Agronomic rate for biosolids application to cropland

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PNW 511

PNW0511e

Worksheet for Calculating Biosolids Application Rates in Agriculture

Overview

This bulletin will walk you through the calculations that yield the biosolids agronomic rate. This rate is based on biosolids quality (determined by analytical results), site and crop nitrogen (N) requirements, and regulatory limits for trace element application. In almost all cases, nitrogen controls the biosolids application rate. Calculating the agronomic rate allows managers to match the plant-available N supplied by biosolids with crop N needs.

On the web

http://soils.puyallup.wsu.edu/biosolids/

NOTE: This is adapted from Pacific Northwest Extension publication number, PNW0511e.

Enter information in these cells as applicable

You must enter information in these cells to determine an application rate

Cells of this color are calulations for your use — Version 20-Dec-07

GENERAL INFORMATION				
Biosolids Source				
Field Number/ID				
Dry tons biosolids available (= wet tons x % solids)		dry tons		
Acres available		acres		
BIOSOLIDS DATA				
Ammonia/ammonium-N		mg/kg	0	#/dry ton
Nitrate-N		mg/kg	0	#/dry ton
Total Kjeldahl N		mg/kg	0	#/dry ton
Percent solids				
Organic nitrogen	0	mg/kg	0	#/dry ton
NITROGEN (N) CREDITS				
PREVIOUS BIOSOLIDS APPLICATIONS	Last Year	2 Years Ago	3 Years Ago	4 Years Ago
Dry tons applied/acre to site				
Organic N concentration (mg/kg)				
N credit (#/dry ton)	0	0	0	0
N credit (#/acre)	0	0	0	0
OTHER CREDITS NOT ACCOUNTED FOR				
Nitrate-N applied in irrigation water		#/acre		
N applied at seeding (starter fertilizer)		#/acre		
Preplant nitrate-N in root zone (east of Cascades)		#/acre	NOTE: not required if accounted for in the nitrogen recommendation in Cell B30	
Plowdown of cover or green manure crop		#/acre	NOTE: not required if accounted for in the nitrogen recommendation in Cell B30	
Previous manure applications		#/acre	NOTE: not required if accounted for in the nitrogen recommendation in Cell B30	
Total N credit	0	#/acre		
NITROGEN FERTILIZER RECOMMENDATION				
Nitrogen recommendation **(via guidelines, agronomist, etc.)**	0	# N/acre/yr		
ESTIMATED BIOSOLIDS PLANT-AVAILABLE NITROGEN				
Percent of ammonium-N retained after application **(see Table 1)**	0%			
Percent of organic N mineralized in Year 1 **(see Table 2)**	0%			
Estimated plant-available N in biosolids	0	# N/dry ton		
Amount of plant-available N needed from biosolids	0	# N/acre		
AGRONOMIC BIOSOLIDS APPLICATION RATE				
Dry tons per acre =	#DIV/0!	dt/acre		
Wet tons per acre =	#DIV/0!	wt/acre		
Cubic yards per acre =	#DIV/0!	yd^3/acre		
Cubic feet per acre =	#DIV/0!	ft^3/acre		
Gallons per acre =	#DIV/0!	gallons/acre		
Acre-inches per acre	#DIV/0!	acre-inches/acre		
ACREAGE NEEDED				
Acres needed	#DIV/0!	acres		

Same calculations found in hardcopy PNW 511.

Download Excel worksheet.

http://soils.puyallup.wsu.edu/biosolids/

Nitrogen controls the application rate for biosolids in most situations.

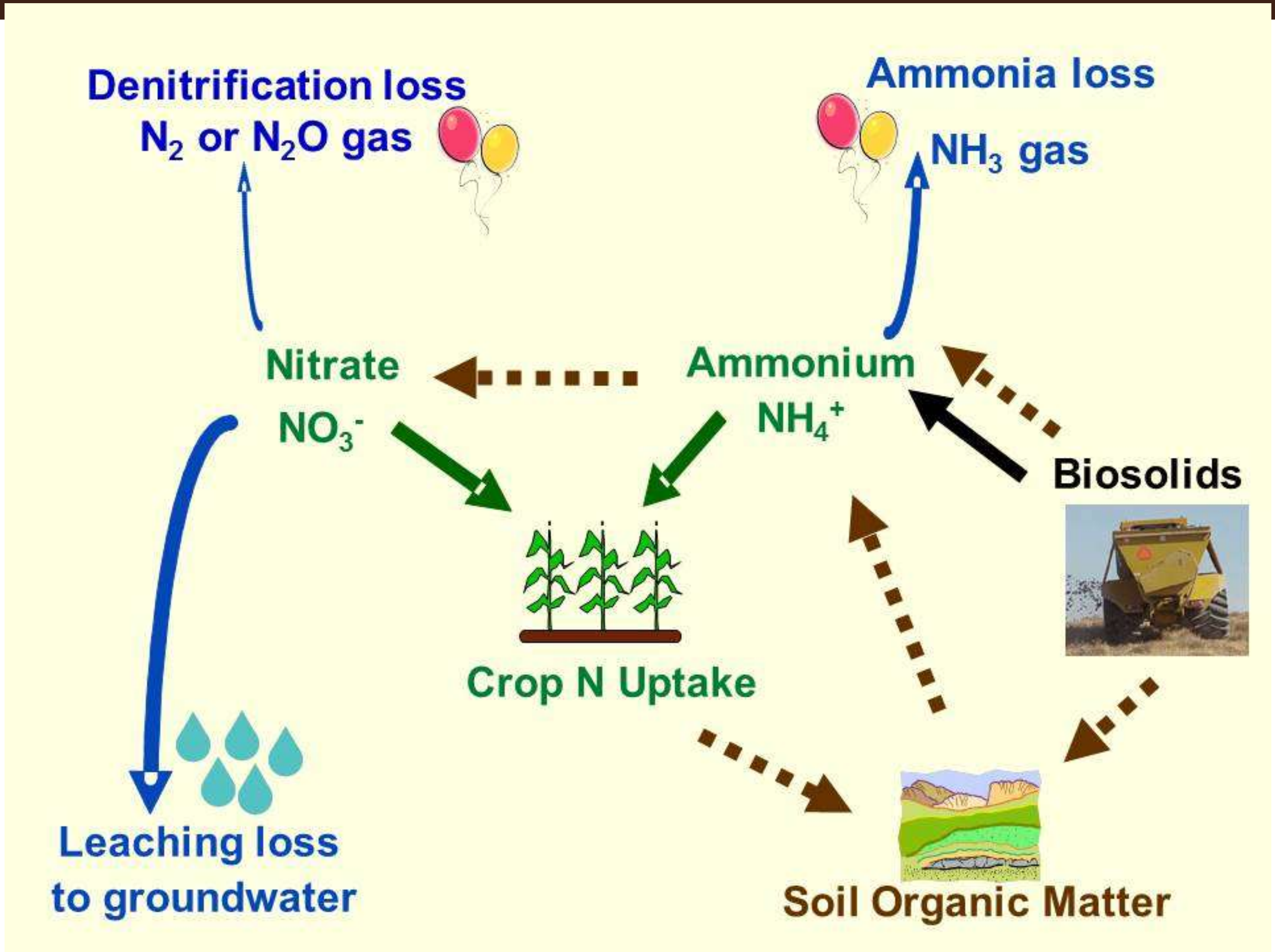
Andy Bary

Figure 8. Crop needs for plant-available N are used to determine agronomic application rates of biosolids.

Agronomic rate balances environmental and economic goals

- **Environmental**:
  Balance crop N demand with plant-available N to prevent nitrate leaching.
- **Economic**:
  Provide enough N for near maximum yield and quality of crop.

Plant available N supply from biosolids depends on rates of mineralization of organic N and retention of ammonium N



