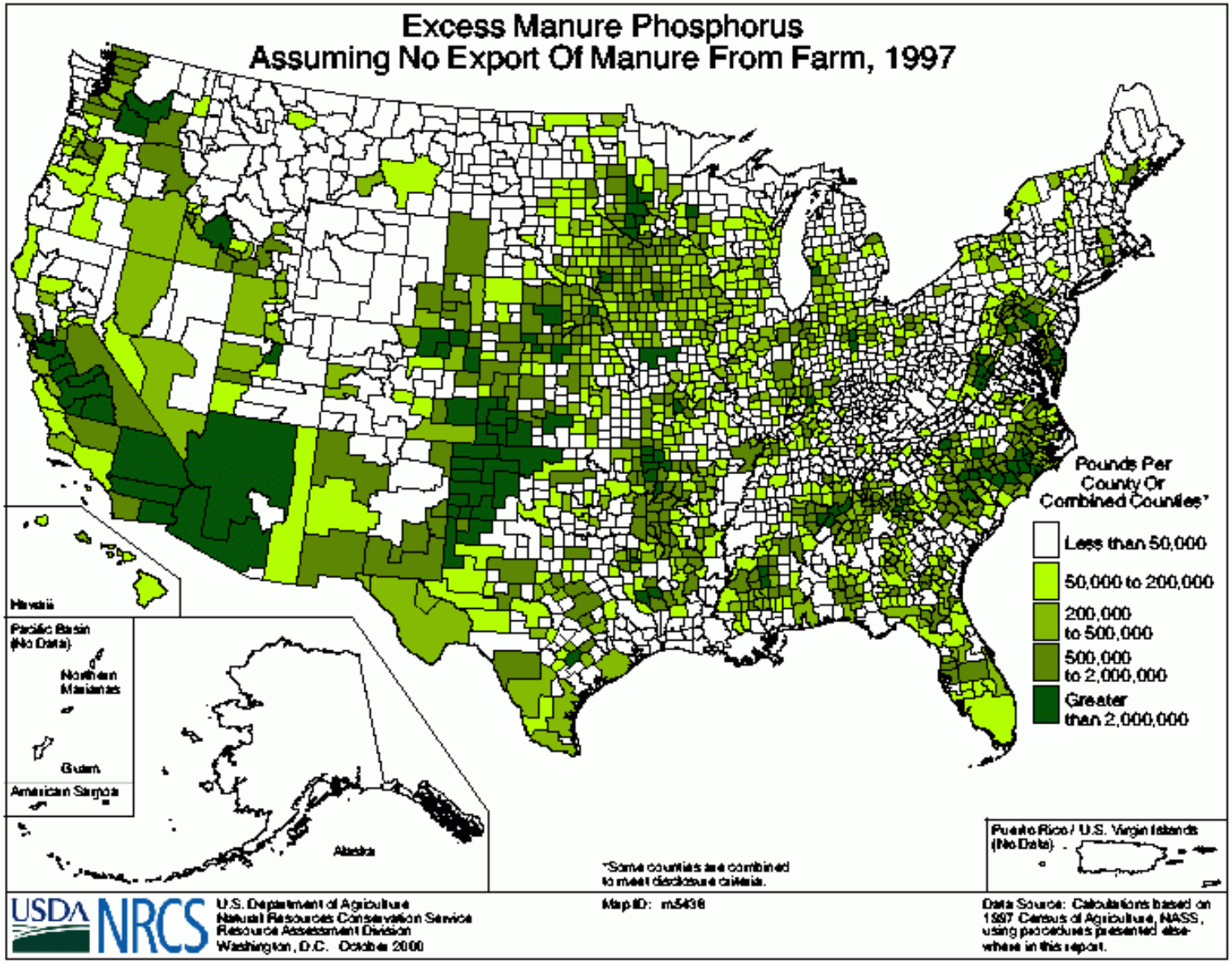
Summary

- Environmental issues – animal production
- Recoverable manure nutrients
- Phosphorus recovery from:

  - liquid swine manure
  - poultry litter

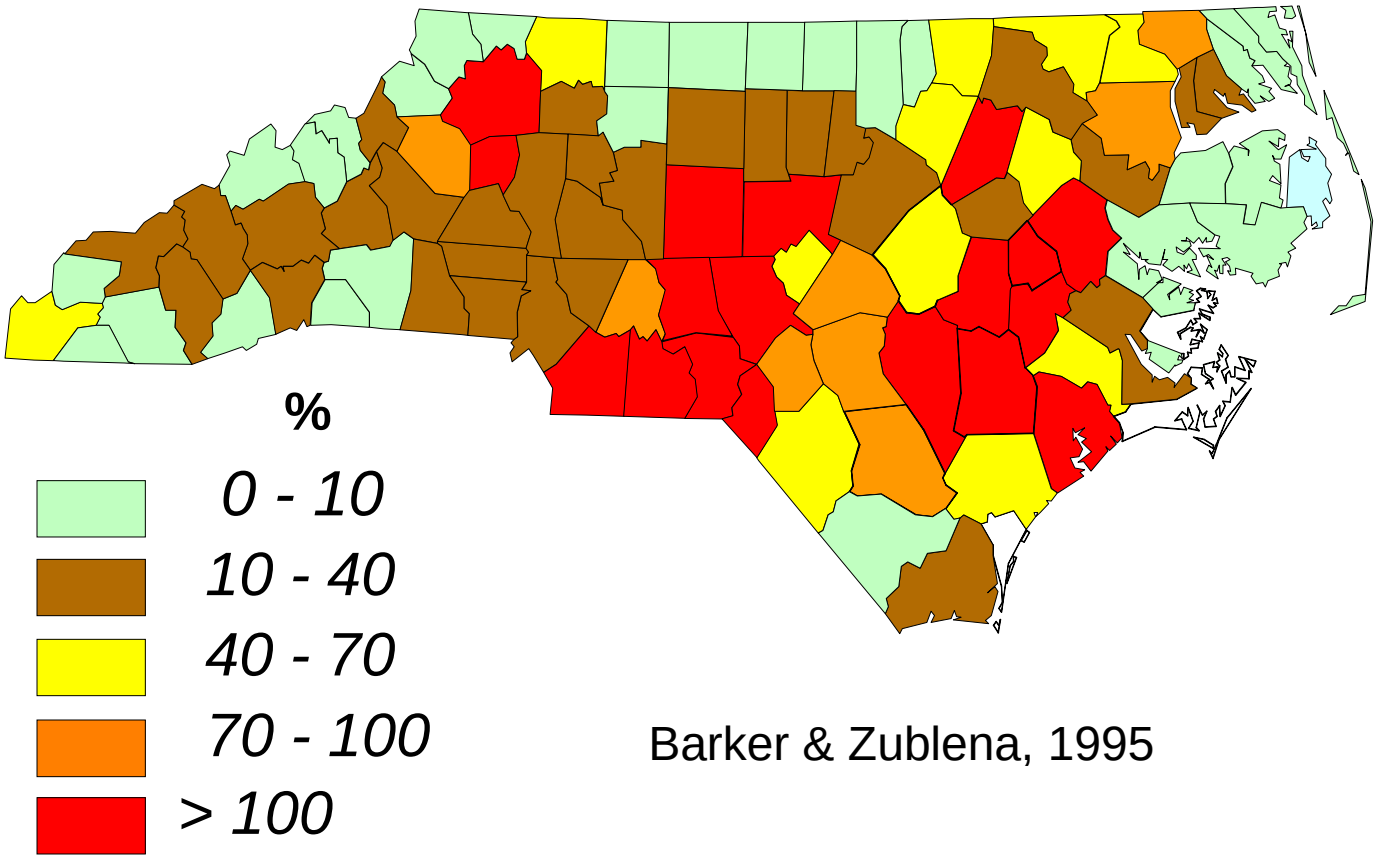
Environmental Issues
Sustainability of Animal Production

