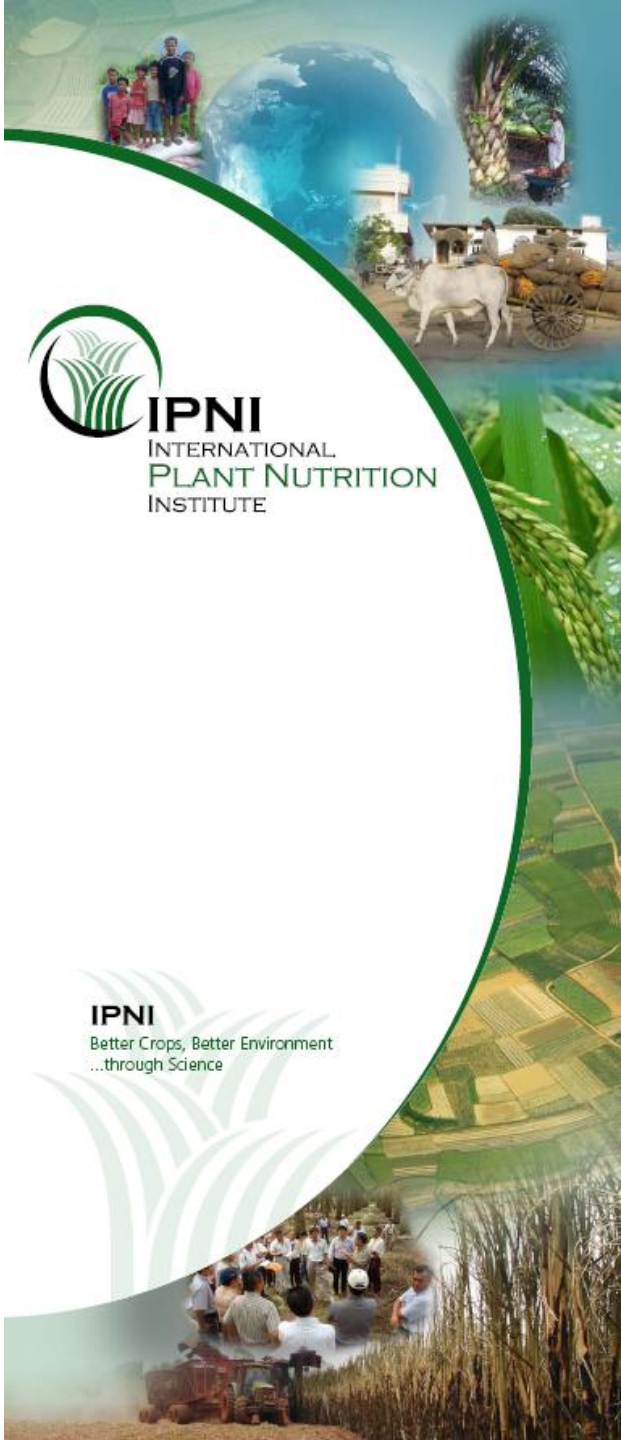
The Potassium Sandwich: Is It Nutritional?

T. Scott Murrell

AGVISE Laboratories Soil Fertility Seminars, 7-9 Jan. 2014.



The K Sandwich (5)

Mineral Transformations (7)

Moist K Test (4)

Site-Specific Soil Test Calibration (4)

K Budgets and Soil Test Changes (7)

Impact of K Fertilization on Mineralogy (4)

Mineralogical Information in Soil Surveys (4)

K Deficiency Symptoms (10)

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The K Sandwich

What is the Potassium Sandwich?

- The “bread” of the sandwich:
  - Phyllosilicate minerals
  - Two basic structural components:
    - Tetrahedral layer
    - Octahedral layer