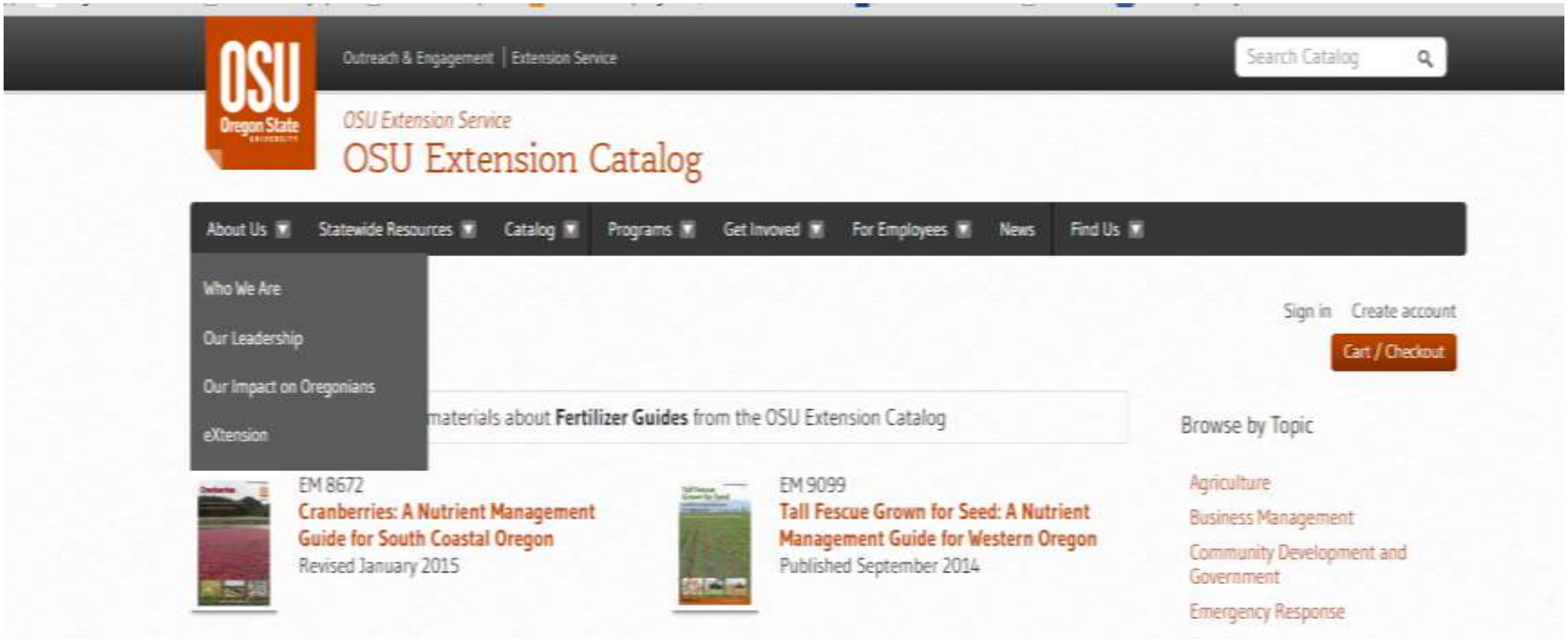
Agronomic Rate Calculation PNW 511 -E

You provide:

- Soil and crop information (needed to use university nutrient/fertilizer guide)
- Biosolids data: N, solids, application method, incorporated or not
- Previous biosolids applications to field (5 yr)
- Other sources of plant-available N
- Appropriate university fertilizer/nutrient management guide(s)

https://catalog.extension.oregonstate.edu/

OSU Extension Catalog "Fertilizer Guides" page



OSU Extension publications

OSU Fert Guide 80

FERTILIZERguide

FG 80
Reprinted April 2007
$1.50

Winter Wheat in Summer-Fallow Systems

(Low precipitation zone)

L.K. Lutcher, D.A. Horneck, D.J. Wysocki, J.M. Hart, S.E. Petrie, and N.W. Christensen

Recommendations in this fertilizer guide apply to tillage fallow-winter wheat and chemical fallow-winter wheat cropping systems. This guide is one of a set of publications that address the nutritional requirements of nonirrigated cereal crops in north-central and eastern Oregon (Table 1).

Recommendations for nitrogen, phosphorus, potassium, sulfur, chloride, and zinc are covered in this guide. Soils in the region supply sufficient amounts of other nutrients for optimum production of high-quality grain.

Use an appropriate fertilizer guide for region and crop

Nitrogen

Calculate nitrogen (N) application rates by subtracting soil test nitrogen from crop demand for nitrogen. Adjust for excessive straw and/or soil sampling in the spring of the summer-fallow year. Evaluate application rates by reviewing the protein content of harvested grain. A detailed explanation is provided on pages 2–4.

Growing conditions

Annual precipitation: Less than 12 inches

Soil: Silt loam and very fine sandy loam

Soil organic matter content: 1 to 2 percent

Expected yield

30 to 50 bu/acre

Table 1.—Fertilizer guides for nonirrigated cereal production in low, intermediate, and high precipitation zones of Oregon.*

Publication #	Title	Precipitation zone
FG 80	Winter Wheat in Summer-Fallow Systems	Low
FG 81	Winter Wheat and Spring Grains in Continuous Cropping Systems	Low
FG 82	Winter Wheat in Summer-Fallow Systems	Intermediate
FG 83	Winter Wheat in Continuous Cropping Systems	Intermediate
FG 84	Winter Wheat in Continuous Cropping Systems	High

*This set of publications replaces FG 54, *Winter Wheat, Non-irrigated, Columbia Plateau.* Precipitation zones are based on average annual precipitation and are defined as follows: Low = less than 12 inches; Intermediate = 12 to 18 inches; High = more than 18 inches.

OSU FG-63 (west of Cascades)
50 to 60 lb N per forage harvest

FERTILIZERguide

FG 63
Reprinted January 2000

Pastures

Western Oregon and Western Washington

J. Hart, G. Pirelli, L. Cannon, and S. Fransen

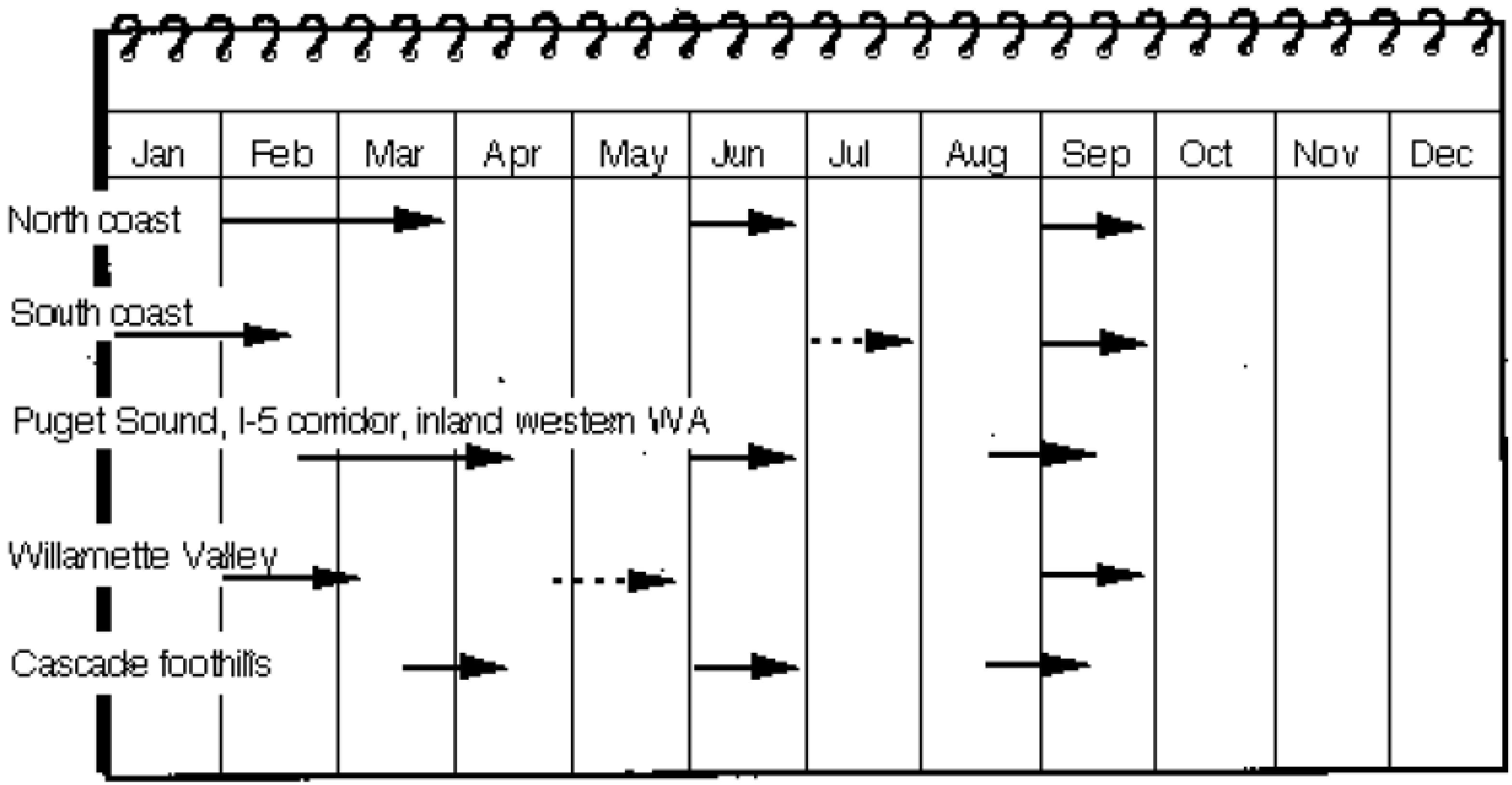


Figure 2.—Pasture nitrogen application calendar. Apply 50 to 60 lb N/a each time a solid arrow appears for your region. Additional applications for irrigated pastures are indicated by dotted lines. See nitrogen section in text for an explanation.

In OSU FG 63. Pastures, western OR and WA

Past biosolids applications contribute to current soil N supply.

