Building a Better Bay Model:

Agricultural Modeling

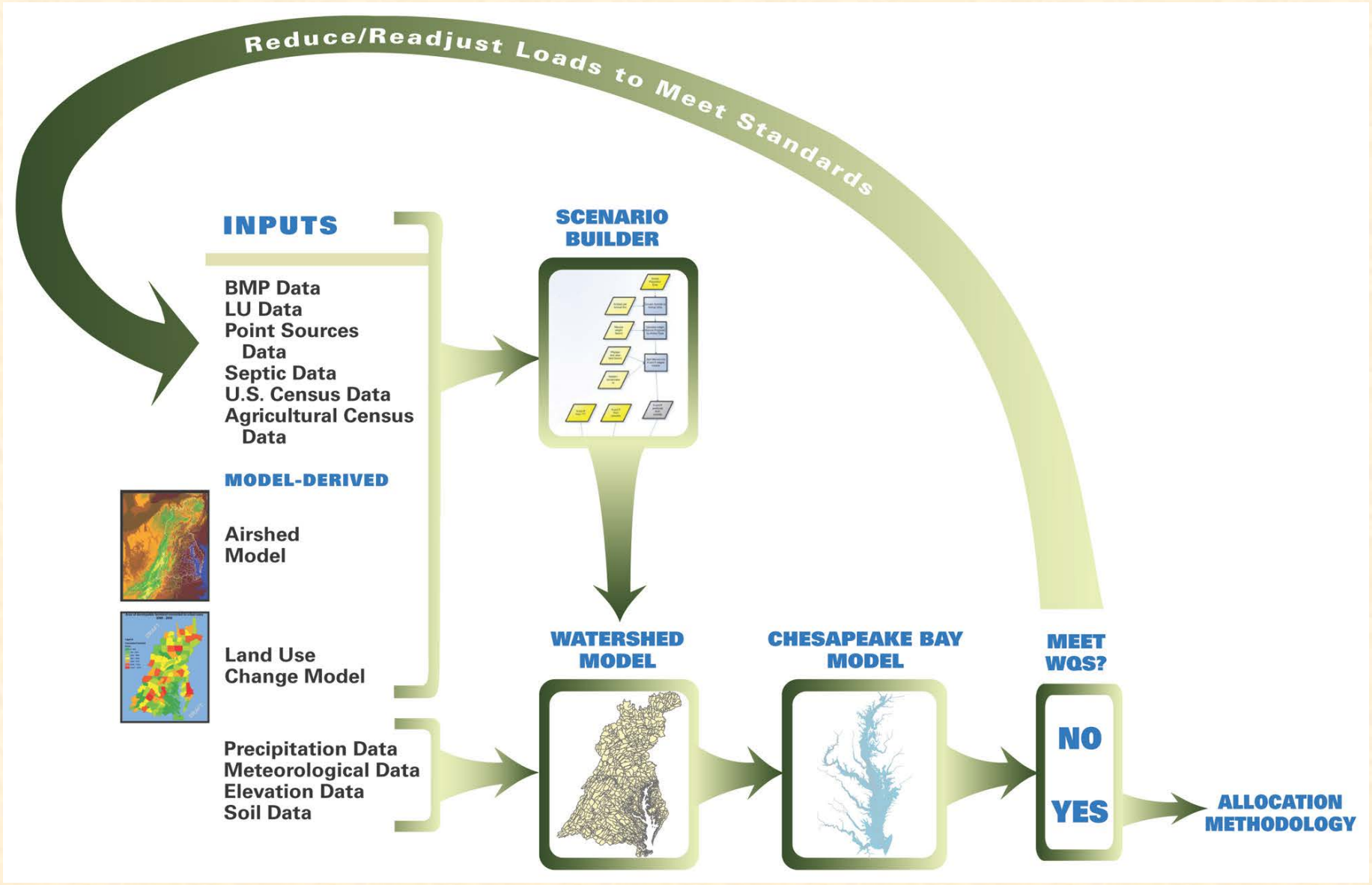
Agronomic Sessions

Nutrient Placement and Usage

Jeff Sweeney
Chesapeake Bay Program Office
jsweeney@chesapeakebay.net
410-267-9844

Building a Better Bay Model Workshop
Marriott Inn, University of MD - College Park Campus
Hyattsville, Maryland
May 22, 2013

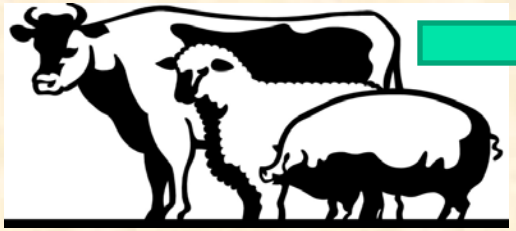
Chesapeake Bay Program Modeling Tools



Scenario Builder

Manure storage practice

Livestock



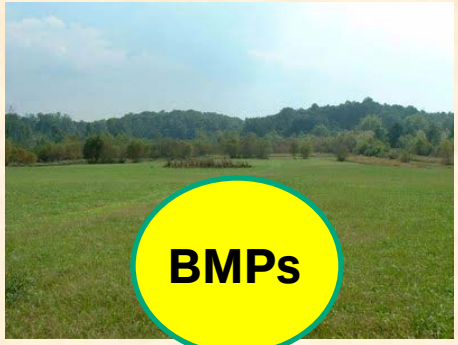
BMPs

BMPs

Crops

BMPs

Pasture



BMPs

Fertilizer

Image Credits
https://utextension.tennessee.edu/lincoln/4-H/Pages/Livestock-Skillathons-%28Beef,-Sheep-and-Swine%29.aspx
Rebelwoodsranch.com
Seaburst.com
http://pubs.ext.vt.edu/442/442-308/442-308.html

Scenario Builder
Data Inputs and Outputs

- BMP Type and location (NEIEN/State supplied)
- Land acres
- Remote Sensing, NASS Crop land Data layer
- Crop acres
- Yield
- Animal Numbers (Ag Census or state supplied)
- Land applied biolsolids
- Septic system (#s)

Inputs

Parameters

(Changeable by user)

- BMP types and efficiencies
- Land use change (BMPs, others)
- RUSLE2 Data: % Leaf area and residue cover
- Plant and Harvest dates
- Best potential yield
- Animal factors (weight, phytase feed, manure amount and composition)
- Crop application rates and timing
- Plant nutrient uptake
- Time in pasture
- Storage loss
- Volatilization
- Animal manure to crops
- N fixation
- Septic delivery factors

- BMPs, # and location
- Land use
- % Bare soil, available to erode
- Nutrient uptake
- Manure and chemical fertilizer (lb/segment)
- N fixation (lb/segment)
- Septic loads

Outputs

Scenario Builder
Documentation

- Estimates of County-Level Nitrogen and Phosphorus Data for Use in Modeling Pollutant Reduction
  - http://www.chesapeakebay.net/documents/SB_Documentation_V24_01_04_2013.pdf

- Chesapeake Bay TMDL – Section 5. Chesapeake Bay Monitoring and Modeling Frameworks
  - http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/FinalBayTMDL/CBayFinalTMDLSection5_final.pdf

- Chesapeake Community Modeling Program – Models & Data, HSPF Phase 5 (Chesapeake Bay Program), Chesapeake Bay Watershed Phase 5.3 Model
  - http://ches.communitymodeling.org/models/CBPhase5/documentation.php#scenario

Data Sources and Methods

- For the current version of Scenario Builder, data sources and methods for agriculture have been approved over time by Agricultural Workgroup, its task groups and higher subcommittees.
  - Predecessors to current groups
  - Array of stakeholders
    - Public and private
    - Academic
    - Industry
    - NGO

Data Sources
Animal Types

- Livestock
  - beef
  - dairy
  - other cattle
  - hogs for slaughter
  - hogs & pigs for breeding
  - horses
  - sheep & lambs
  - angora goats
  - milk goats
- Poultry
  - layers
  - pullets
  - broilers
  - turkeys

Data Sources
Animal Populations – Head Count

- All animals except horses
  - U.S. Census Bureau. Economics and Statistics Administration. 1982, 1987, 1992, 1997, 2002, 2007. U.S. Department of Commerce. 2002 Census of Agriculture. (Geographic Area Series 1C). Government Printing Office, Washington, DC.
  - Scale = county and state
  - Category = inventory
- Horses
  - State reported – census
- Categorization changes among censuses
- Bio-solids
  - State reported by VA only