- Pollution concerns because of excess soil N & P
- Export or spatial transfer of nutrients with animal feed
- Imbalance of N:P ratio in animal waste


Excess Manure Phosphorus
Assuming No Export Of Manure From Farm, 1997
Pounds Per County Or Combined Counties*
Less than 50,000
50,000 to 200,000
200,000 to 500,000
500,000 to 2,000,000
Greater than 2,000,000
Hawaii
Pacific Basin (No Data)
Northern Marianas
Guam
American Samoa
Alaska
Puerto Rico / U.S. Virgin Islands (No Data)
*Some counties are combined to meet disclosure criteria.
USDA NRCS
U.S. Department of Agriculture
Natural Resources Conservation Service
Resource Assessment Division
Washington, D.C. October 2000
Map ID: m5436
Data Source: Calculations based on 1997 Census of Agriculture, NASS, using procedures presented elsewhere in this report.

Animal Manure – Excess P

Percent of Agronomic Crop and Forage Phosphorus Needs Supplied by Recoverable Plant Available Manure Phosphorus at the County Level in North Carolina



Barker & Zublena, 1995

Barker, J.C., and J.P. Zublena. 1995. Livestock nutrient assessment in North Carolina. p. 98–106. In Proc. 7th Int. Symp. on Agric. & Food Proc Wastes. Am. Soc. Agric. Eng., St. Joseph, MI.

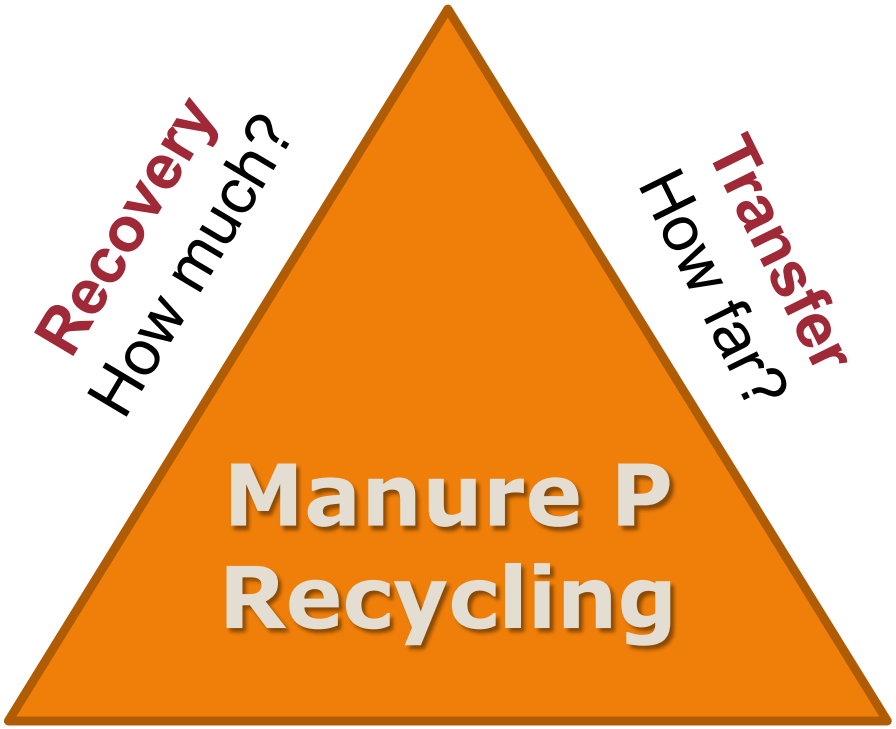
N:P Ratio – Selected Crops

Crop	N:P ratio
Bermudagrass	13.4:1
Tall fescue	11.9:1
Corn	7.5:1
Cotton	6.2:1
Ryegrass	3.3:1
Liquid swine manure	**3.2***
Poultry litter	**2.1:1 to 2.6:1**

Source: Edwards and Daniels, 1992; *Barker and Zublena, 1995

Edwards, D.R., and T.C. Daniel. 1992, Environmental impacts of on-farm poultry waste disposal. Bioresour. Technol. 41:9-33.

Livestock Manure Recycling of Excess P



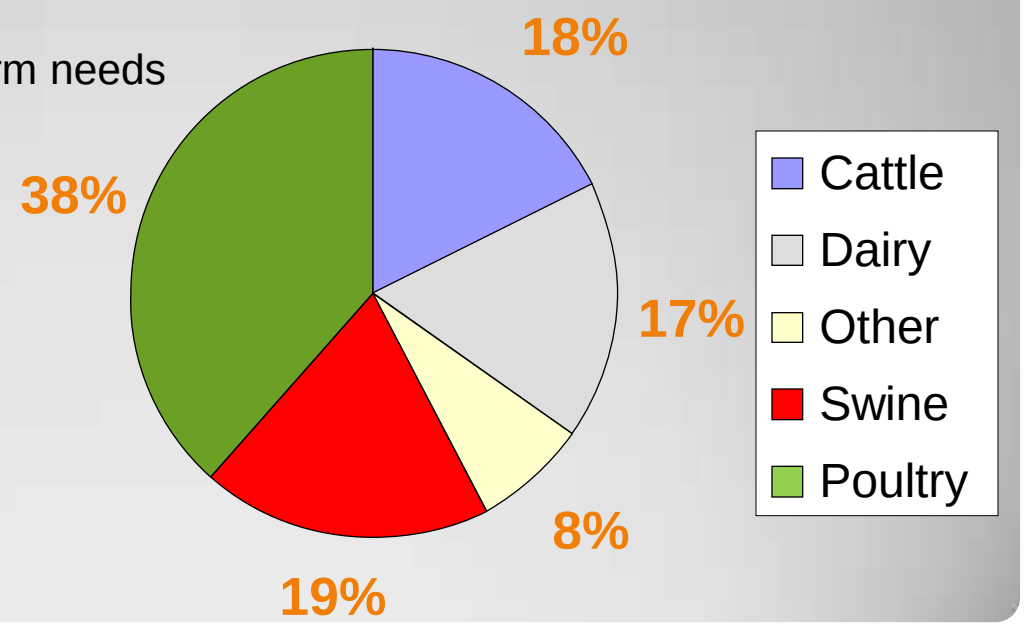
Utilization

Valuable byproducts?