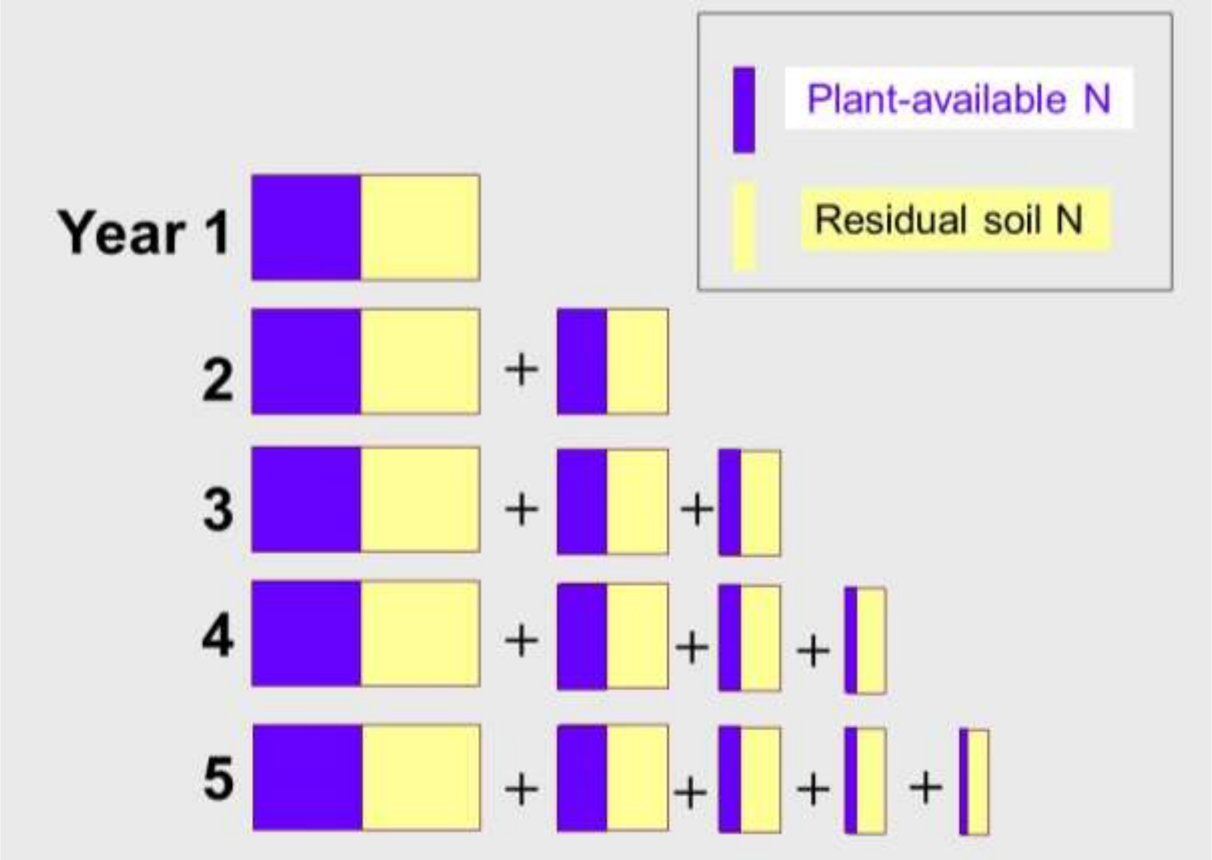


Figure 2. Conceptual illustration of biosolids N cycling over the long term, when biosolids are applied annually.

Estimated nitrogen credits for **previous biosolids applications** at a site

	Years After Biosolids Application			
	Year 2	Year 3	Year 4 and 5	Cumulative (Years 2, 3, 4 , and 5)
Biosolids Organic N as applied	Percent of Organic N Applied First Year			
	8	3	1	13
mg/kg (dry wt basis)	Plant-available N released, lb N per dry ton			
10000	1.6	0.6	0.2	2.6
20000	3.2	1.2	0.4	5.2
30000	4.8	1.8	0.6	7.8
40000	6.4	2.4	0.8	10.4
50000	8.0	3.0	1.0	13.0
60000	9.6	3.6	1.2	15.6

Source: Table 1 in PNW 511 (2007)

Example 1: Grass Hay, West of Cascades

- Soil: *Jory silty clay loam*
- Crop: *grass hay*
- Yield goal: two cuttings per year
- Plant-available N needed: 120 lb N/acre
- Plant available N from other sources: *none*

Example 1: Grass Hay, West of Cascades

- Biosolids form: *solid (cake)*
- Biosolids processing: *anaerobic*
- Method of application: *surface*
- Days before incorporation: *never*
- Expected application season: fall or early spring
- Biosolids analysis: Next page

Biosolids analysis

- Total N = 5%
- Ammonium-N = 1%
- Total solids = 20%

Example 2: dryland winter wheat wheat/fallow cropping system

< 12 inch precip zone

- Soil: *silt loam*
- Crop: *Wheat-fallow*
- Yield goal: 40 *bushels/acre (soft white wheat)*
- Plant-available N needed: use worksheet in fertilizer guide

Example 2: dryland winter wheat wheat/fallow cropping system **< 12 inch** precip zone

- Biosolids form: *solid (cake)*
- Biosolids processing: *anaerobic*
- Method of application: *incorporated*
- Days before incorporation: *4 days*
- Expected application season: fallow year
- Biosolids analysis: 5% total N, 1% NH4-N, 20% total solids

N credit for previous biosolids application determined by soil testing

Table 3.—Soil test nitrogen for samples collected in 1-foot increments. Values are used for the application rate calculations on page 3.

Soil depth (inches)	Ammonium nitrogen (NH_4-N) (lb/acre)	Nitrate nitrogen (NO_3-N) (lb/acre)	Total soil test nitrogen (NH_4-N + NO_3-N) (lb/acre)	Amount to subtract (lb/acre)
0–12	5	15	20	20
13–24	—	15	15	15
25–36	—	10	10	10
37–48	—	5	5	5
Profile*	**5**	**45**	**50**	**50**
49–60**	—	12	12	—
61–72**	—	10	10	—

* Calculation of the nitrogen application rate should be based on soil test results from the top 4 feet or the effective root zone.
** Nitrogen in the fifth and sixth foot usually does not contribute to yield, but may increase grain protein.

In OSU FG 80. WW in wheat fallow, low precip. zone

Example 1. A nitrogen application rate calculation for soft white common and club-type winter wheat (10% protein).

Assumptions include:

- Expected yield of 40 bu/acre
- Soil test nitrogen = 50 lb N/acre
- Effective rooting depth of 4 feet

	(lb N/acre)
Crop demand for nitrogen*	
(Expected yield) **x** (per-bushel N requirement) at desired protein	
(40 bu/acre) x (2.4 lb N/bu) @ 10% protein	**95**
Subtract soil test nitrogen	
0–12"	20
13–24"	15
25–36"	10
37–48"	5
Total soil test nitrogen	**50**
Nitrogen application rate	**45**

*Crop demand for nitrogen rounded to nearest 5 lb.

In OSU FG 80. WW in wheat fallow, low precip. zone

Research

- Biosolids can improve soil health
- Long term trials needed to measure soil health benefits

Biosolids applications improve soil in the long run by building organic matter

Table 5. Ways in which biosolids can improve soil quality.

Physical	• Greater water-holding capacity • Improved tilth • Reduced soil erosion
Chemical and biological	• Increased cation exchange capacity • Slow release of plant-available N and S from organic forms • Correction of micronutrient deficiencies • Increased earthworm and microbial activity

Evidence for long-term biosolids effects on nutrient management and soil organic matter:

Dryland wheat in central Washington

WASHINGTON STATE UNIVERSITY
EXTENSION

Long-term dryland wheat-fallow experiment 1994-present

- Alternating winter wheat and fallow
- Biosolids applied every 4th year, crop harvested every 2 years

Long-term dryland wheat-fallow experiment

Biosolids rates:

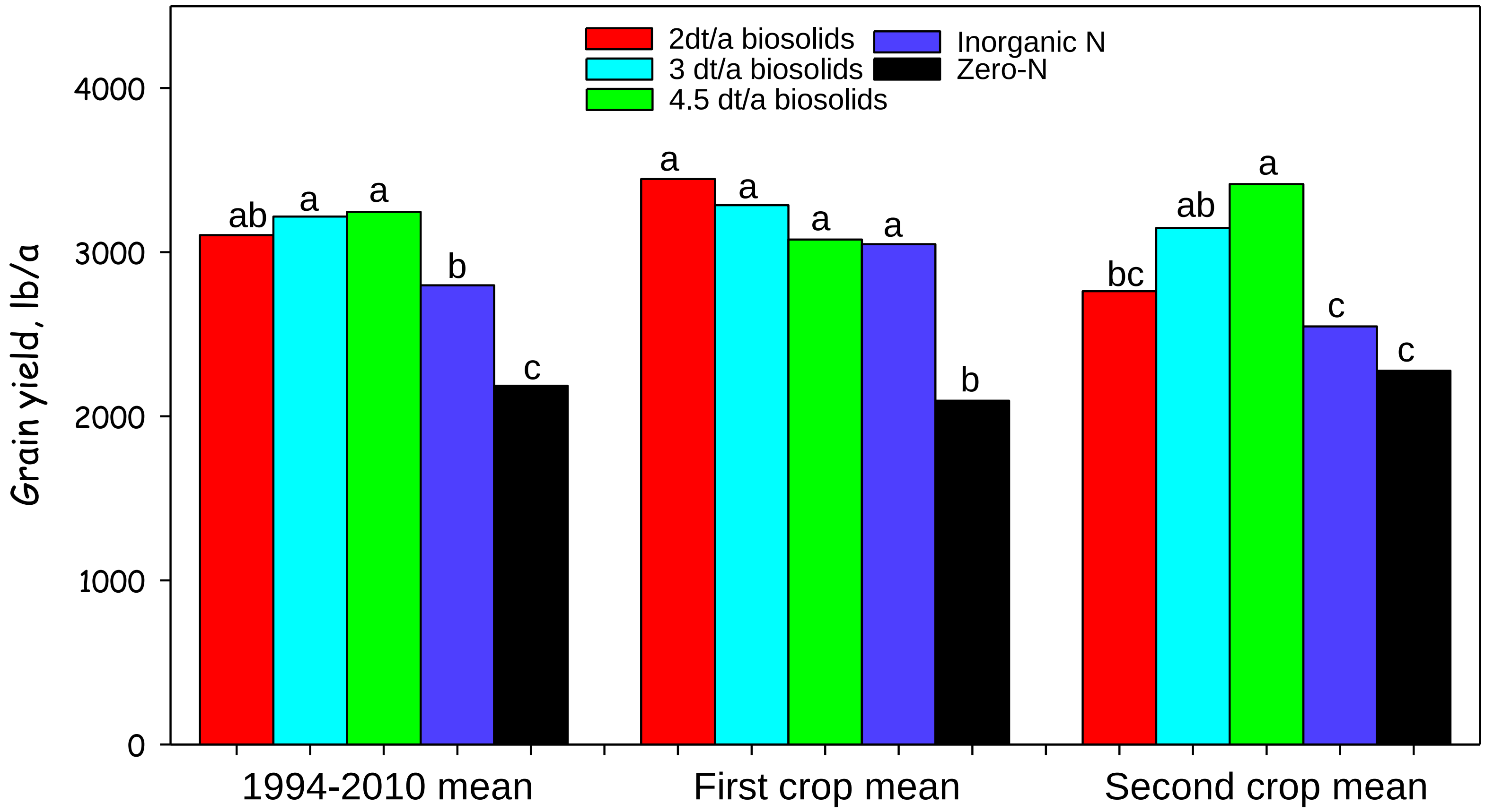
2, 3, 4 dry tons/acre each application

Inorganic N 50 lb/acre each crop

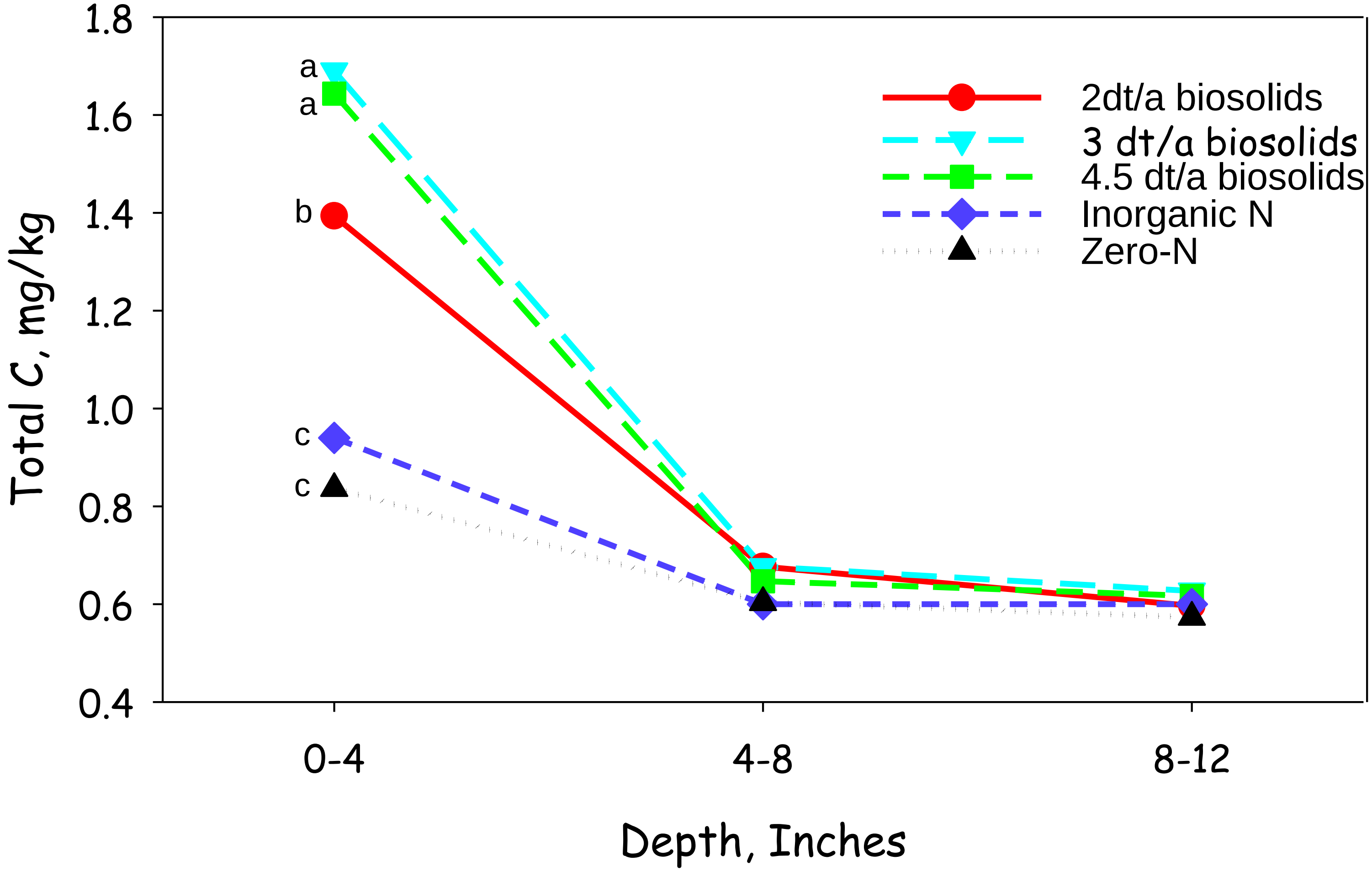
Zero-N control

Total biosolids applied 1994 – 2010: 10-20 dry tons/acre

Biosolids had equal or greater grain yields than inorganic N treatment



All biosolids application rates increased organic matter in the upper 4 inches of soil



C and N accumulation in soil as % of biosolids C and N applied

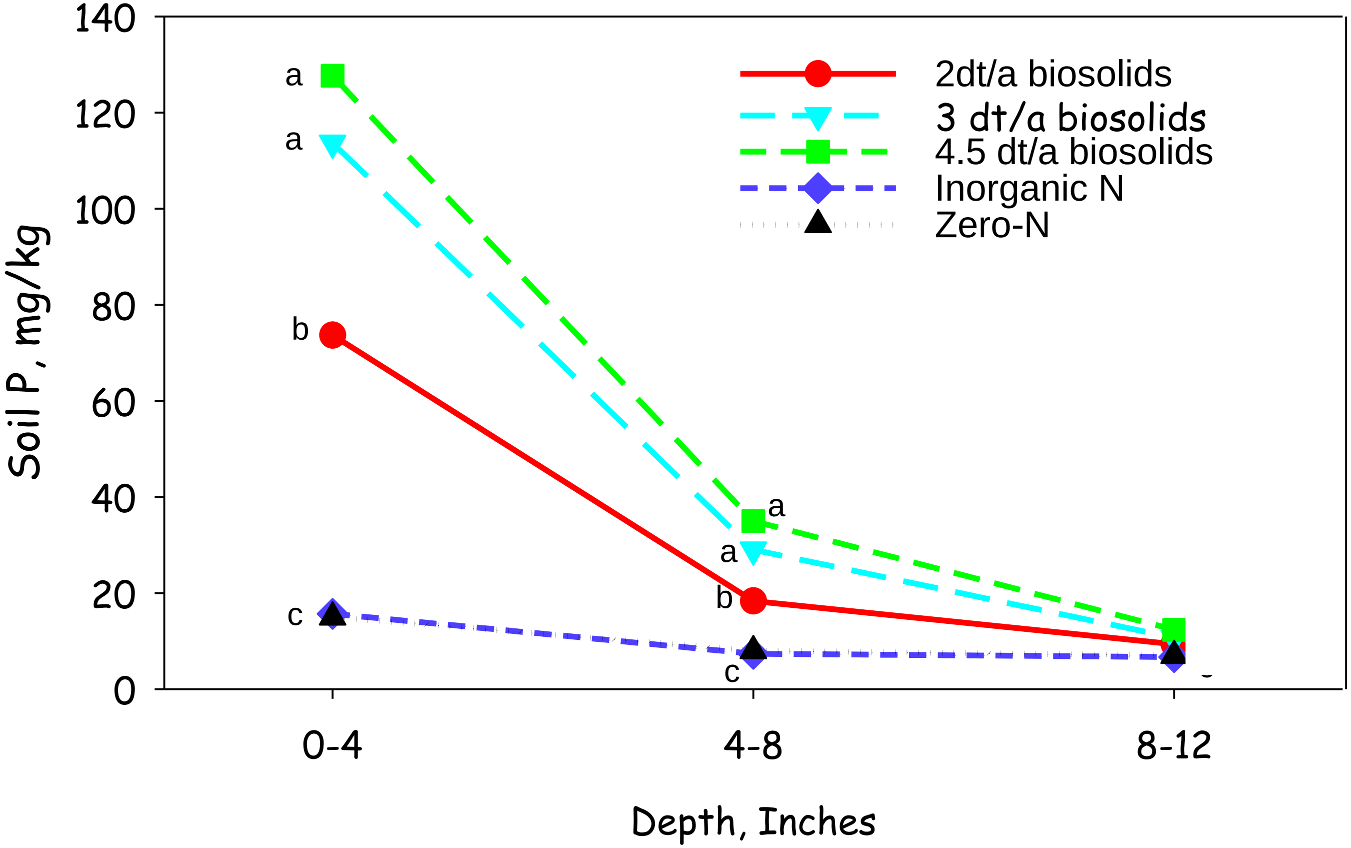
Wheat: Applied every 4th year since 1994