Data Sources
Animal Populations – Animal Units

- Conversion of head counts to animal units
  - Kellogg, R.L. et al., 2000. Manure nutrients relative to the capacity of cropland and pastureland to assimilate nutrients: Spatial and temporal trends for the United States. Proceedings of the Water Environment Federation, 2000(16), 18–157.
- Animal Unit = 1,000 lbs / avg. weight of animal

Data Sources
Manure Mass and Nutrients

- As excreted
- Manure mass and concentrations
  - ASAE. 2003. Manure Production and Characteristics. In ASAE Standards. D384.1. St. Joseph, MI, pp. 683-685 (American Society of Agricultural Engineers)
    - Data in this publication are combined from a wide base of published and unpublished information on livestock manure production and characterization.
    - Data source is used because it contains nutrient concentrations for all animal types in a single well-recognized and reputable document.
    - Allows for equity among animal industries

Data Sources
Manure Mass and Nutrients

- Nutrient species in Scenario Builder:
  - Nitrogen
    - NH3
    - Organic N
    - Mineralized N
    - NO3
  - Phosphorus
    - PO4
    - Organic P
    - Mineralized P

Nutrients Applied To Land
Manure + Chemical Fertilizer

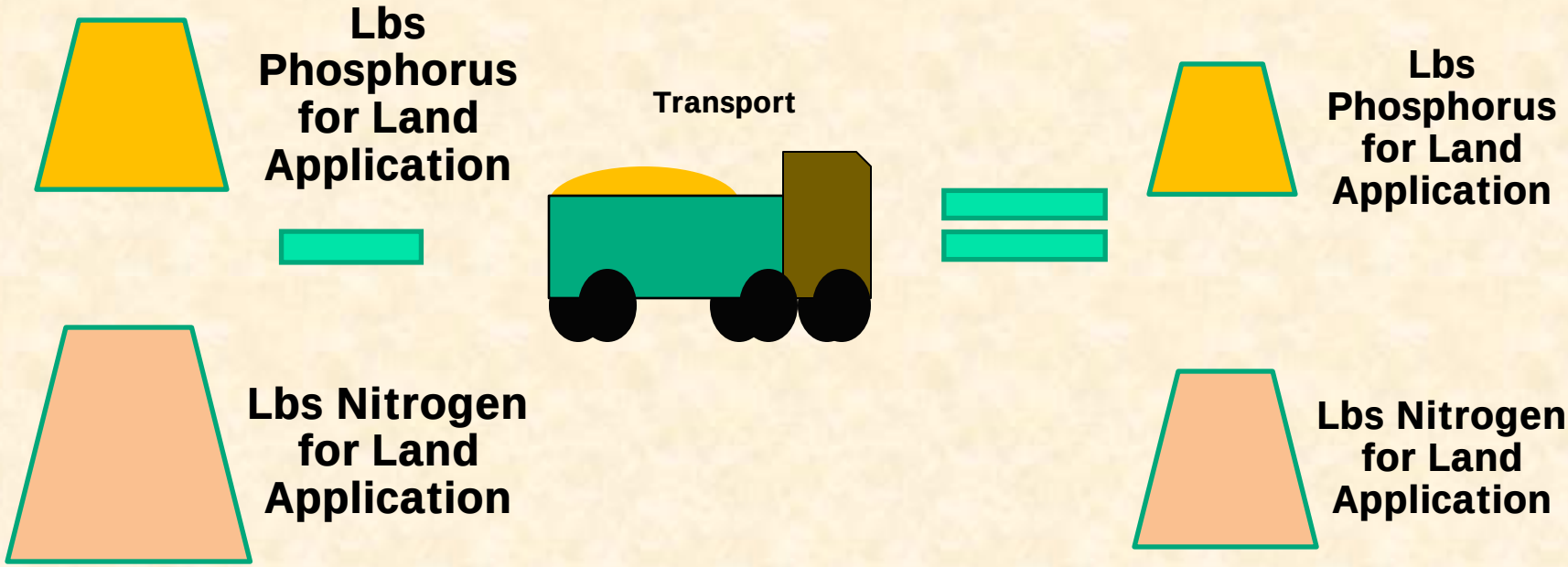
- Elements included in determination of mass of nutrients applied to crops:
  - Division between confined and pastured time
    - Data from states for time spent in pasture by animal type, county, and month
    - Recommendations on other data sources
  - Ammonia volatilization – recommendations on data sources for “inherent” transfer of emission to atmospheric deposition

Nutrients Applied To Land
Manure + Chemical Fertilizer

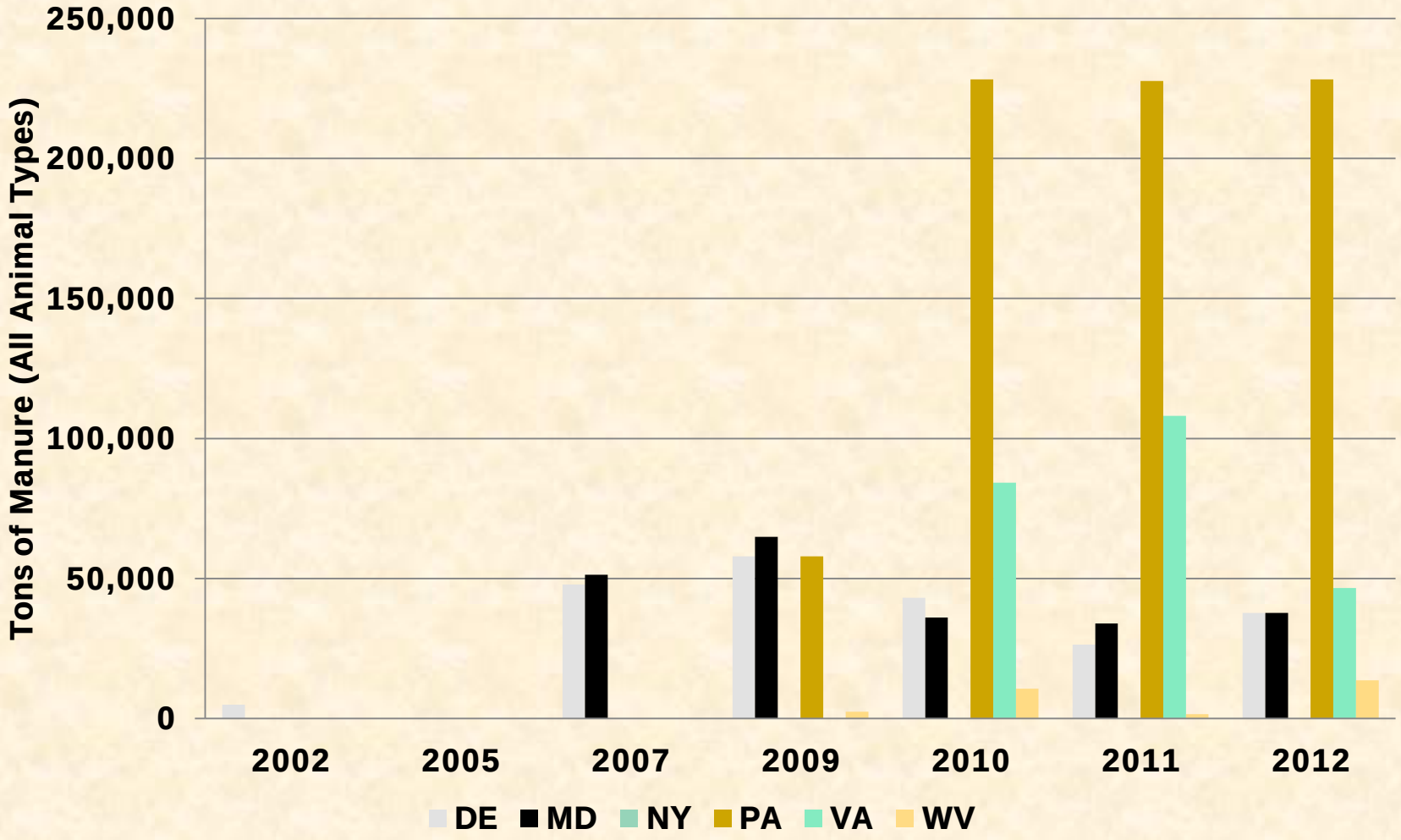
- Elements included in determination of mass of nutrients applied to crops:
  - BMPs
    - Reductions to nutrients generated – benefits of genetics and feed technologies such as phytase in poultry and swine, dairy feed management
    - Storage and handling losses – production area losses offset by Animal Waste Management Systems and Mortality Composting; recommendations on data sources for potential loss prior to storage
    - Manure transport – reductions through transport out of watershed or to counties with nutrient need, as reported by jurisdictions and part of plans
    - Lower application rates for nutrient application management

Manure Transport

- Manure generated in a county is assumed to be available for crops in that county unless reported as transport.
- Manure transport reduces the manure available for crops in one county by shipping it to another county in or out of the CB watershed.



