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Quantifying the phosphorus footprint and interventions for urban areas

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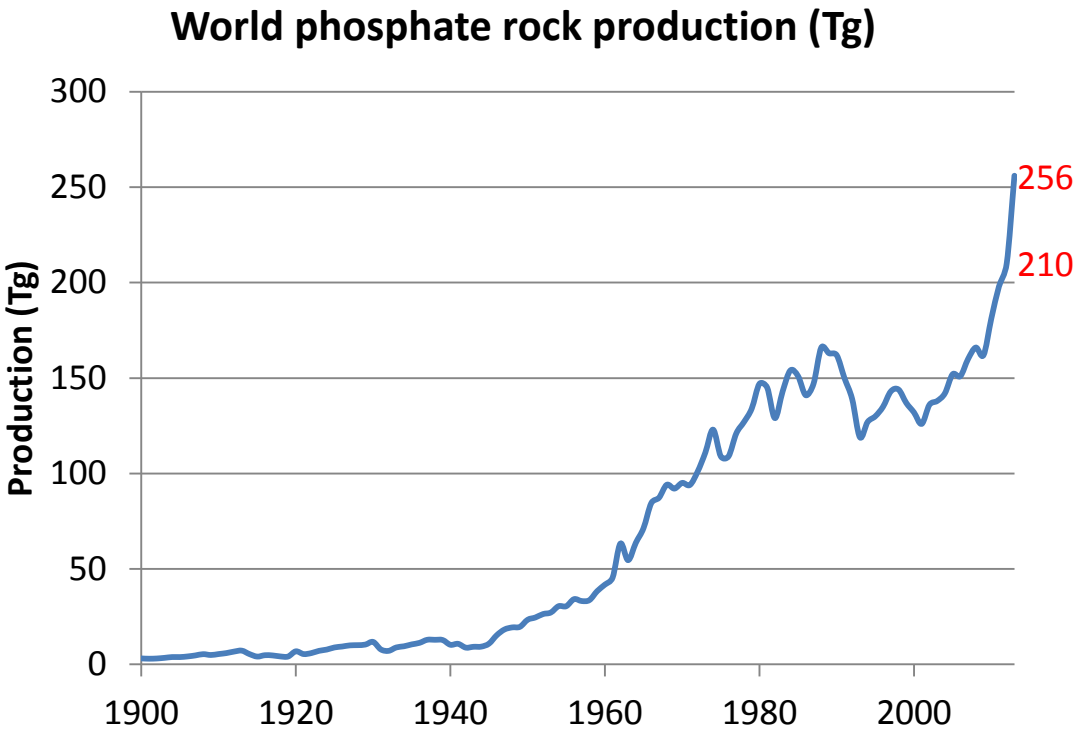
Outline