C increase = **57%** of total C applied

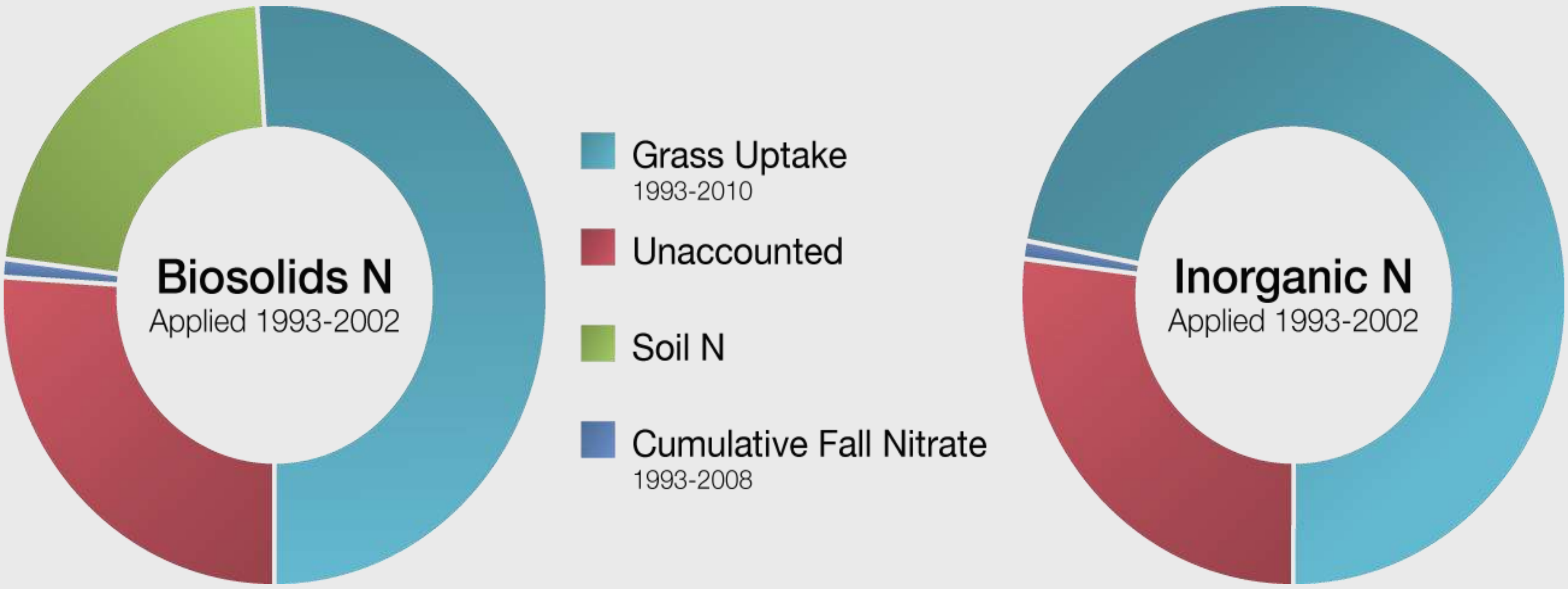
N increase = **33**% of total N applied

Improves soil and sequesters carbon

Soil test P increased in the biosolids treatments.



Fate of biosolids N and inorganic (fertilizer N)



Soil sampled in 2011, 10 yr. after last biosolids application

Cogger et al., Puyallup, WA (WSU)

Biosolids research summarized in 2015 PNW Extension publication

Questions?

Northwest Biosolids Management Association

oregon association of CLEAN WATER agencies

Fertilizing with Biosolids

Andy Bary

Soil Scientist

Crop & Soil Science

Washington State University Puyallup

What’s on the menu?

- Preview new Extension publication
- Soil testing as a “value-added” service of your biosolids program
- What a soil test measures
- Choosing a lab and requesting appropriate testing methods
- Guide to soil sample collection
- Phosphorus: agronomic vs. environmental interpretation

Pacific NW Extension publication 508-E

Table 1. Biosolids organic matter and macronutrients (dry weight basis).[a]

	Usual range (%)[b]	
Nutrient	**Low**	**High**
Organic matter	45	70
Nitrogen (N)	3	8
Phosphorus (P)[c]	1.5	3.5
Sulfur (S)	0.6	1.3
Calcium (Ca)	1	4
Magnesium (Mg)	0.4	0.8
Potassium (K)[c]	0.1	0.6

Biosolids: fertilizer replacement value of nutrients

Nutrient	Fertilizer replacement value of biosolids nutrient ($/dry ton)
Nitrogen	19.95
Phosphorus	21.80
Potassium	4.14
Sulfur	2.66
Total	48.55

Role of soil testing in nutrient management

Nutrient management

- Plan
- Implement
- Monitor
- Then modify based on what monitoring data (soil, plant, irrigation water) tells you

Role of soil testing in biosolids management program

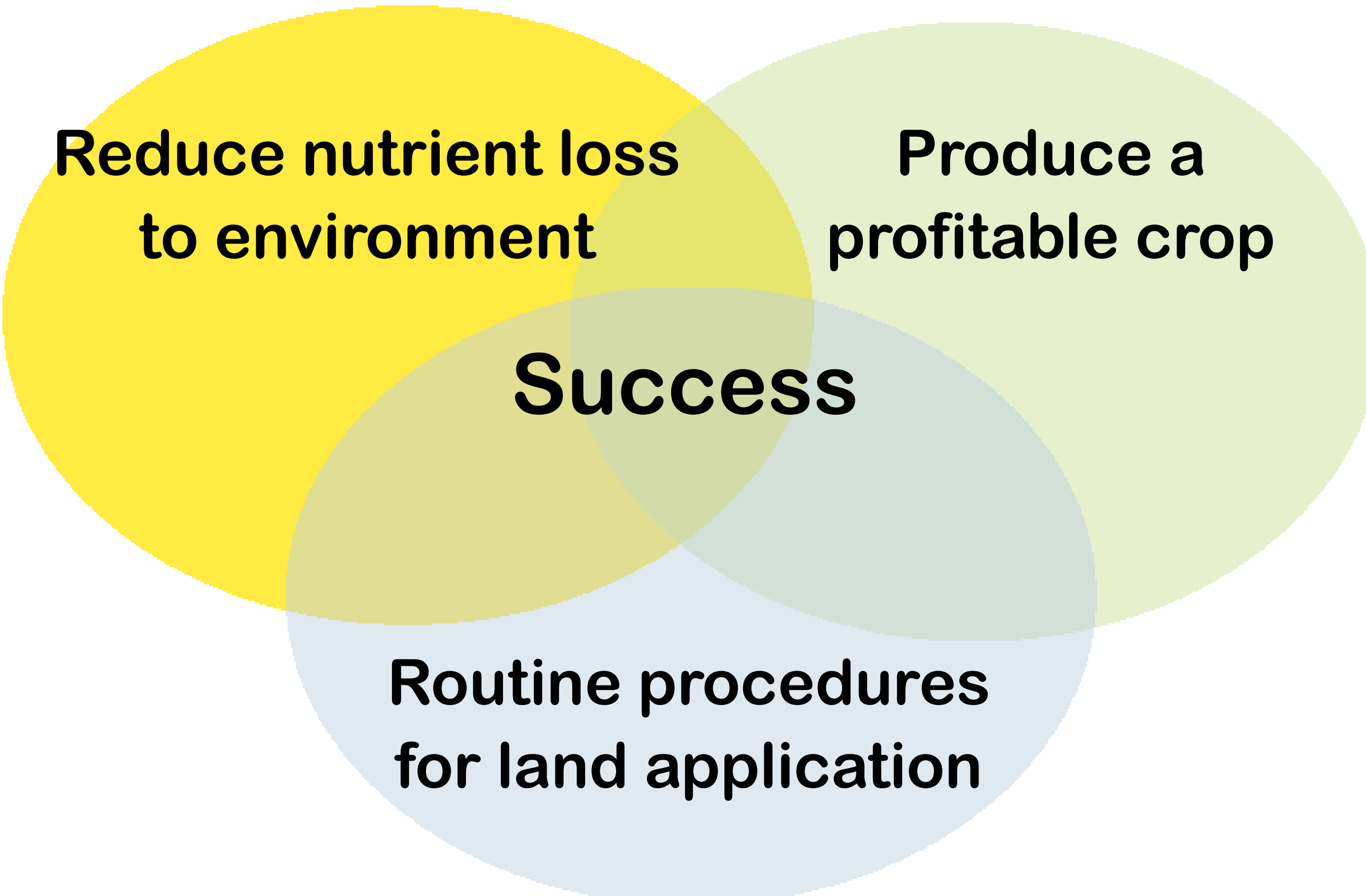
Nutrient management goals for biosolids managers

- Regulatory compliance: agronomic rate
- Assisting farmer with his business: crop production
- A well-designed soil testing program is an essential part of pro-active biosolids management
- Build trust in local agriculture community

Soil testing: role in biosolids management

- Ag professionals and farmers are familiar with soil testing as a management tool
- But, they may not understand organic fertilizers
- And may not understand what an “agronomic rate” is

Soil testing: overlap of regulator, grower, and biosolids manager goals



Soil testing methods and interpretations

- Land grant universities OSU, WSU, U of I
  - developed soil test methodology and interpretations
- Pacific Northwest is unique in US
  - cross-border cooperation in nutrient management among universities
- Crop specific soil test interpretations
  - Similar across state lines
  - for agro-ecoregions (e.g. irrigated or Columbia Basin)