Manure Transport
Through Time



Nutrients Applied To Land
Manure + Chemical Fertilizer

- Calculated for each:
  - County
  - Crop type
    - 100+ crop types eventually aggregated to 13 landuses
  - Month
  - Nutrient species
    - Nitrogen = NH3, Organic N, Mineralized N, and NO3
    - Phosphorus = PO4, Organic P, and Mineralized P

Nutrients Applied To Land
Manure + Chemical Fertilizer

- Elements include
  - Manure
  - Chemical Fertilizer
  - Sewage Sludge
    - currently only in VA
  - Nitrogen fixation
    - Total fixed includes uptake
  - Uptake
    - Includes whole plant uptake, not just removal

Crops

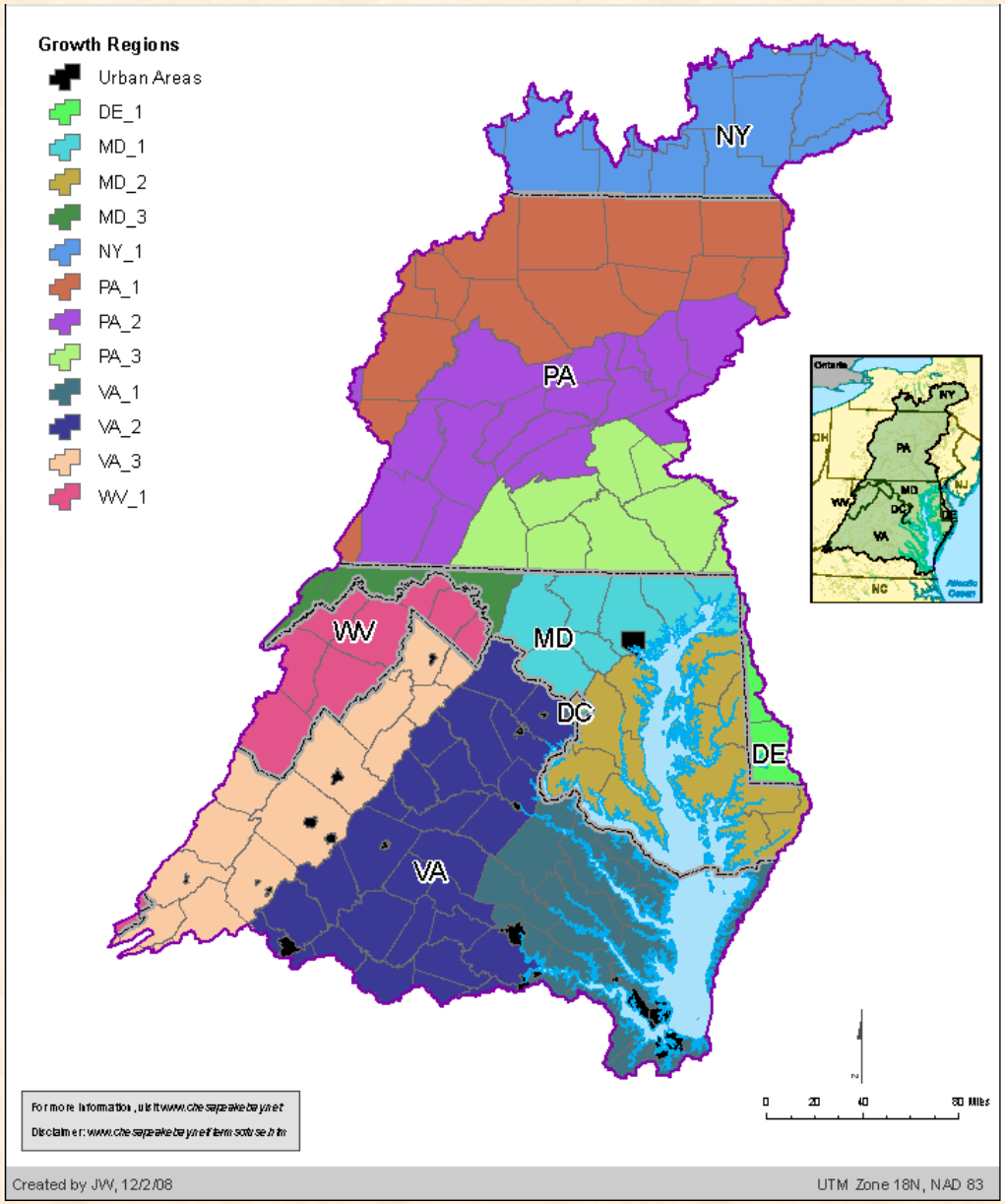
- Most of those in the Agricultural Census are used
- 100+ total
  - Most are fruits and vegetables
  - ~ dozen are greenhouse crops grown under cover
- Crop acres for each county
  - Years between Ag Censuses are interpolated
  - Years beyond Ag Census are projected

State	County Name	Crop Name	1997	2002	2007
DE	Kent	Corn for Grain Harvested Area	42,274	43,548	55,105
DE	Kent	Soybeans for beans Harvested Area	80,709	68,647	57,251
DE	Kent	Wheat for Grain Harvested Area	26,229	20,509	22,367

Nutrient Mass Apportioning

- Nutrient application rates and timing are governed by the following principles:
  - Temperature zone variations
  - Agricultural practice data
    - Found in state nutrient management and land grant university cooperative extension recommendations
  - Actual yield history
    - From NASS Census of Agriculture
  - Allowances for variation among planting and harvest dates

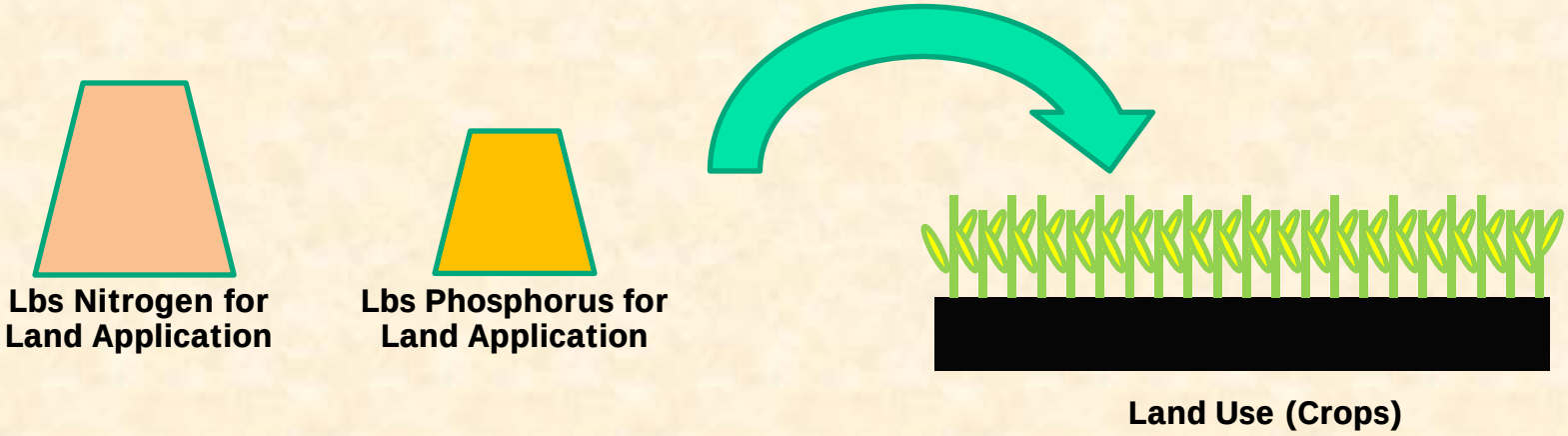
Nutrient Mass Apportioning
Scenario Builder Growth Regions



- Scenario Builder has 12 growth regions that inform plant and harvest dates for all crops based on first and last frost dates.
- Used to inform timing of nutrient application, plant uptake, and legume fixation.