1. Rationale
2. Research Goals
3. Literature Review
4. Methodology
5. Results
6. Discussion/ Conclusion

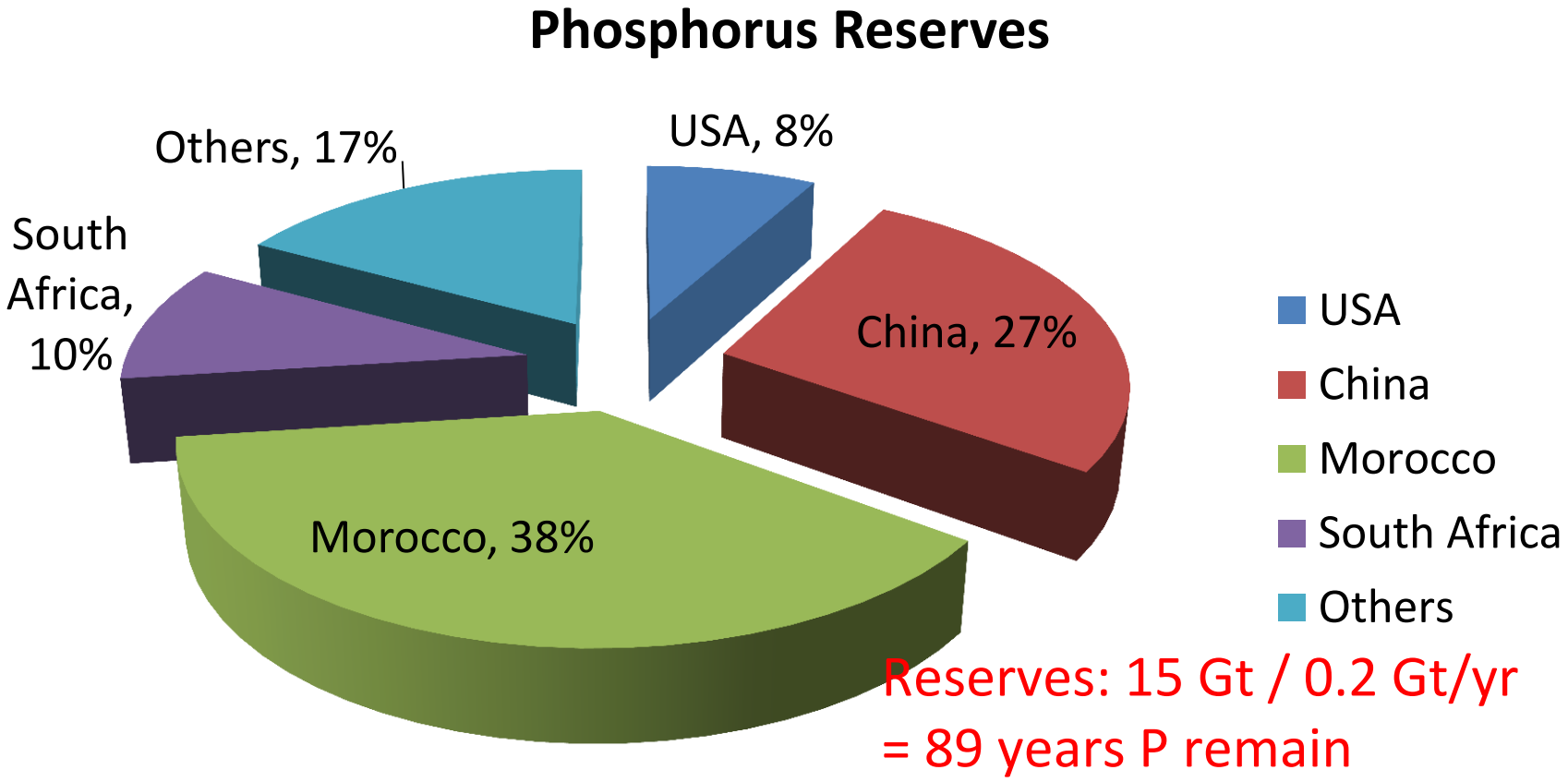
Paper Rationale: Phosphorus – Resource – Global scarcity

- Limited , Expensive



- **Tg = Teragram. Note, 2012 (210 Tg) and 2013 (256 Tg) are USGS estimate and prediction, respectively. USGS (2013)**

Paper Rationale: Phosphorus – Resource –Uneven Global Deposits



Reserves: 15 Gt / 0.2 Gt/yr
= 89 years P remain

Source: USGS Data on phosphate production October 9, 2007

Paper Rationale: Phosphorus – Regional Pollutant - Eutrophication

Introduction

- Worldwide, cities are pledging to reduce phosphorus emissions, compelled to conserve valuable resource
- Thus there is a need for tools to show how infrastructure design and policies are shaping phosphorus flows
- City-scale phosphorus accounting confounded by three factors:
  1. Beyond food, there is also embodied phosphorus in other goods and services traded across city boundaries
  2. Hidden nature flows of phosphorus are missed
  3. Phosphorus flows only recently became relevant (phosphorus accounting methods at city scale minimal, and miss community-wide flows)

Unique Contributions of Paper

1. Mineral impurities as a Phosphorus Resource
2. Phosphorus Intensity Vector
   - Convert monetary flows to phosphorus flows
3. Urban-level direct and upstream P flows
   - Community-Wide Infrastructure Footprint
   - P-Containing Infrastructure materials:
     - Iron
     - Cement
     - Coal
     - Wood