Recoverable Manure P

How much?

- Quantity of the nutrient available for land application or utilization for other purposes
- Mass of nutrient per ton of manure remaining after nutrient losses during manure collection, transfer, storage, and treatment
- Total U.S. annual production of recoverable P_2O_5 = 650 M kg with 480 M kg in excess of on-farm needs
- Annual U.S. consumption P_2O_5 =1,680 M kg (PPI, 2002)
- Recovery of manure P could substitute about 25% of annual U.S. consumption of P

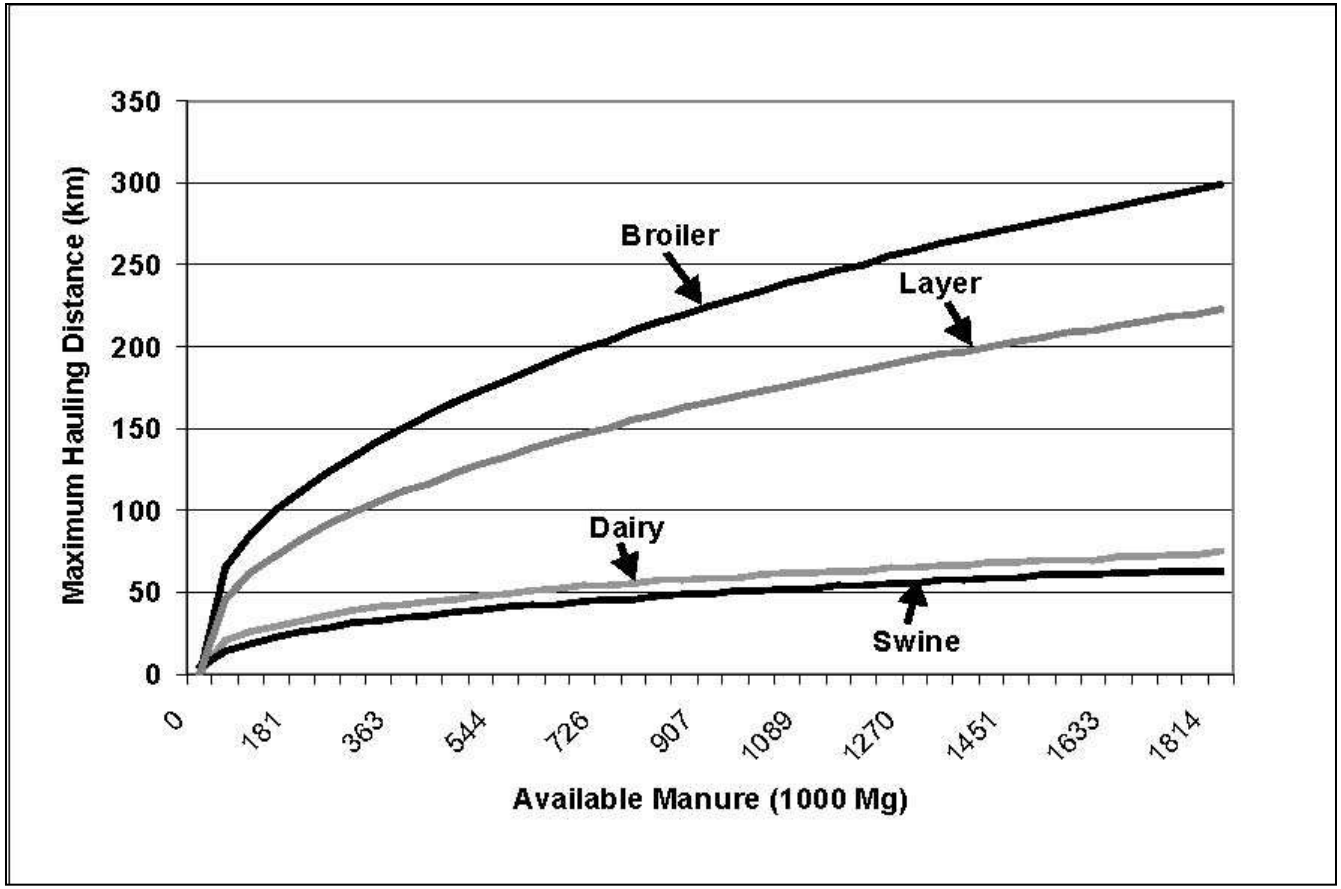


Source: USDA-ERS (Kellog et al. 2000)

Kellogg, R.L., C.H. Lander, D.C. Moffitt, and N. Gollehon. 2000. Manure nutrients relative to the capacity of cropland and pastureland to assimilate nutrients: Spatial and temporal trends for the United States. NRCS and ERS GSA Publ. No. nps00-0579. Washington, D.C.

Manure Transfer

How Far?