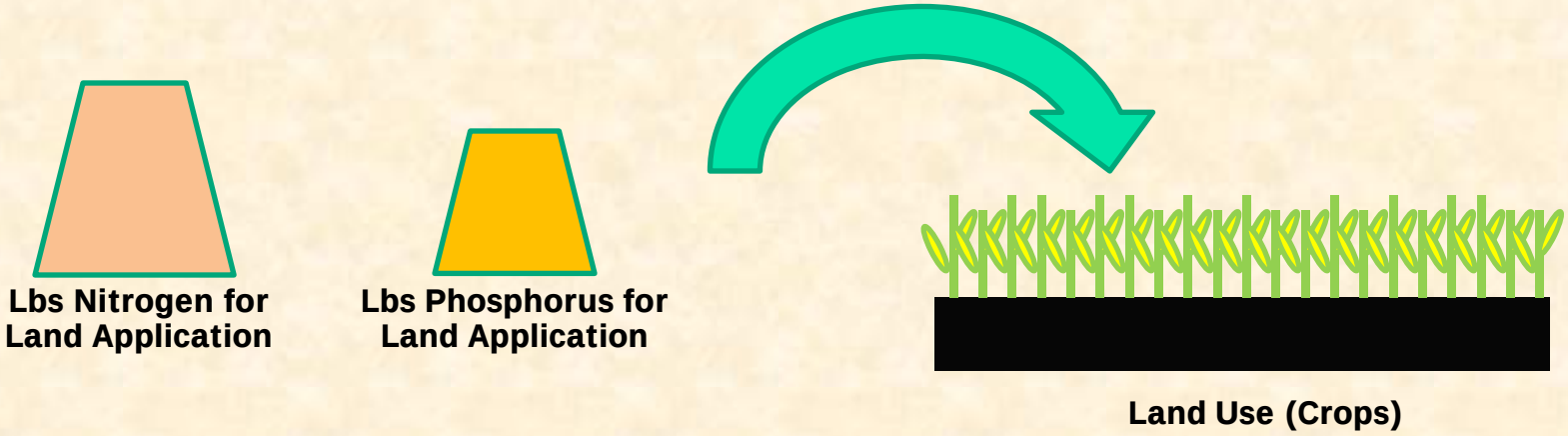
Nutrient Mass Apportioning

- Nutrient types include bio-solids, manure and chemical fertilizer.
- Manure has nutrients not available for plant need.
- Fertilizer is assumed to be 100% available for plant need.
  - Fulfills a crop whose need MUST be filled by inorganic nutrients as defined by agronomy guides, and
  - Fulfills the leftover crop need when all organic nutrients are applied.



Nutrient Mass Apportioning

- Order by Nutrient Source
  1) Starter fertilizer
  2) Direct deposition
  3) Bio-solids (to land under nutrient application management first if available)
  4) CAFO manure (to NM land first if available)
  5) AFO manure
  6) Fertilizer (to supplement remaining need)
  7) Disposal sequence



Nutrient Mass Apportioning
Initial Fertilizer Applications

- 1st in Scenario Builder sequence
- Fertilizer put down prior to or at the time of planting and prior to manure distribution
- Application specific for crop type, county and timing
- Considered a portion of the total amount applied toward meeting the application need.

Nutrient Mass Apportioning
Bio-solids Applications

- 2nd in Scenario Builder sequence = sewage sludge
  - Prior to manure applications
  - Regulated , i.e., on lands in nutrient management
- Only VA has provided bio-solids data to-date
  - Annual mass
  - Proportioned across the months based on the un-met amount in the application rate
  - Crop is eligible to receive bio-solids if it is eligible to receive manure and in nutrient application management.
- Crop need will be met earlier where bio-solids are available.
  - Likely to be more excess nutrients from manure in counties with bio-solids and a high acreage of regulated land.

Nutrient Mass Apportioning
Manure Applications

- 3nd in Scenario Builder sequence
- Only on eligible crops
  - Specified by Agricultural Workgroup and its task groups, e.g., not fruits and vegetables
- Crop is also eligible to receive manure if need not already met by initial inorganic (i.e., starter) and bio-solids.

Nutrient Mass Apportioning
Manure Applications

- Amount of manure available to be applied to crops =

manure produced –

direct excretion –

feed additive BMPs –

volatilization (for ammonia-N) –

storage and handling loss ±

manure transport

Nutrient Mass Apportioning
Manure Applications

- Manure assumed to have been stored and no winter application of manure.
  - Data unavailable on the type and capacity of manure storage facilities throughout the CB Watershed.
  - Assumed that manure storage is available to handle the volume produced until applied = annual total.
  - Manure applied only when the crop can utilize nutrients.
- Manure from CAFO animals applied prior to manure from animals designated as AFO.
  - AFO:CAFO splits from state-supplied data

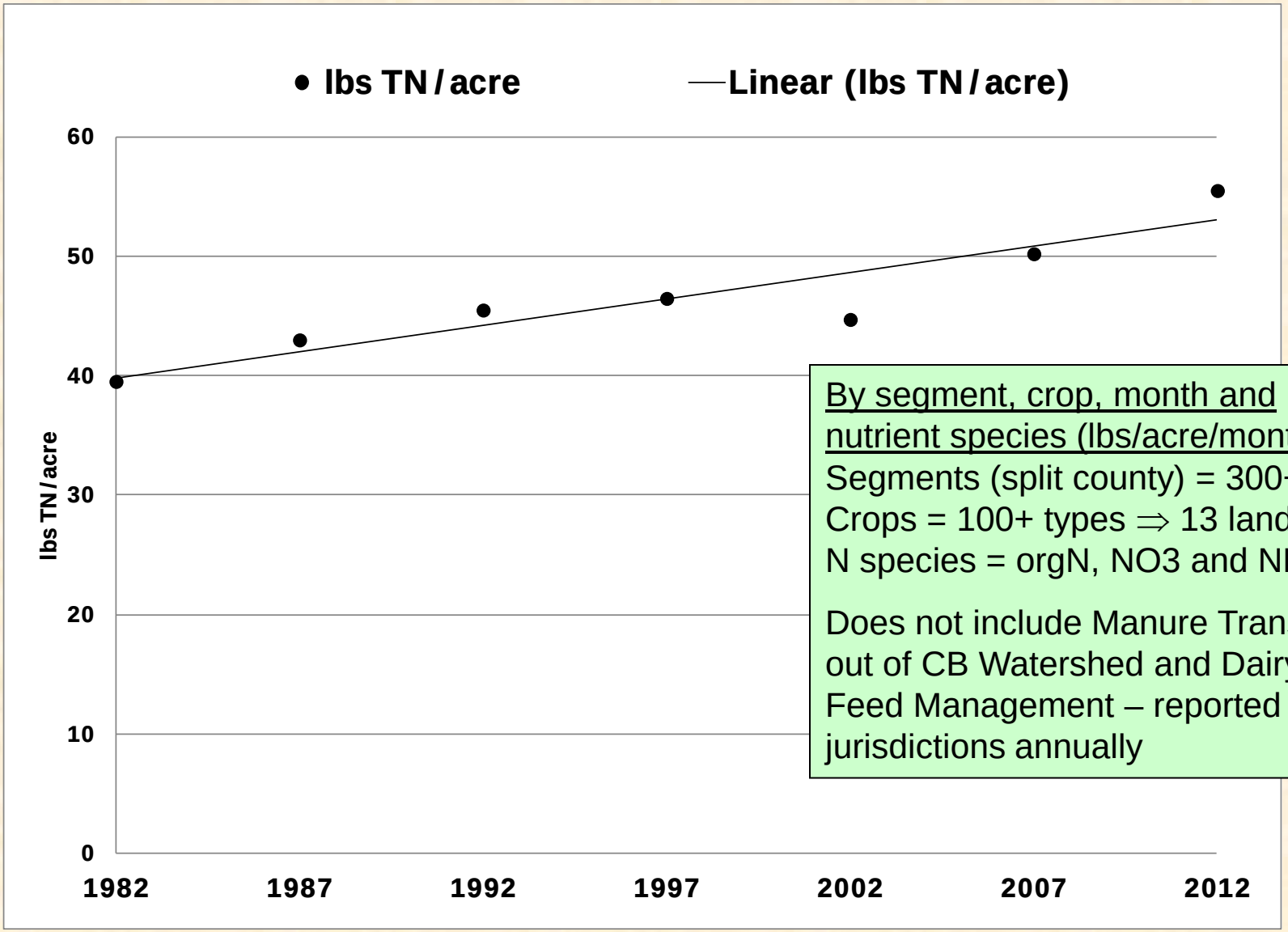
Nutrient Mass Apportioning
Mineralization