Objectives

1. Phosphorus flows
   - Include phosphate rock, natural phosphorus + P as impurities
2. Phosphorus Intensity Vector
   - Convert monetary to P flows
   - Complete for all 440 sectors of economy
3. Urban phosphorus footprint
   - Material Flow Analysis
   - Life Cycle Assessment
   - Community-Wide
   - Trans-boundary
   - Embodied flows
4. Intervention Quantification
   - Wastewater treatment
   - Diet
   - Manufacturing practices

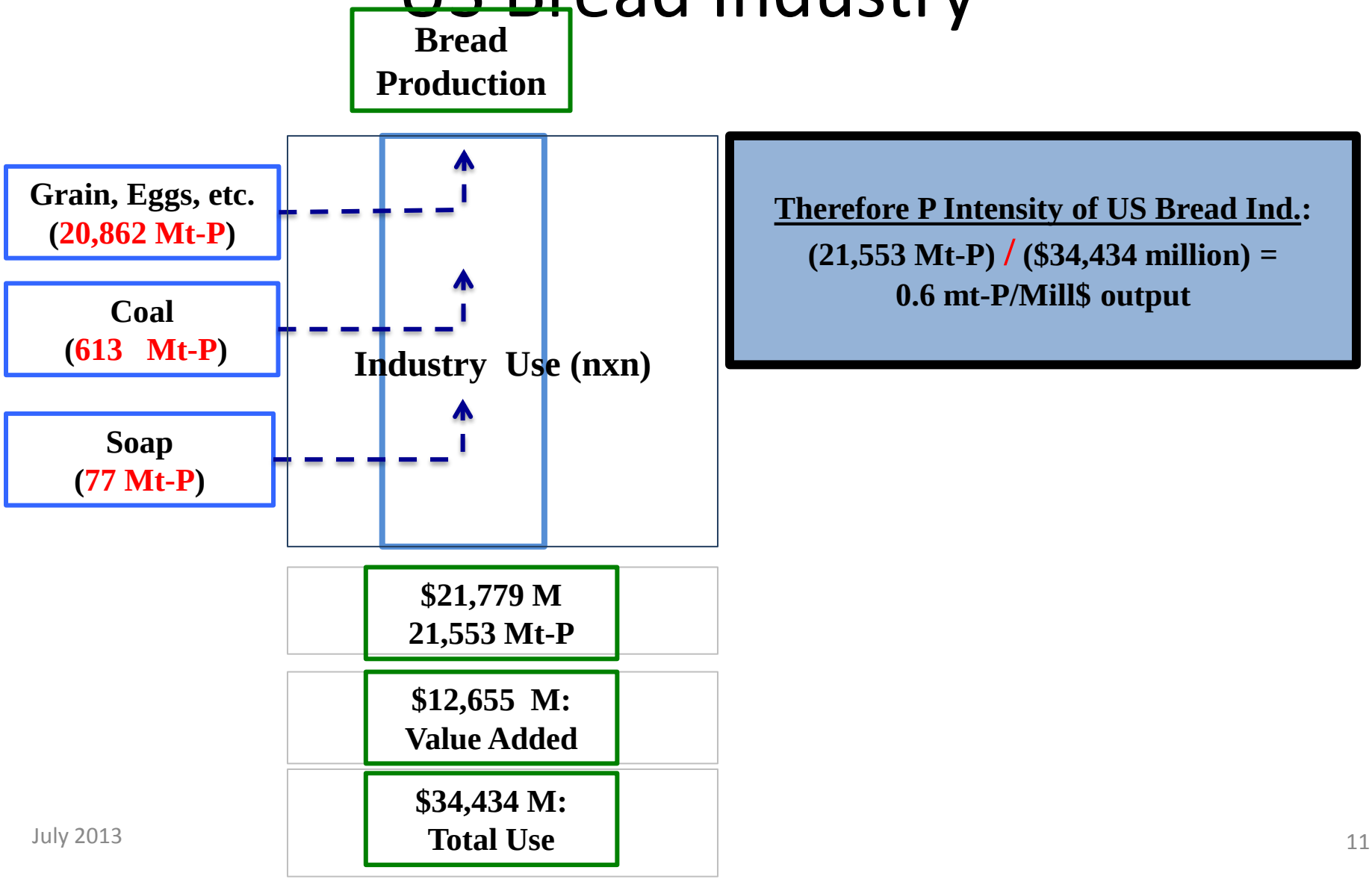
Method: Primary Production P Input Vector: Process-Sum LCA