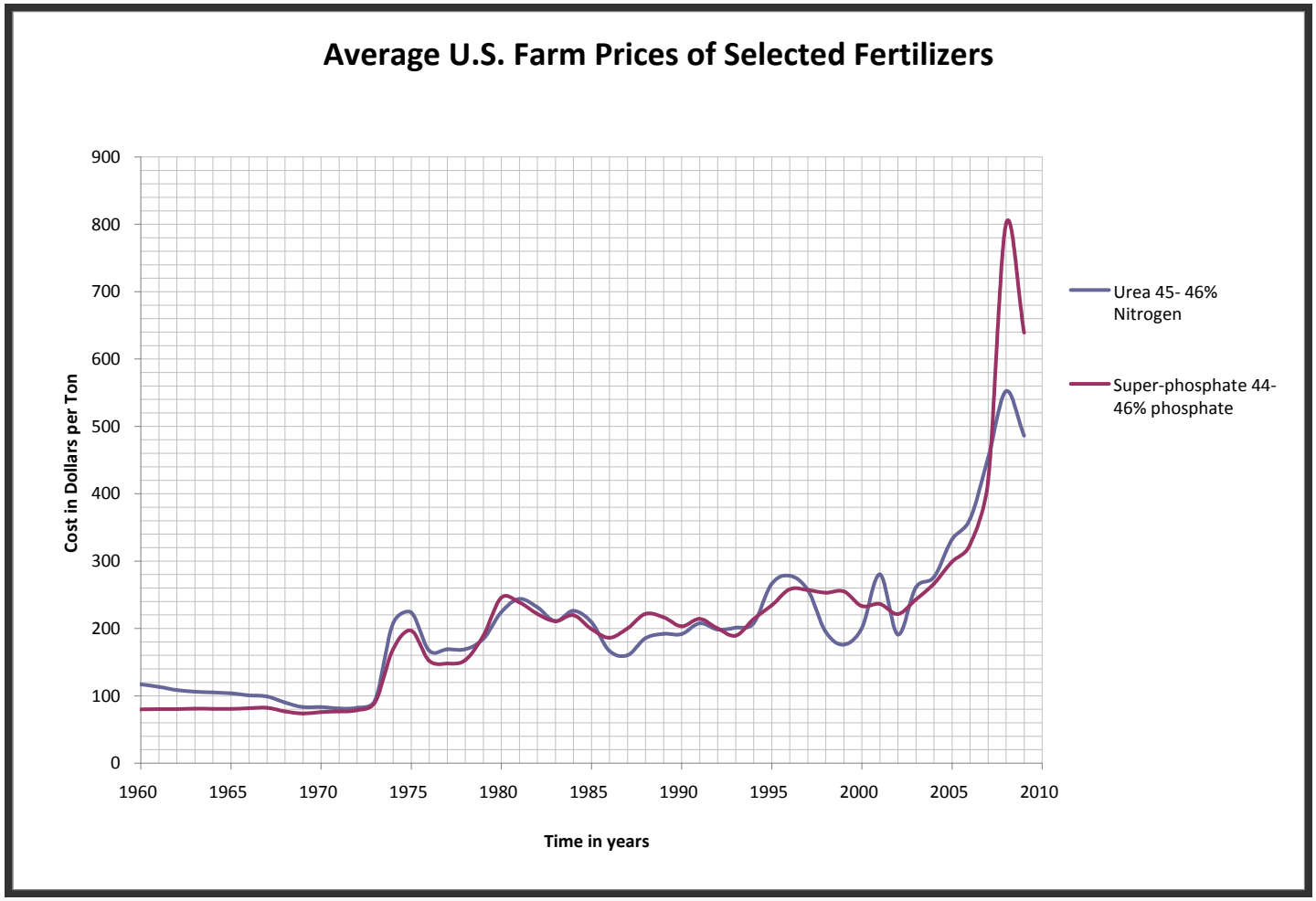
Source: Keplinger and Hauck, 2006

Keplinger, K.O., and L.M. Hauck. 2006. The economics of manure utilization: Model and application. J. Agric. Resour. Econ. 31, 424-440.

Global Use of Fertilizers

- World fertilizer prices soar:

  merge of food and fuel economies



Source: USDA-ERS, Fertilizer Use and Prices. http://www.ers.usda.gov/Data/FertilizerUse/

Utilization

Valuable byproducts?