Soil Test Interpretation Guide

D.A. Horneck, D.M. Sullivan, J.S. Owen, and J.M. Hart

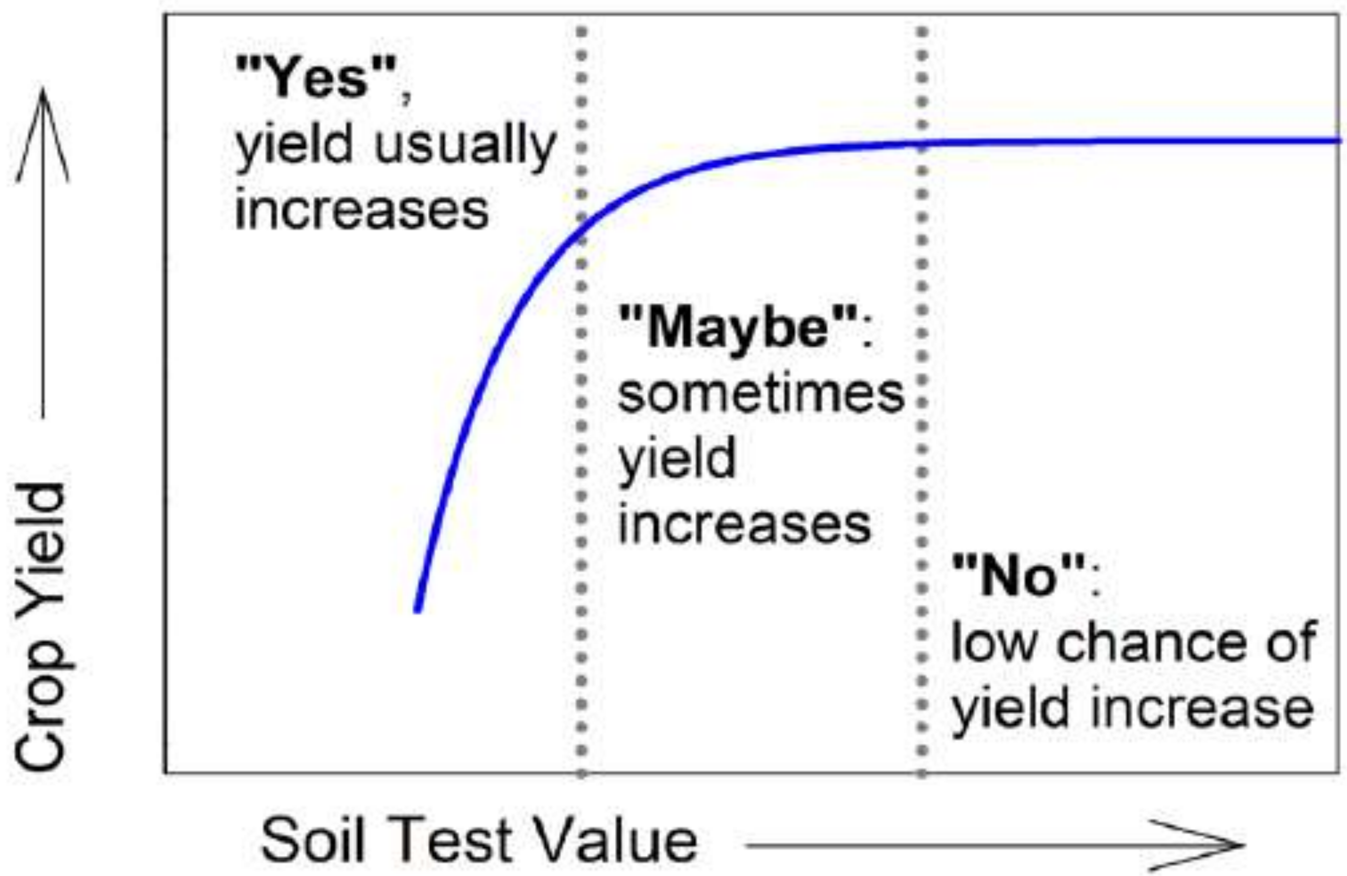
EC 1478 • Revised July 2011

- OSU EC 1478-E
- Most recent summary of applicable soil test methods used in the Pacific Northwest
- General reference: “approved” method, general interpretation: low, medium, high
- More specific information provided in crop/region specific nutrient management guides

What to expect from a soil test

- Determine soil nutrient status with respect to crop production (deficient, adequate, excess)
- Determine need for lime or other amendments to adjust soil pH
- Measure change over time due to management practices, including fertilizer source, rate, timing….

Soil test value vs. crop yield response to nutrient addition



Soil analyses: west of Cascades

(pH < 7; precipitation 30 to 50+ inches)

- soil pH
- lime requirement: SMP buffer test
- Bray P1 phosphorus
- Exchangeable cations (Ca, Mg, K)
- hot-water extractable B
- Post-harvest NO3-N?
  - Sept 1-Oct 15

Soil analyses: east of Cascades

(pH > 7; precipitation 6 to 20 inches)

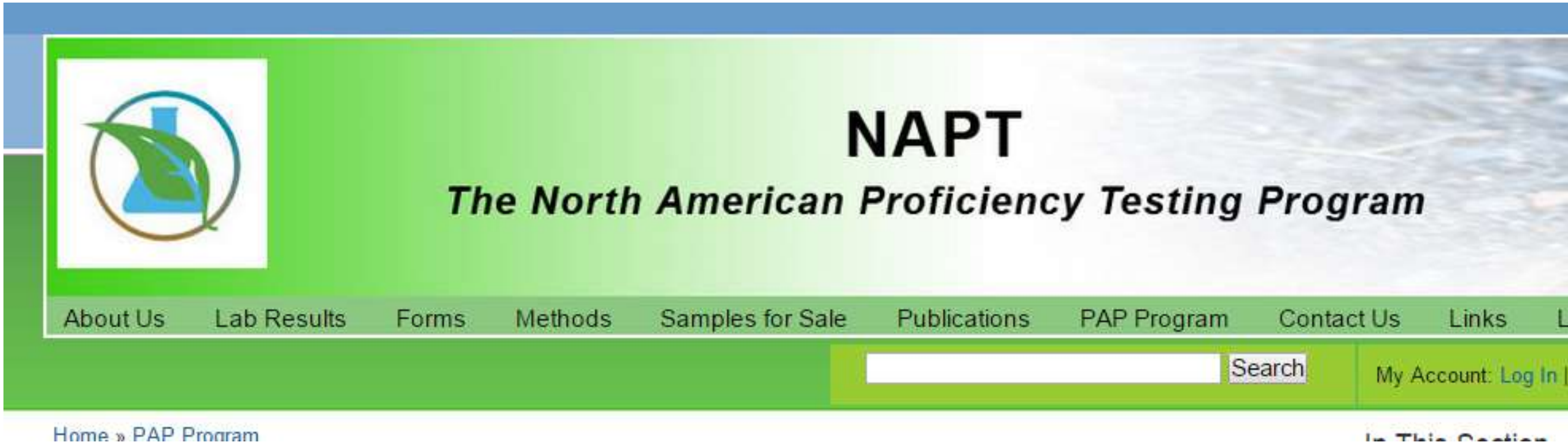
- soil pH
- soluble salt (EC)
- Olsen phosphorus
- Exchangeable cations, including sodium (Na)
- hot water extractable B
- Preplant NO_3-N (consult university nutrient guide for sample depth)
- % $CaCO_3$ (free lime)
- DTPA extract: Zn, Fe, Mn

Interesting but probably not essential

- Ammonium-N (NH4-N)
- Sulfate-S (SO4-S)
- Percent base saturation
- Cation exchange capacity (CEC)
- Nutrient ratios
- Soil texture
- Mineralizable N, total N
- Soil health score (Haney test)
- Organic matter or soil carbon
  - Sometimes useful for long term monitoring

Choosing a laboratory

- NAPT-PAP
- Lab choosing tips
  - Talk to them
    Visit the lab
    See lab report
    Use same lab consistently



- http://www.naptprogram.org/pap
- Voluntary soil testing quality control program supervised by Soil Science Society of America
- About 10 labs in West were "certified" in 2014
- Based on annual performance in accurate analysis of "double-blind" soil samples
- Must use NAPT-PAP lab when sampling under cost-share agreement with NRCS for nutrient management

“Reference” soil samples for sale at NAPT-PAP website

Home

Samples for Sale

Soil For Sale & Plants For Sale

To place an order for any of the samples, please complete the "Laboratory Information" and "Reference Items" section on our Enrollment/Order Form. Enrollment in the NAPT Program is not required to order reference samples.

Note: In addition to inventory, five small containers of each soil have also been set aside for research.

Soil Name	Year	Number	Small Containers	Buckets	Notes	pH, sp	EC, sp	P, Olsen	P, M-3	NO3-N
Timpanogas	2008	101	24		Multi quarter 101, 107, 113, 120	5.83	2.20	31.0	82.4	94.0
Hublersburg	2008	102	28			5.00	1.42	31.0	64.5	5.0
Fallsington	2008	103	26	1/2 bucket		6.66	0.48	29.8	89.0	15.6
Declo	2008	104	31			7.86	0.76	35.0	96.9	10.0
Freehold	2008	106	31		Same as 2012-102	5.35	0.23	45.9	130.0	5.0
Blue Creek	2008	107	34		Multi quarter 101, 107, 113, 120	5.85	220.0	30.1	81.0	93.6
Ririe	2008	109	34	3 1/2 buckets		7.97	0.54	26.0	96.0	8.0

Soil sample with a known analysis using approved agricultural soil testing methods

Can be used to assess accuracy and consistency of analyses over time.