- Mass-phosphorus for US Production of commodities
- Follows material (and P) flows through Input life cycle of particular process (product / commodity)
- Used to track primary input phosphorus-containing commodities
- Necessary to have mass flow data
  - Mass commodity flows used to calculate upstream flows
- Necessary to have monetary flow data
  - Monetary flows used to create intensity factor
- Necessary to have P content data
  - P content used to create intensity factor

Method: Economy-Wide P Footprint: EIO-LCA

- Used for mass-energy relationship which a very complex
- Tracks monetary exchanges between 440+ sectors of an economy (1st done for 42 US sectors for 1919 by Leontief)
- Matrix couples sector exchanges (vs. complex process flow diagram)
- Sophisticated method to complete LCA quickly
- Only monetary inputs necessary
- Only production phase outputs provided in EIO-LCA (e.g., not phosphorus use or final disposal)

Creation of IF_P Vector – Shown through US Bread Industry



Management Strategies
Evaluate P-Footprint strategies

- Review methods for mitigation at the urban level and quantify potential impacts.
- Use same urban footprint methodology, to compare potential mitigation strategies
- Impacts
  - Wastewater Recovery
  - Diet
  - Farm
  - Detergent
  - Fertilizer

Data Challenges

- Mixed flows don't detail P-Containing Items
  - Non-Metallic Mineral = Phosphorus + many others
  - 'Other basic inorganic chemicals' = Refined P + others
  - 'Fish' – Tuna large production in some cities, not others
  - Fertilizer P Content varies through US
- Waste / Loss
  - Accounted for in product that produced waste
    - Example: Fertilizer manufacturing waste accounted for in footprint for 'Fertilizer', as well as waste in mined rock to fertilizer.
- Primary (FAO) & Secondary (IMPLAN) Data Source Matching
  - 'Animal' = Meat + Offal + Oil
  - Fish = Only fish (oil not included)
  - Butter & Cream excluded from 'Milk & Dairy Cows'
  - Greenhouse – Use portions of other aka USDA
  - Dairy – Include about 20% cattle