- Compost
- Phosphates
- Organic soil amendments

Nutrients Recovered from Swine Manure

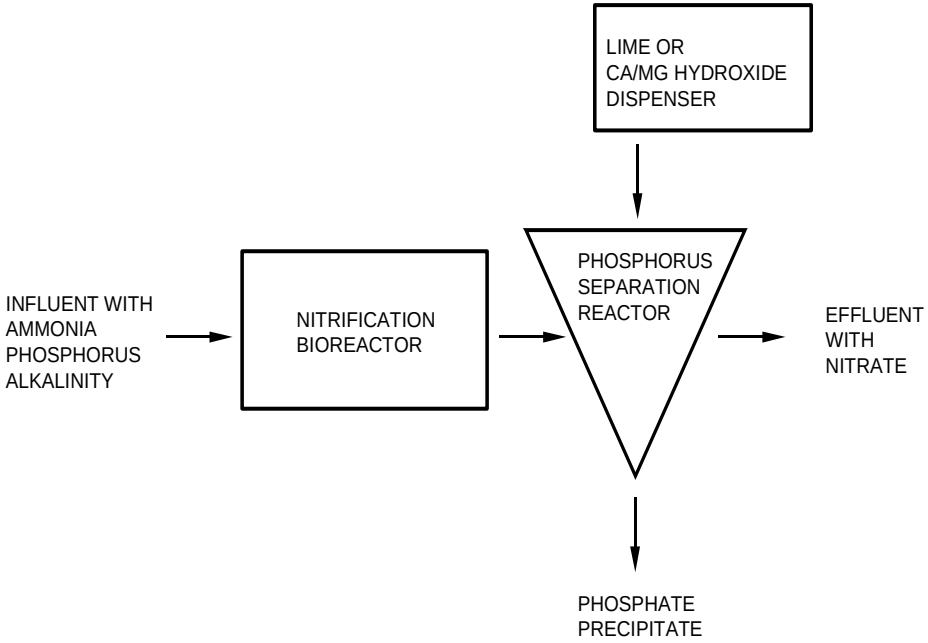
- Compost – N & P

- Phosphate

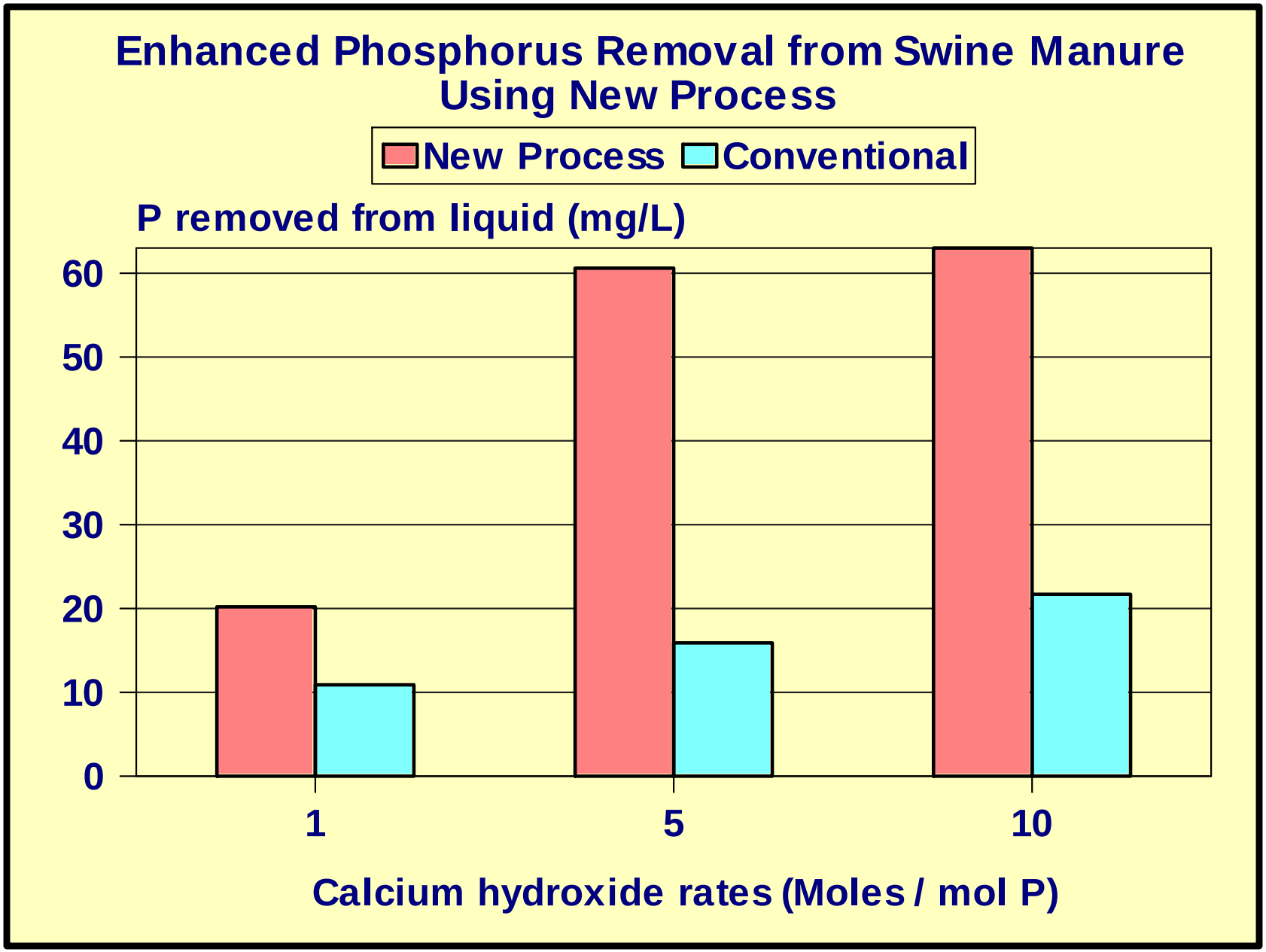
USDA-ARS Wastewater Treatment System

Phosphorus Removal and Recovery from Liquid Swine Manure

FIG. 1



Wastewater Treatment System
U.S. Patent 6,893,567 B1


Enhanced Phosphorus Removal from Swine Manure Using New Process
New Process
Conventional
P removed from liquid (mg/L)
60
50
40
30
20
10
0
1
5
10
Calcium hydroxide rates (Moles / mol P)

Environmentally Superior Technology (EST) State of North Carolina

- Permitable by government authority
- Technically, operationally and economically feasible

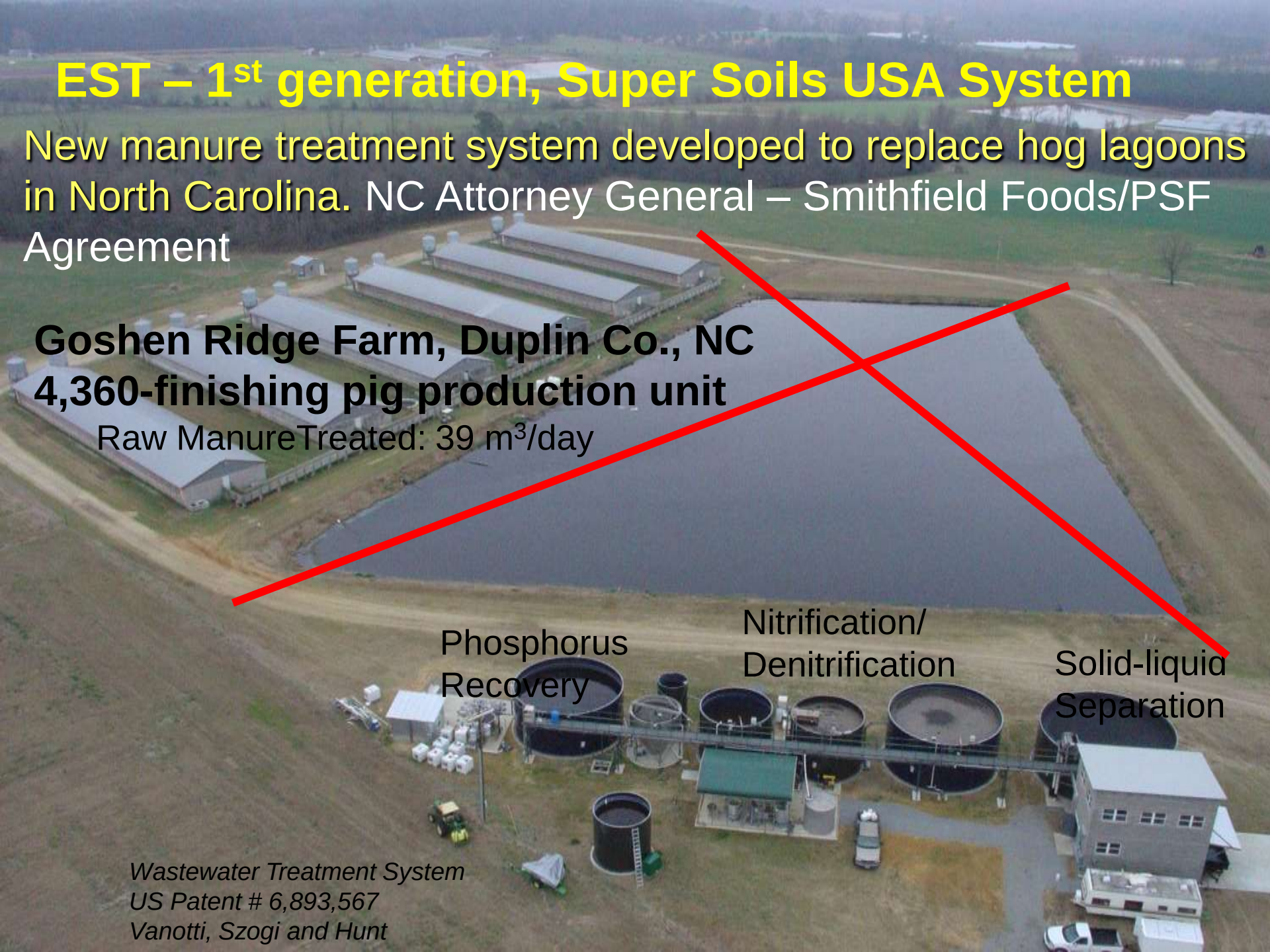
- Meets these environmental performance standards:
  - Eliminate discharge to surface and groundwater
  - Substantially eliminate ammonia emissions
  - Substantially eliminate odor emissions beyond farm boundaries
  - Substantially eliminate pathogens
  - Substantially eliminate nutrient and heavy metal contamination of soil and water.