A Guide to Collecting Soil Samples
for Farms and Gardens

M. Fery and E. Murphy

Without a soil analysis, it's nearly impossible to determine what a soil needs in order to be productive. Laboratory soil analyses (soil tests) provide information on your soil's available nutrient-supplying capacity. This information helps you select the correct kind and amount of fertilizer and liming material, which helps you develop and maintain more productive soil and increased crop production.

Recommendations in this publication are based on the results of fertilizer experiments, soil surveys, and results obtained by farmers.

Why should I collect a soil sample?

Reasons for soil sampling include the following:

- Establish baseline soil nutrient status for new landowners
- Measure change in soil nutrient status over time
- Document soil nutrient management for certification

OSU Extension pub EC 628
Good summary
of general principles

This publication is not intended to be a guide for obtaining soil samples for environmental testing.

Melissa Fery and Elizabeth Murphy, instructors, Extension Small Farms Program, Oregon State University

EC 628
Revised September 2013

Soil sampling
PNW Extension publication 570-E

PNW 570-E • October 2003

Monitoring Soil Nutrients Using a Management Unit Approach

M.L. Staben, J.W. Ellsworth, D.M. Sullivan, D. Horneck, B.D. Brown, and R.G. Stevens

Consistent soil sampling depth is critical

- Nutrients like P and K are often much higher in top inches of soil
- Especially in no-till or pasture:

  nutrients accumulate and pH changes mostly at the soil surface (0-2 inches)
- Standard sampling depth for most soil test interpretations in university guides is 12 inches in the PNW
- Consult nutrient management guide for crop before sampling

Soil probe

Photo: OSU Extension

- Collect same amount of soil from each depth
- Known sampling depth
- Easy to clean out between samples

Use shovel?

- Depth unknown
- More soil from top than from bottom of hole
- May be zinc plated

Photo: Virginia Tech

Different probes suited for different sampling situations

Foot probe

Open-ended "gator" probe

What changes you expect from repeat biosolids application

- Increase soil test P
- Maintain or decrease soil test K
- Increase soil organic matter (and total N & C)
- Increase soil NO3-N (preplant application)
- Utilize most of the soil NO3-N near crop harvest time (low NO3-N in fall is the goal)
- pH and soluble salt (EC) similar to mineral N fertilization program (e.g. urea)

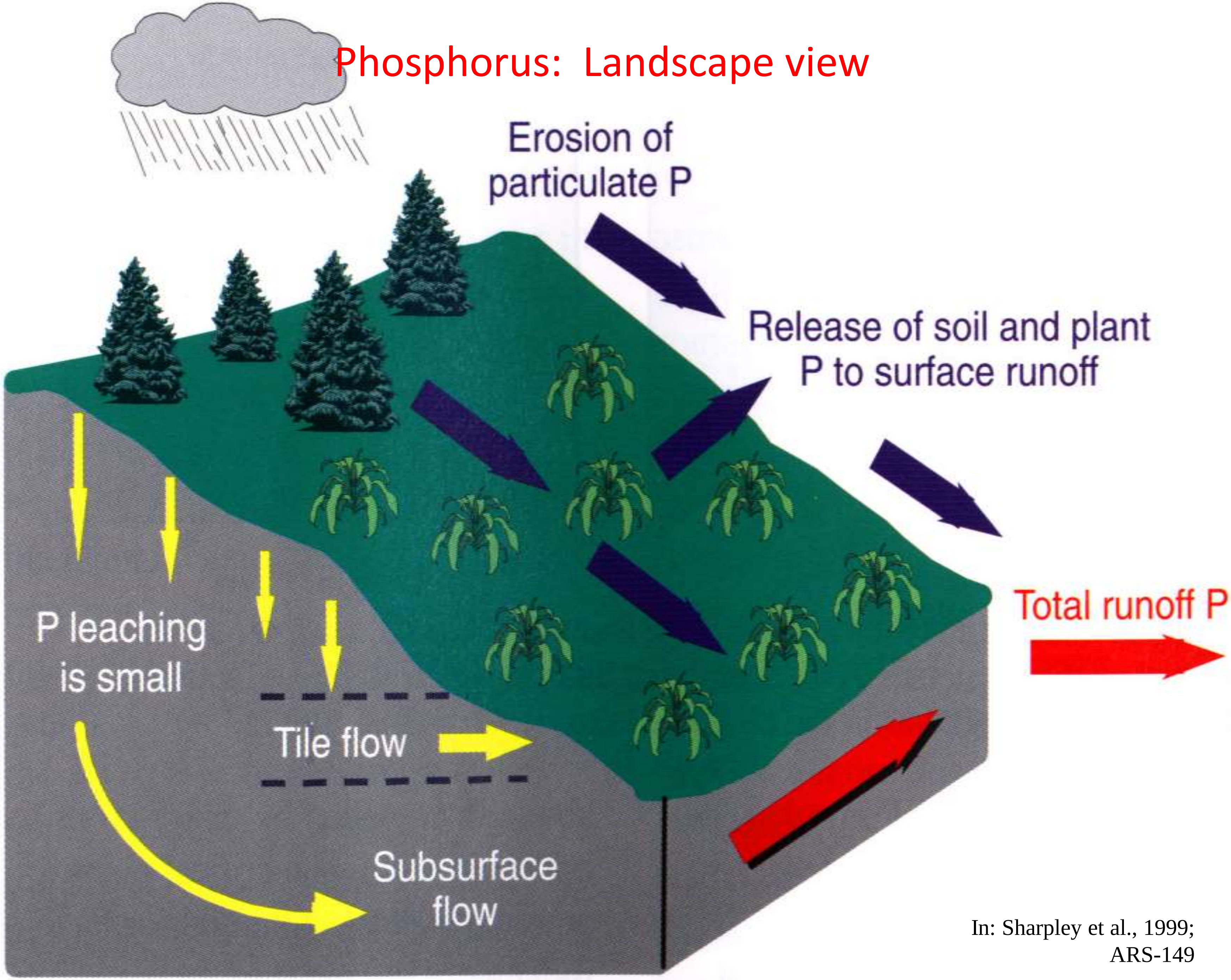
Phosphorus

- Plant nutrient
- Potential water pollutant
- Biosolids are rich in P
- When applied to supply N for a crop, P accumulates
- P accumulation monitored by agronomic soil testing
- Agronomic testing extracts a small fraction of total soil P that is correlated with P that roots can “extract” from soil.

Total vs. available nutrients in biosolids

Nutrient	Expressed as	Total nutrient (% dry wt)	Available nutrient (% of total nutrient)
Nitrogen	N	5.0	35
Phosphorus	P	2.5	40
Potassium	K	0.3	100
Sulfur	S	1.0	35
Total	—	—	—