- A portion of organic N and organic P mineralized is included in the calculation of plant-available nutrients.
  - The other portion of the manure (organic N that is not mineralized) is applied to land as well but not counted toward the full application rate.
  - Crop need is met through the nutrient forms of NH3, mineralized N, and NO3.

Excess Manure

- Occasionally there's manure generated within a county that exceeds the nutrient needs of a county's crop needs.
- States defined which land uses should receive disposal manure, in which order, and at which rates.
- Because a crops' needs are already met, disposal load will increase nutrient export from the land.

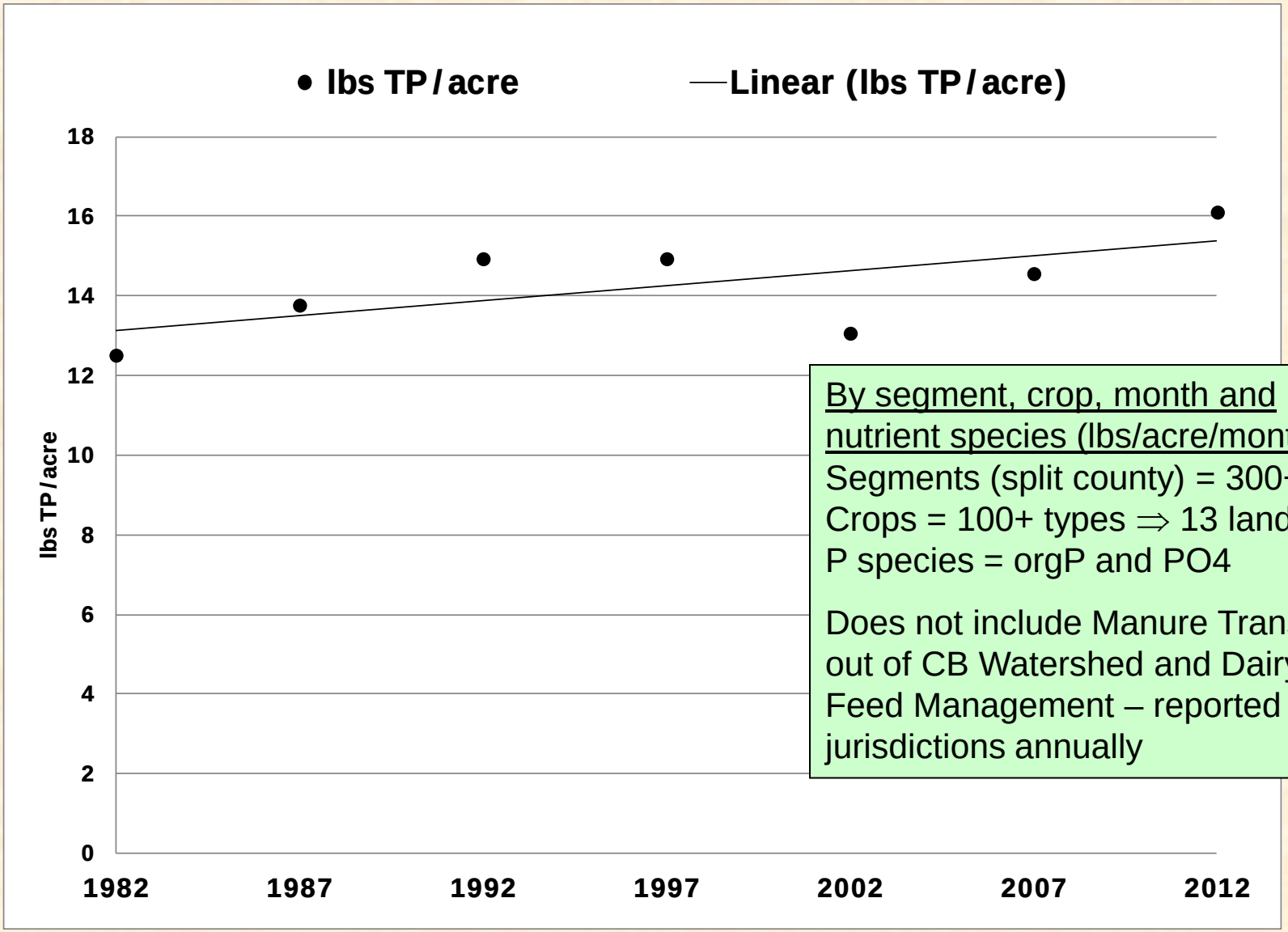
Manure Nitrogen Crop Application Rates
CB Watershed-wide (lbs/acre)



By segment, crop, month and nutrient species (lbs/acre/month)
Segments (split county) = 300+
Crops = 100+ types ⇒ 13 landuses
N species = orgN, NO3 and NH3

Does not include Manure Transport out of CB Watershed and Dairy Feed Management – reported by jurisdictions annually

Manure Phosphorus Crop Application Rates
CB Watershed-wide (lbs/acre)



By segment, crop, month and nutrient species (lbs/acre/month)
Segments (split county) = 300+
Crops = 100+ types ⇒ 13 landuses
P species = orgP and PO4

Does not include Manure Transport out of CB Watershed and Dairy Feed Management – reported by jurisdictions annually

Inorganic Fertilizer Applications

- Inorganic fertilizer is applied last in the sequence of nutrient applications.
- Where the crop need has not already been met with manure nutrients, inorganic fertilizer is applied to meet the nutrient management application rate.
  - Chemical fertilizer is not a limited nutrient and is never under or over-applied.
  - Chemical fertilizer is assumed to be mixed to specification.
  - If N was met through manure, then chemical fertilizer containing only P may be applied.

Nutrient Mass Apportioning
Nutrient Applications

- In Scenario Builder, crop needs (nutrient application rates) are informed by Agricultural Census.
  - Only available data at county scale across 64K square-mile watershed through time period 1982-2007 (and soon 2012).
  - Soil test data meeting requirements have been unavailable for Scenario Builder use.
  - On-farm yield records meeting requirements have also been unavailable for Scenario Builder use.

Nutrient Mass Apportioning
Maximum Uptake

- Scenario Builder defines nutrient uptake as all the nutrients removed from harvest AND from the roots and shoots of crops.
- Maximum Uptake for a crop is the 95th percentile yield multiplied by the uptake per yield unit and adjusted downward 30% for typical maximum.
- Theoretical Nutrient Uptake values for each crop are calculated by combining Ag Census and literature.
- This theoretical uptake is transformed into Monthly Nutrient Uptake for each crop for each growing region based upon crop yield information and the number of growing degree days in each month.