Results

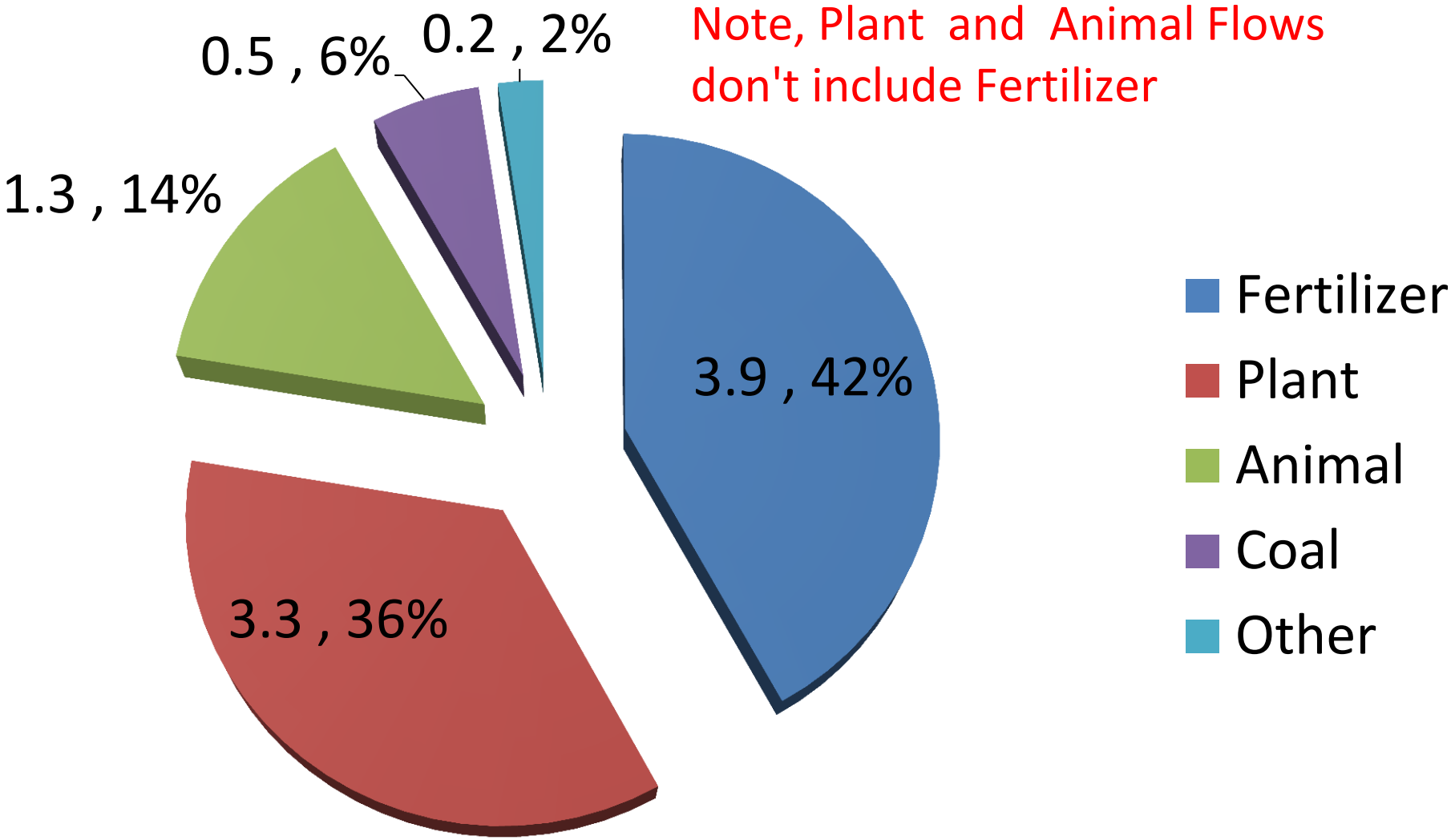
Primary Phosphorus-containing Sectors (24/440 Total)

1. Food
    1. Oilseeds
    2. Grains
    3. Vegetables
    4. Fruit
    5. Nuts
    6. Greenhouse
    7. Sugar
    8. Other crops
    9. Beef Cattle
    10. Dairy
    11. Poultry and eTg
    12. Animal – other
    13. Fish
    14. Game, pelts & furs
2. Goods
    1. Fertilizer
    2. Soap
    3. Cotton
    4. Tobacco
    5. Nursery Products
3. Infrastructure
    1. Cement
    2. Lime
    3. Iron
    4. Coal
    5. Wood

US Production 2010: Create Footprint for 24 Commodities: Calibration

- Calibrations Made:
  - Calibrated to FAOStat 2013
    - Fertilizer Production (Overall %P Content from USDA)
    - Animal Feed Additive
  - Calibrated to Villalba et al. (2008)
    - Soap %P Content