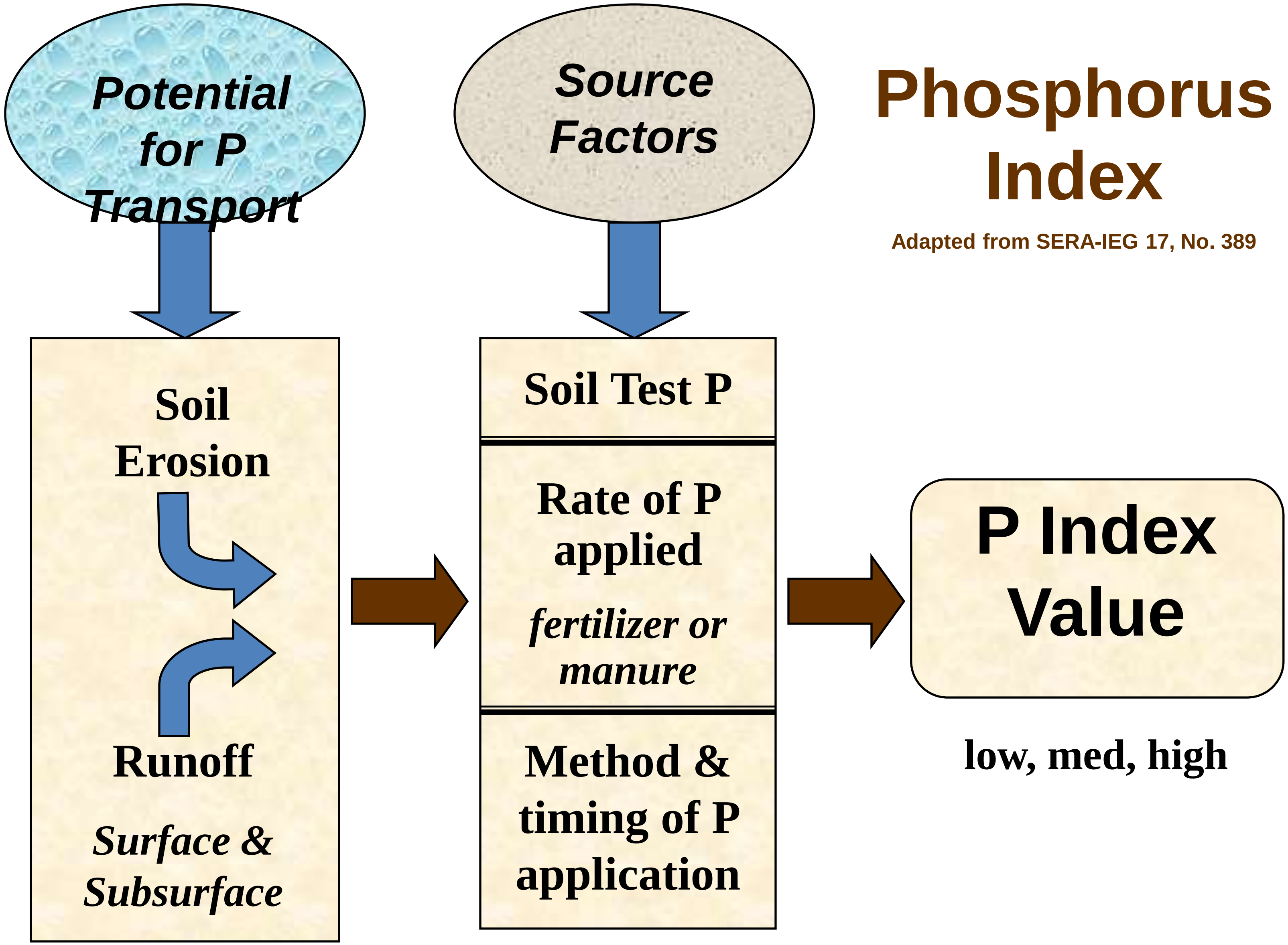
Phosphorus: Landscape view



In: Sharpley et al., 1999; ARS-149

Phosphorus Index

Adapted from SERA-IEG 17, No. 389



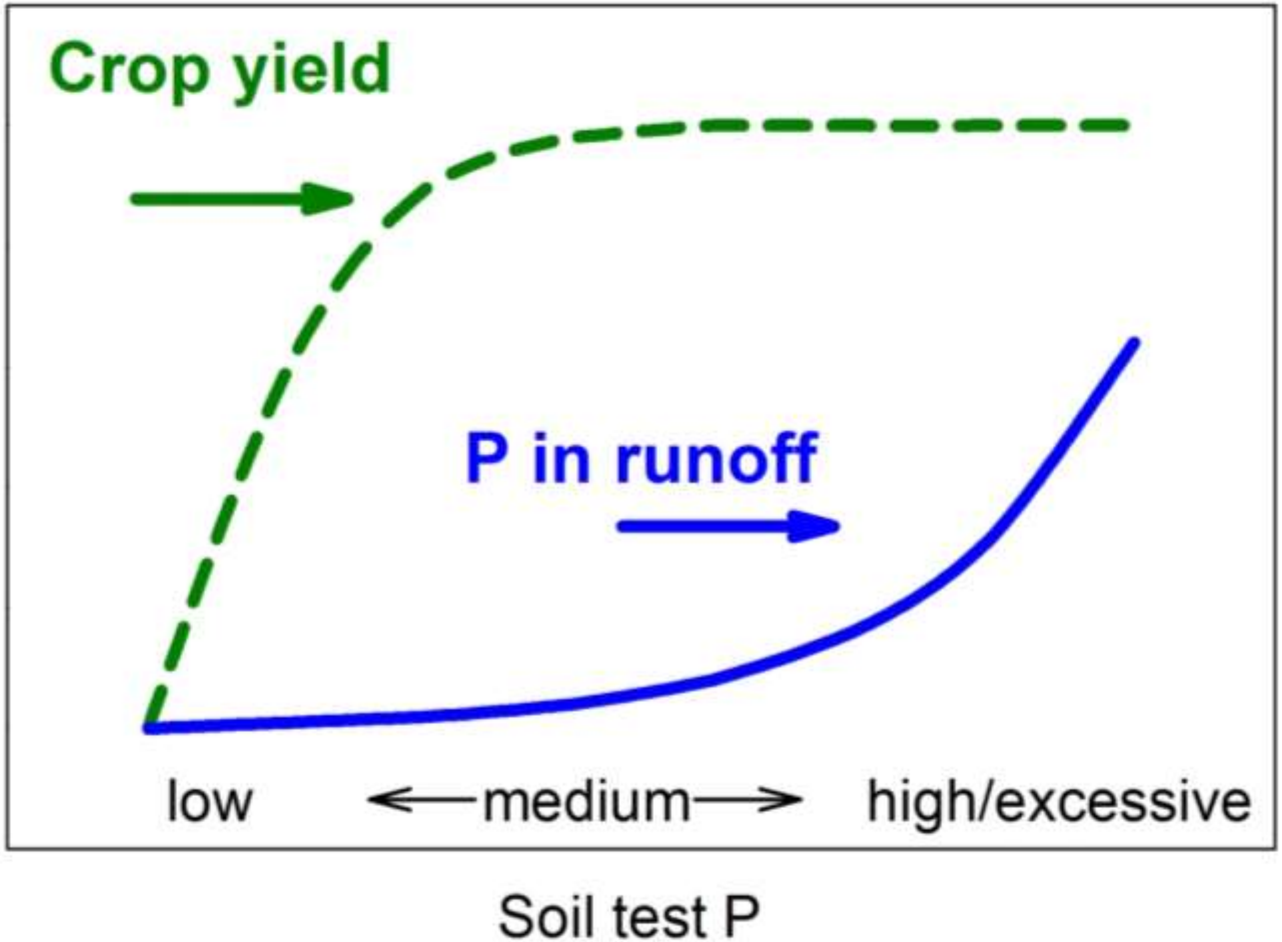
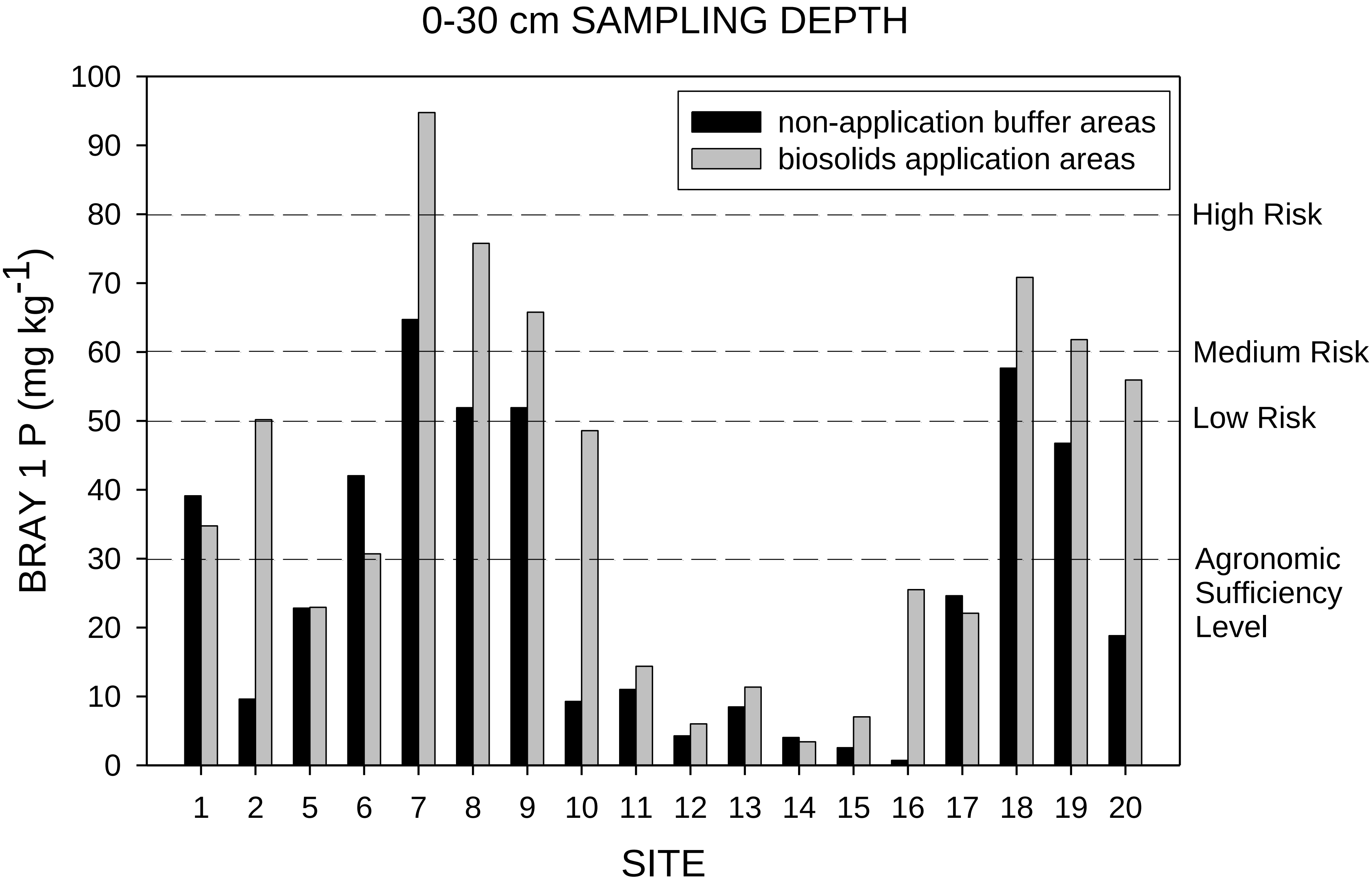


Figure 3. Agronomic and environmental interpretations of soil test P.


0-30 cm SAMPLING DEPTH
BRAY 1 P (mg kg-1)
100
90
80
70
60
50
40
30
20
10
0
non-application buffer areas
biosolids application areas
High Risk
Medium Risk
Low Risk
Agronomic
Sufficiency
Level
1
2
5
6
7
8
9
10
11
12
13
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SITE

Questions?