EST – 1st generation, Super Soils USA System

New manure treatment system developed to replace hog lagoons in North Carolina. NC Attorney General – Smithfield Foods/PSF Agreement

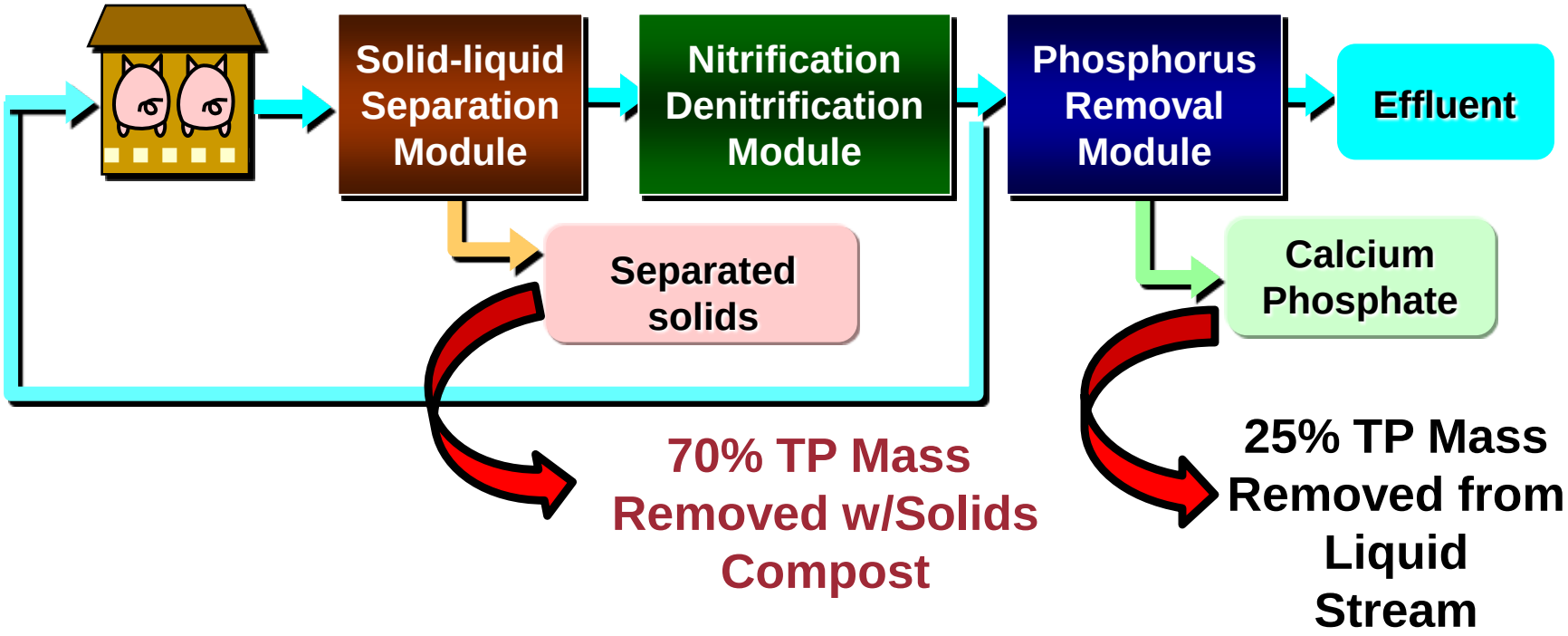
Goshen Ridge Farm, Duplin Co., NC
4,360-finishing pig production unit

Raw ManureTreated: 39 m^3/day



Wastewater Treatment System
US Patent # 6,893,567
Vanotti, Szogi and Hunt

EST On-Farm Treatment System



95% TP Removed from Farm

System Performance

2003-2004	INFLUENT (mg/L)	EFFLUENT (mg/L)	Efficiency (%)
Suspended Solids	11,051	264	98
Volatile solids	8,035	85	99
TKN	1,584	23	99
TAN	872	11	99
COD	16,138	445	97
BOD	3,132	10	100
TP	576	29	95
Cu	26.8	0.36	99
Zn	26.3	0.25	99


Separated Solids

Manure solids processed into plant growth media

Step 3: Phosphorus Removal

Dewatering and bagging of calcium phosphate

P sludge production = 700 kg/year

Recovered P in sludge = 99.5%

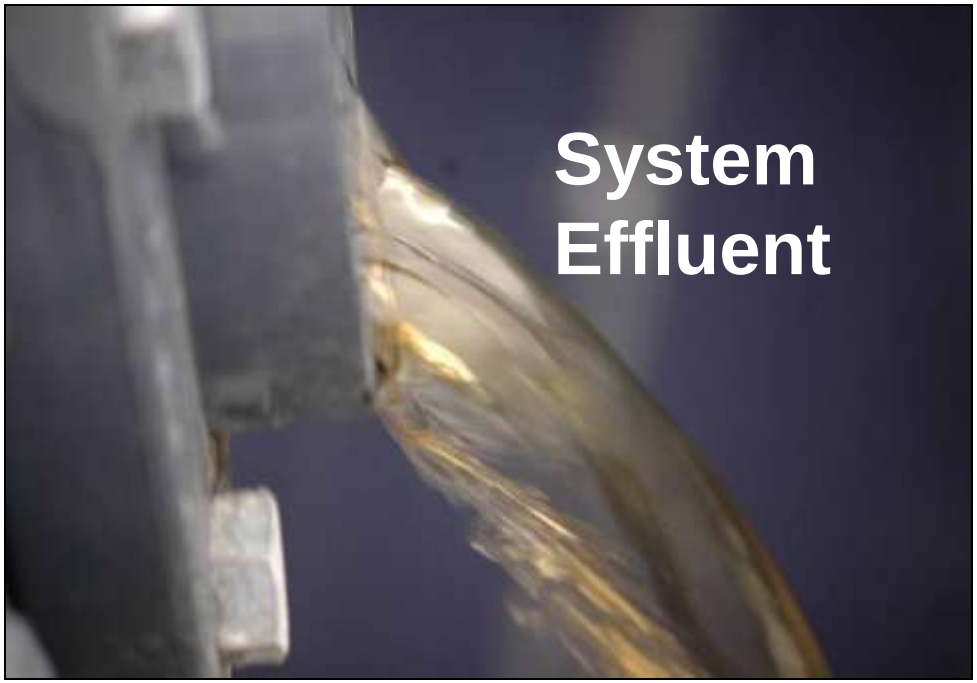
4,360 Finishers Production Unit

2nd Generation EST

2nd Generation System: 5600-finishing pigs in North Carolina

Nitrification/denitr.

Phosphorus
and pathogens



Vanotti, Szogi, Fetterman, U.S. Patent 7,674,379 B2. U.S. Patent and Trademark Office. 2010.