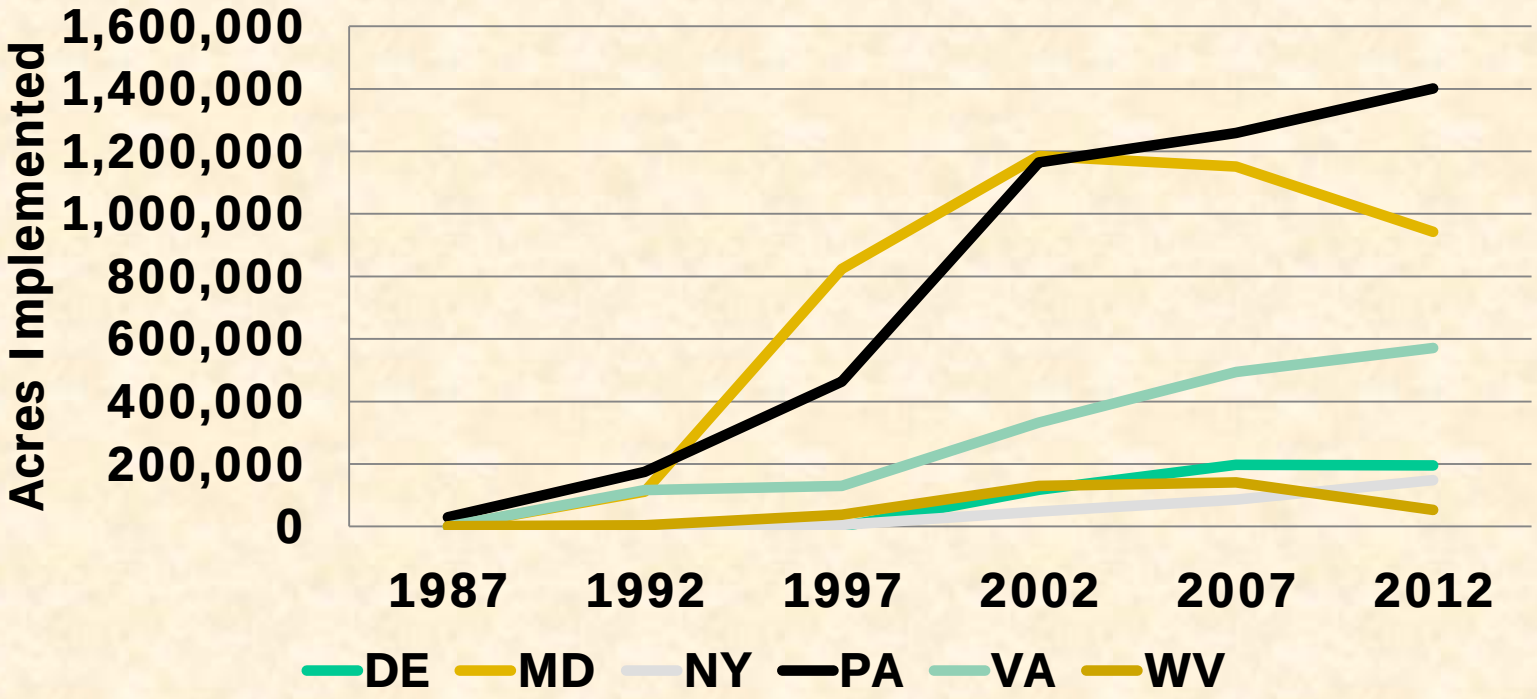
Nutrient Mass Apportioning
Local application Rates

- States calculate "best potential yield" by crop and county
  - DE = Average of the highest 4 of the 7 Ag Census yields
  - MD = Average of the highest 60% of available Ag Census yields
  - NY, PA, VA, WV = Average of highest 3 of last 5 Ag Census yield
- The calculated value is limited to the 95th percentile of all years and counties.

Nutrient Application Management
Nitrogen or Phosphorus-Based

- Manure nutrients may be applied on either N or P-based nutrient management basis.
  - Opposite nutrient (P for an N-based plan) may be over or under applied depending on manure content of animal type. and crop application rate requirements.
  - Remaining secondary nutrient need is only considered when applying fertilizer.
  - No P-based nutrient application management has been reported for “credit” by jurisdictions nor for plans, i.e., Milestones and Watershed Implementation Plans.

Nutrient Application Management



- Nutrient application management acres are reported each year by states for accounting.
- Nutrient management acres have lower crop need, and therefore lower application of nutrients to meet crop need.

Legumes

- Some crops fix nitrogen from the atmosphere – accounted for in Scenario Builder as a source that fulfills a crop's nitrogen need.
- Nitrogen fixation by leguminous plants
  - Lbs/acre ammonia (NH3) fixed by crop, county, month, and year
  - Examples: alfalfa hay and seed, birdsfoot trefoil seed, dry edible beans and green lima beans, snap beans, peanuts for nuts, peas (Chinese, Green and Green Southern), red clover seed, soybeans for beans, vetch seed)
  - Includes portion fixed in the roots and taken up into plant
  - Only occurs when the plants are growing = days between the plant and harvest dates

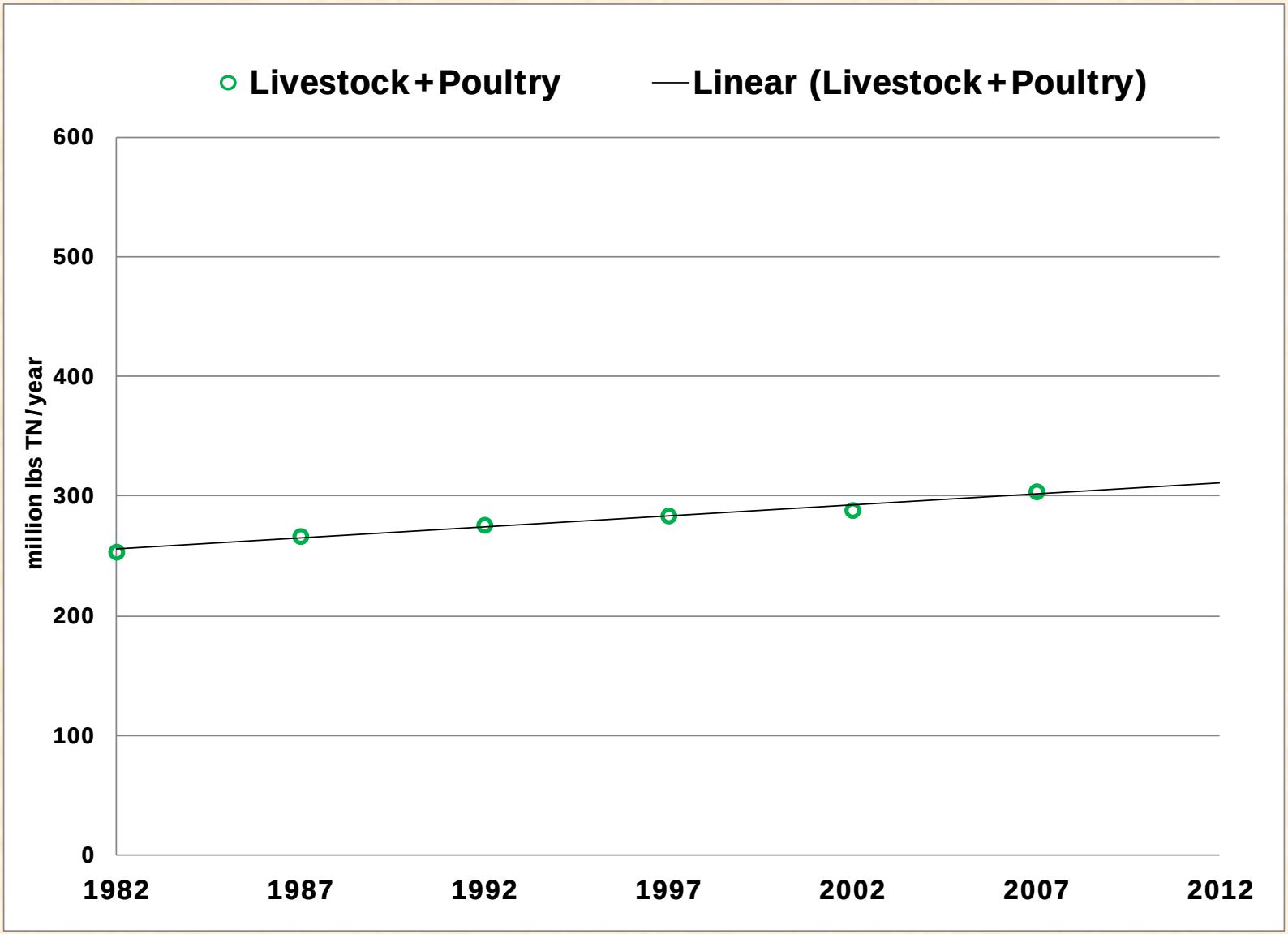
Nutrient Mass Apportioning
Summary

- Organic nutrients are generated by animals across a county.
- Organic nutrients are applied to cropland after accounting for direct deposition on pasture, storage and handling losses on animal production areas, volatilization, BMPs.
- Organic nutrients are applied to fulfill crop nutrient needs.
- Excess organic nutrients are applied in a state-specified sequence across land uses.
- Remaining crop need is fulfilled with inorganic fertilizer.