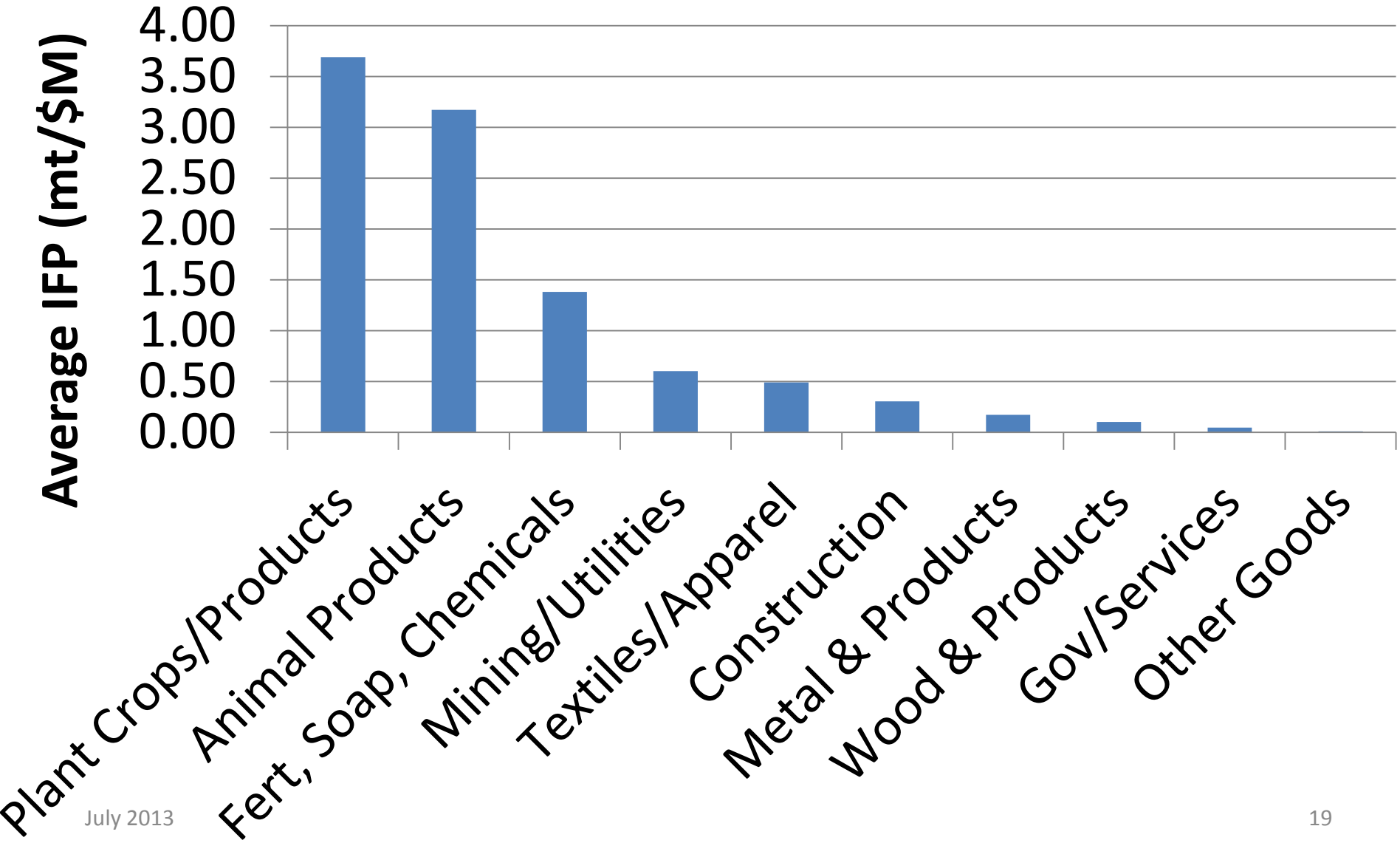
Primary Flows of P into US Economy, 2010 (Tg P)



Life Cycle P Intensity mt P/ M$ of output

Commodity Description	mt P/M$
Fertilizer	59
Grains	23
Oilseeds	13
Soybean oil and cakes and other oilseed products	18
Corn sweetners, corn oils, and corn starches	15
Flour and malt	14
Wild game products, pelts, and furs	9
Poultry and egg products	9
Agriculture and forestry support services	9
Cotton	8
Processed poultry meat products	8
Other animal food	7
All other crop farming products	6
Coal	6
Refined sugar from sugar beets	6

Phosphorus Intensity Vector, US, Category Averages



15 Highest Phosphorus Sectors US

Commodity Description	Phosphorus Tg
Fertilizer	1.8
Grains	1.4
Oilseeds	0.4
Soybean oil and cakes and other oilseed products	0.4
Corn sweetners, corn oils, and corn starches	0.4
Processed poultry meat products	0.4
Flour and malt	0.3
Poultry and egg products	0.3
Processed animal (except poultry) meat and rendered byproducts	0.3
Other animal food	0.3
Agriculture and forestry support services	0.2
Coal	0.2
All other crop farming products	0.2
Soaps and cleaning compounds	0.2
Cattle from ranches and farms	0.2