Benefits of new technology have potential to pay for all the cost of treatment

	Anaerobic Lagoon Technology	2nd Generation Superior Technology
	$ / 1000 lb SSLW / year	
Treatment Cost	**90**	**132**

Benefits of new technology have potential to pay for all the cost of treatment

	Anaerobic Lagoon Technology	2nd Generation Superior Technology
	$ / 1000 lb SSLW / year	
Treatment Cost	**90**	**132**
Carbon Credits Benefits	**0**	**32**
Productivity Enhancement Benefits	**0**	**120**

Compost – Swine Manure Solids

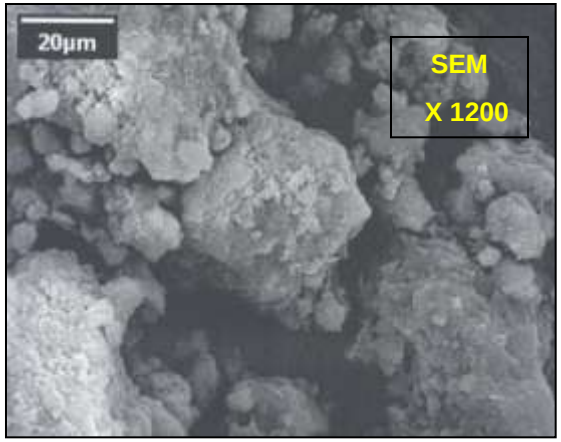
Constituent	Percentage
Total N	5.3
Total P	4.0
Calcium	2.3
Potassium	0.5
Magnesium	2.1

Separated solids composted with cotton gin residue

Recovered Phosphates

Chemical Composition

Constituent	Percentage
P_2O_5	24.4
Calcium	27.3
Potassium	0.9
Magnesium	1.8



Recovered P – Swine Manure Fertilizer Manufacture

Photos: ARS & IFDC

Poultry Litter

Manure + Bedding Material

Nutrients Recovered from Poultry Litter USDA-ARS Florence, SC

Washed Solids

Recovered P

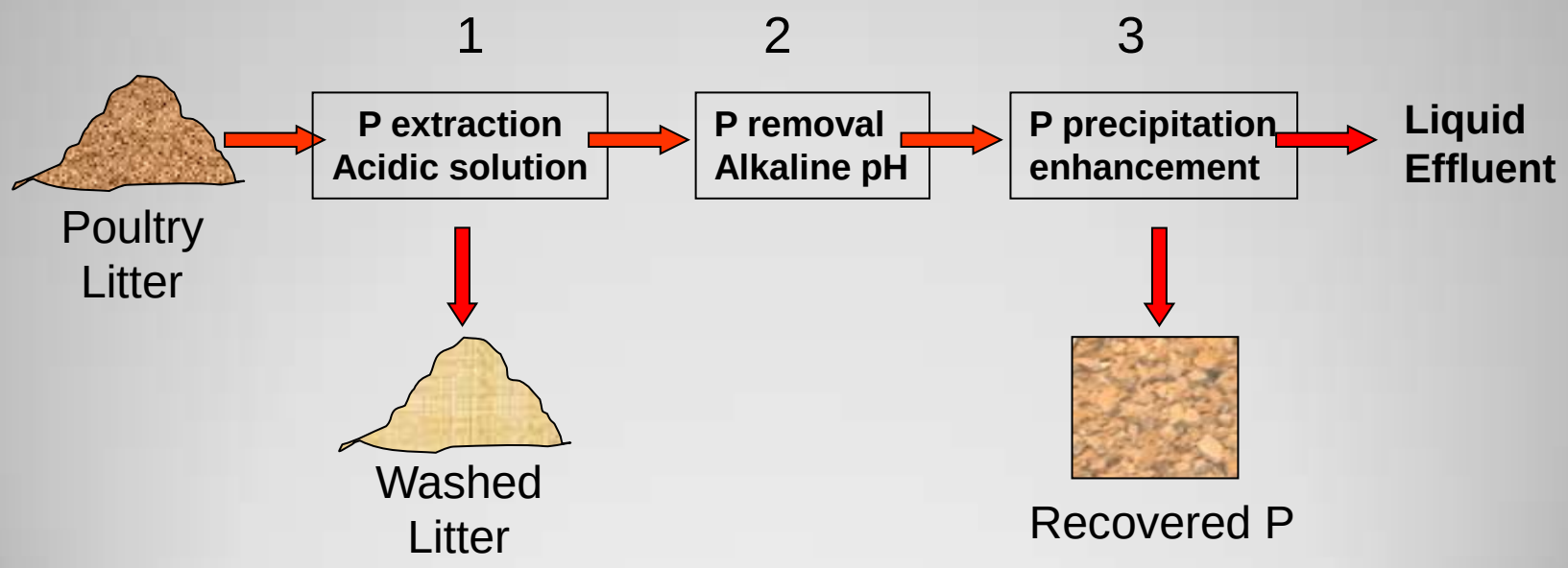
- **Process selectively extracts up to 80 percent of the phosphorus from poultry litter, but little of the nitrogen**

- **It produces two useful materials:**
  - **The washed solids, with a balanced N:P ratio for crop production**
  - **A "slow-release" phosphorus fertilizer**

- **ARS has granted an exclusive license to Renewable Organics LLC, of N.C., for the commercial development of the process**