Nitrogen

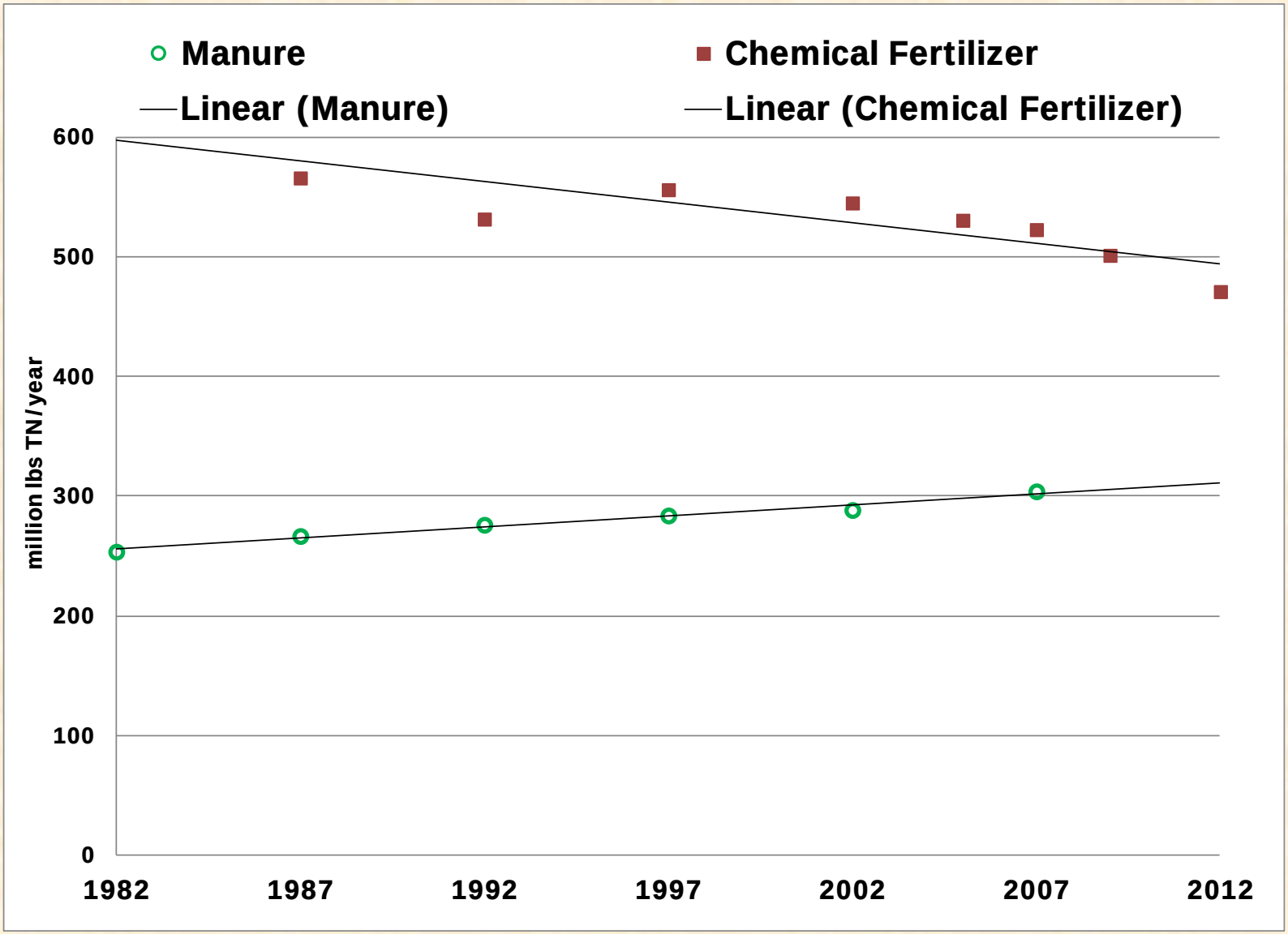
Manure Nitrogen for Crop Application

All Animals (million lbs/year)



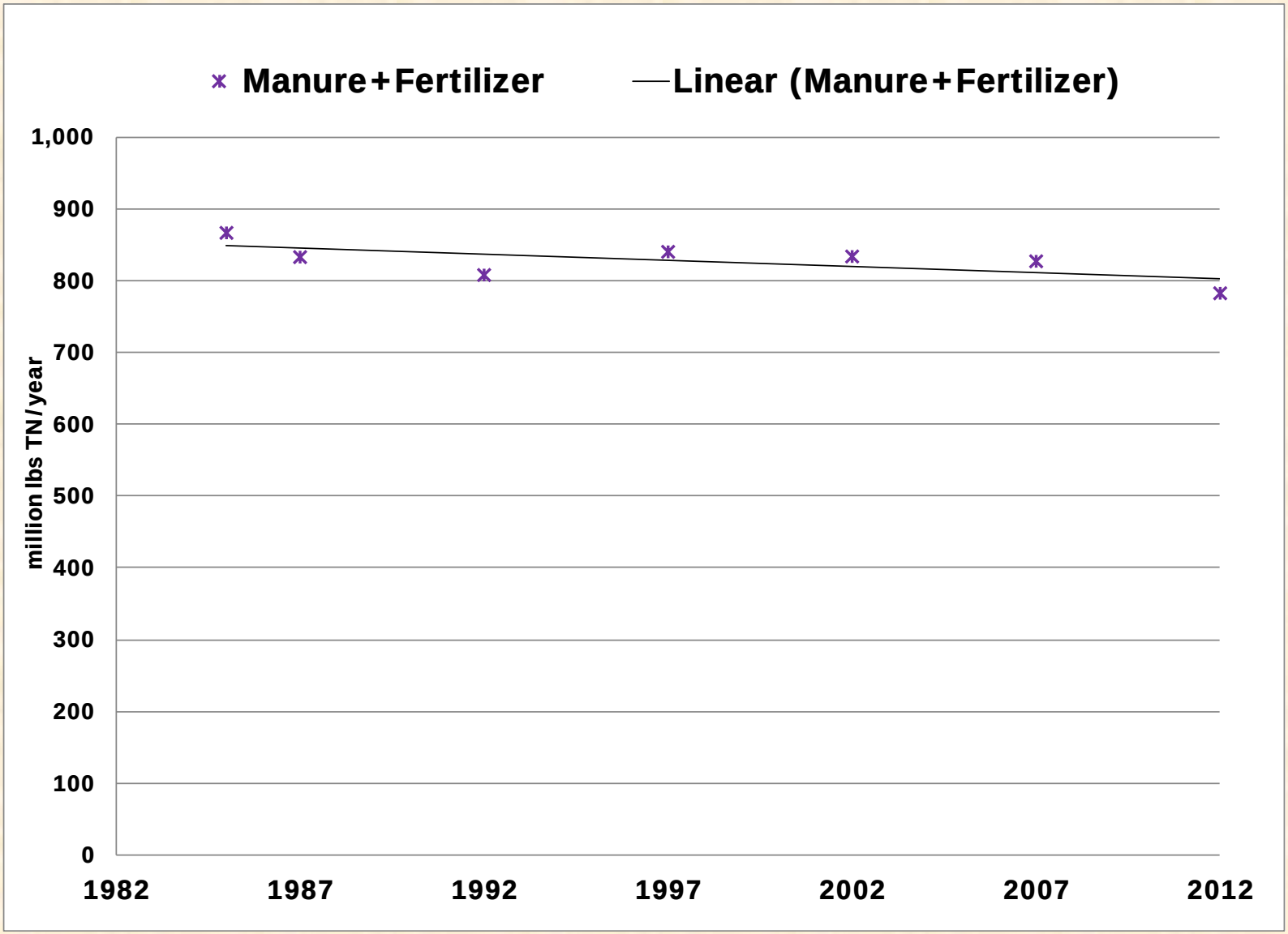
Manure and Fertilizer Nitrogen for Crops