Poultry Litter Phosphorus Removal and Recovery

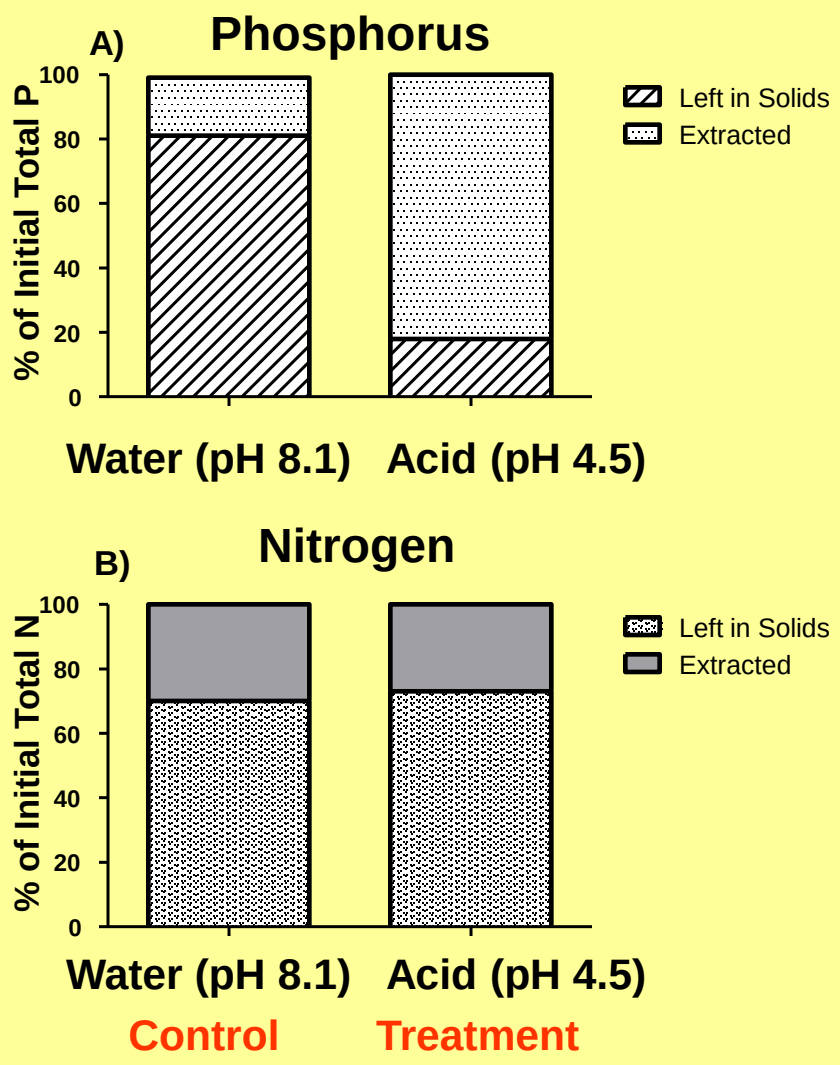
Quick Wash (Chemical) Process



Szogi et al. Process for removing and recovering phosphorus from animal waste. Patent Appl. No. 20090193863. U.S. Patent Office. Washington, DC.

Quick Wash

Selective Extraction of Phosphorus



N:P 1.8:1 5.8:1

Manure Wash Pilot Experiment

Quick Wash

Step 2
P removal
Lime addition
pH 9 - 10

Step 3
P enhancement
Flocculant addition
(PAM -)

Quick Wash
Products

Poultry litter after quick wash

P recovered from poultry litter

Phosphorus material recovered from poultry litter using the Quick Wash process

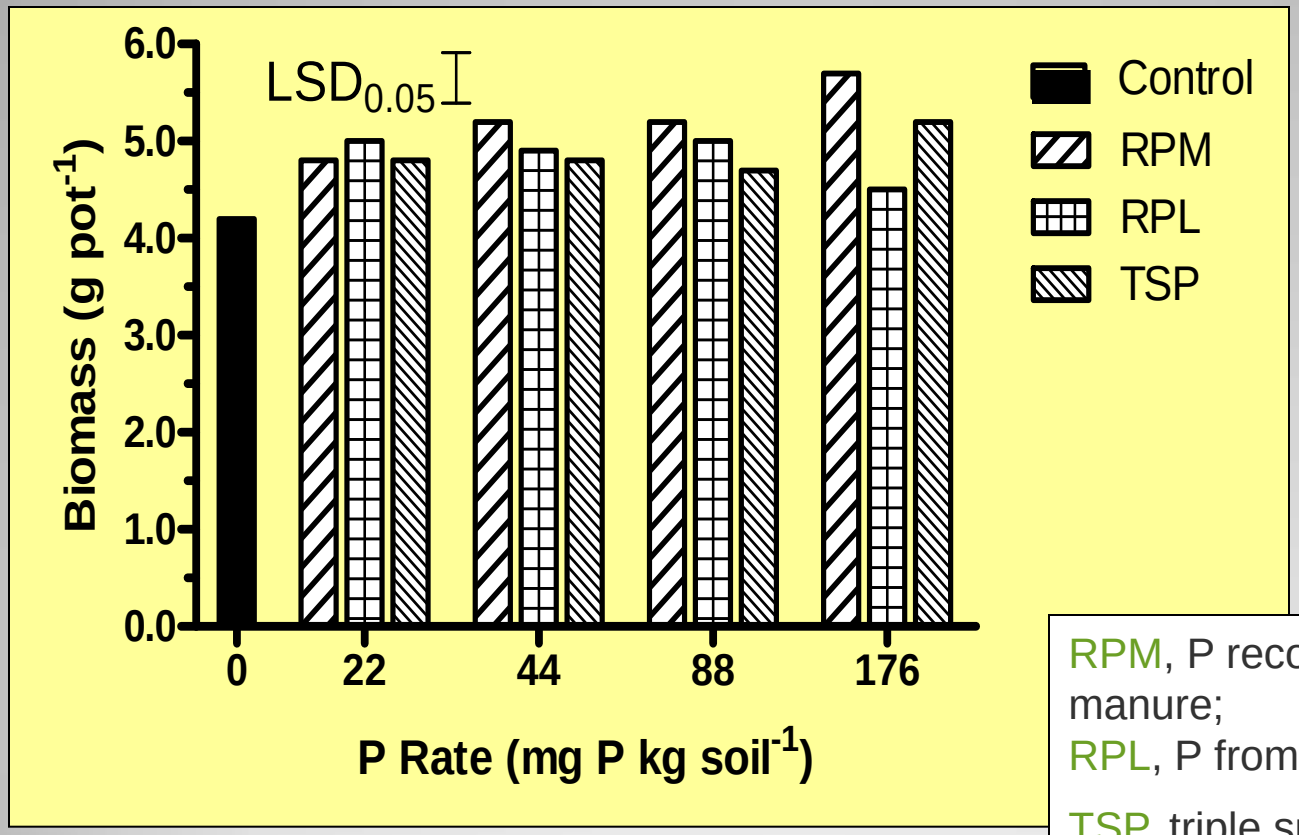
Constituent	Mean
	g per 100 g
Phosphorus	5.9
P_2O_5	13.5
Carbon	23.8
Nitrogen	2.4
Calcium	13.4
Magnesium	1.0
Potassium	1.1
Sodium	0.3

Use of Recovered Phosphate as Fertilizer

- Green house tests using P recovered from: 1) pig manure (**RPM**), and 2) from poultry litter (**RPL**)
- Applied at 0, 20, 40, 80 and160 mg/kg soil
- Commercial triple super phosphate (**TSP**) was used as fertilizer control

Plant : *Annual ryegrass*
Soil: *Uchee sand*
Amendment: Lime (pH ~6.5)
Air temperature: 25.5 – 32.0 ^{o}C
Biomass harvested @:
19, 34, and 47 d after planting

Effect of fertilizer material and P rate on ryegrass biomass



RPM, P recovered from pig manure;
RPL, P from poultry litter;
TSP, triple superphosphate.

Conclusions

- Nutrient recovery technologies offer the opportunity to resolve problems of excess application of manure phosphorus to land.
- N & P concentration in manure byproducts should be sufficiently high to allow long distance transportation.
- The aspect of P recovery and reuse is important for the global cycling of these nutrients (e.g.: energy savings and limited resource).

Relevant References: USDA-ARS Developed Technologies for Recovering Manure

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http://www.ars.usda.gov/main/site_main.htm?modecode=66-57-00-00