CB Watershed-wide (million lbs/year)



Manure + Fertilizer Nitrogen for Crops

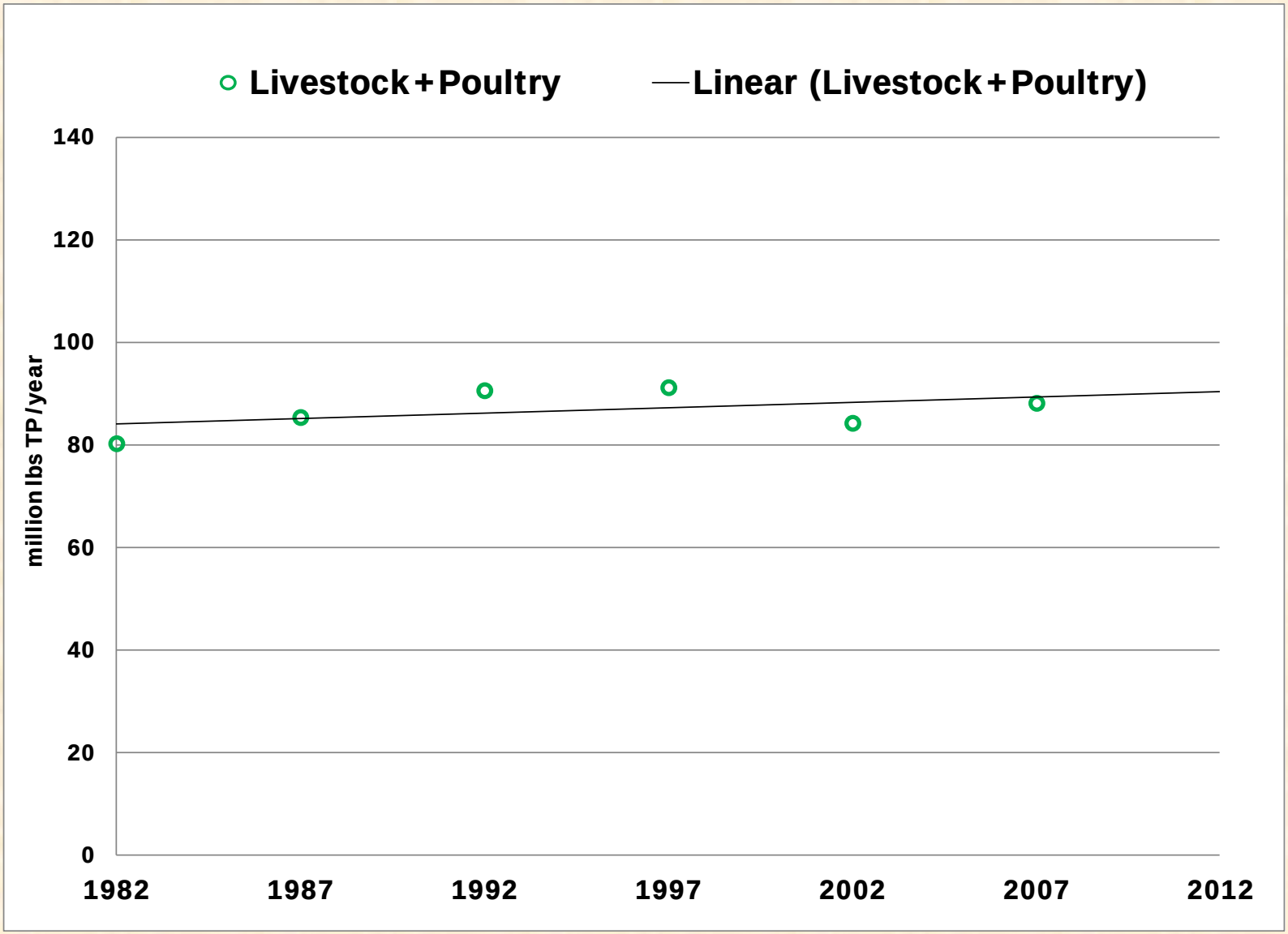
CB Watershed-wide (million lbs/year)



Phosphorus

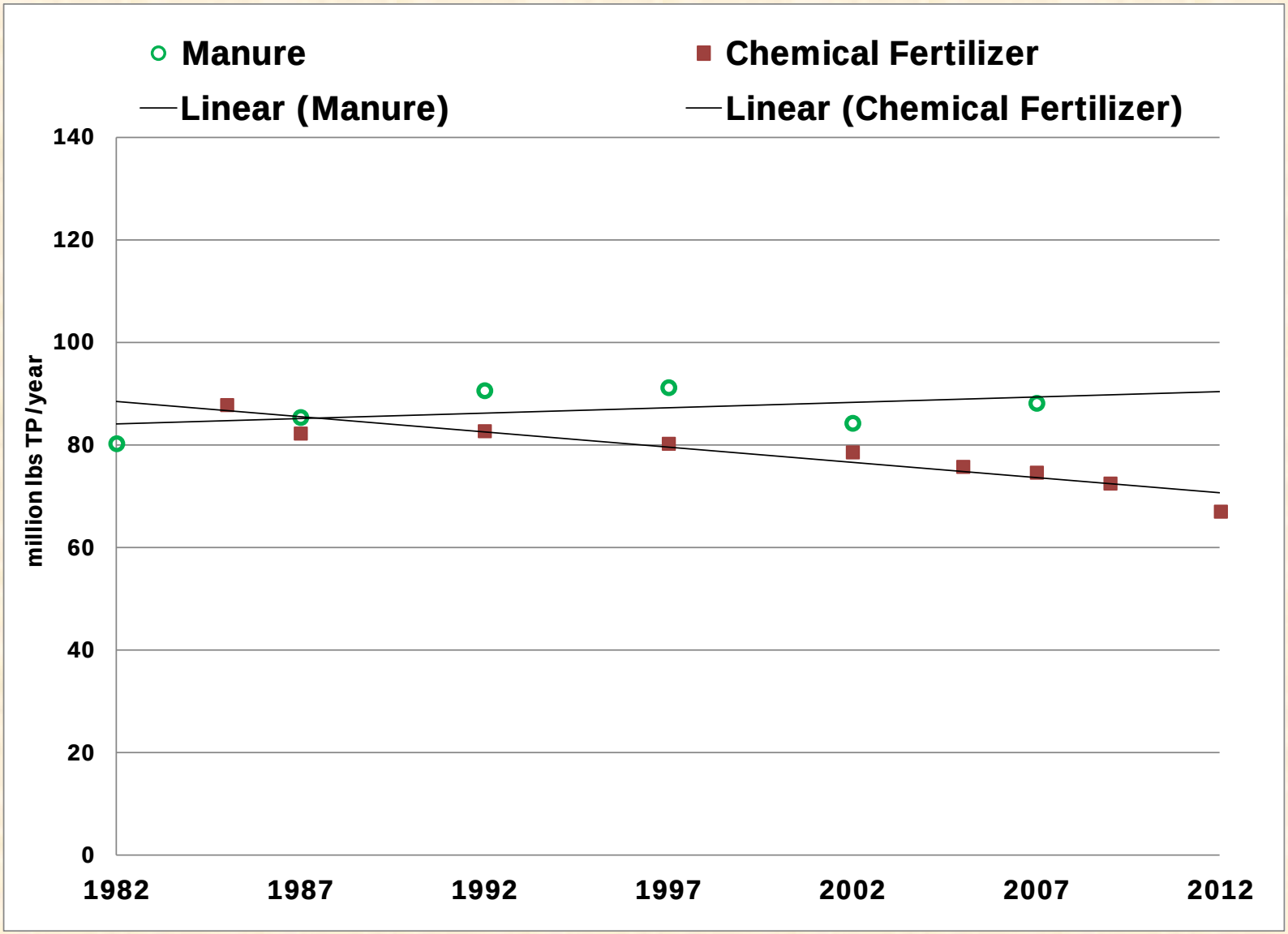
Manure Phosphorus for Crop Application

All Animals (million lbs/year)



Manure and Fertilizer Phosphorus for Crops

CB Watershed-wide (million lbs/year)



Manure + Fertilizer Phosphorus for Crops

CB Watershed-wide (million lbs/year)