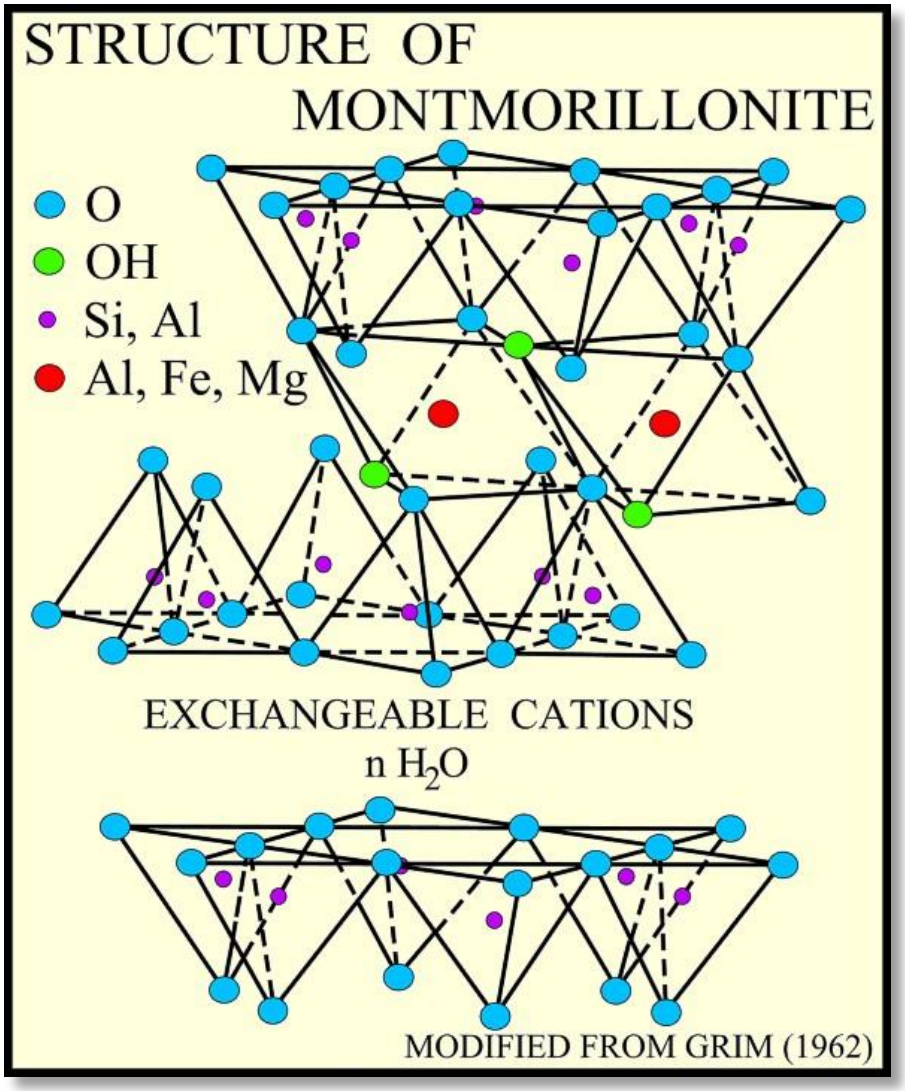


Image available at: http://pubs.usgs.gov/of/2001/of01-041/htmldocs/clays/smc.htm (verified 5 Jan. 2014).

Phyllosilicates: Layer Structure

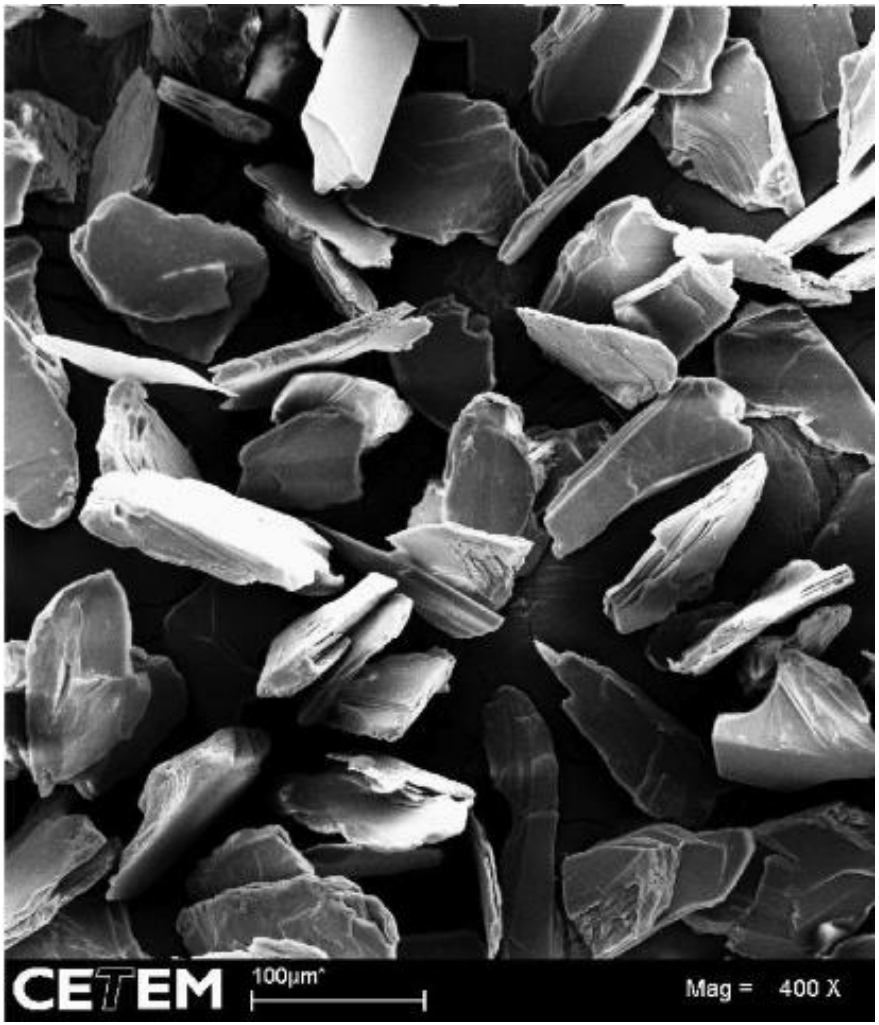


Photo: Michele Hogan

da Silva, A. de A.S., J.A. Sampaio, A.B. da Luz, S.C.A. França, and C.M. Ronconi. 2013. Modeling controlled potassium release from phlogopite in solution: Exploring the viability of using crushed phlogopite rock as an alternative potassium source in Brazilian soil. J. Braz. Chem. Soc. 24:1366-1372.

“Fixed” K

Mica and Illite examples

“Fixed K”

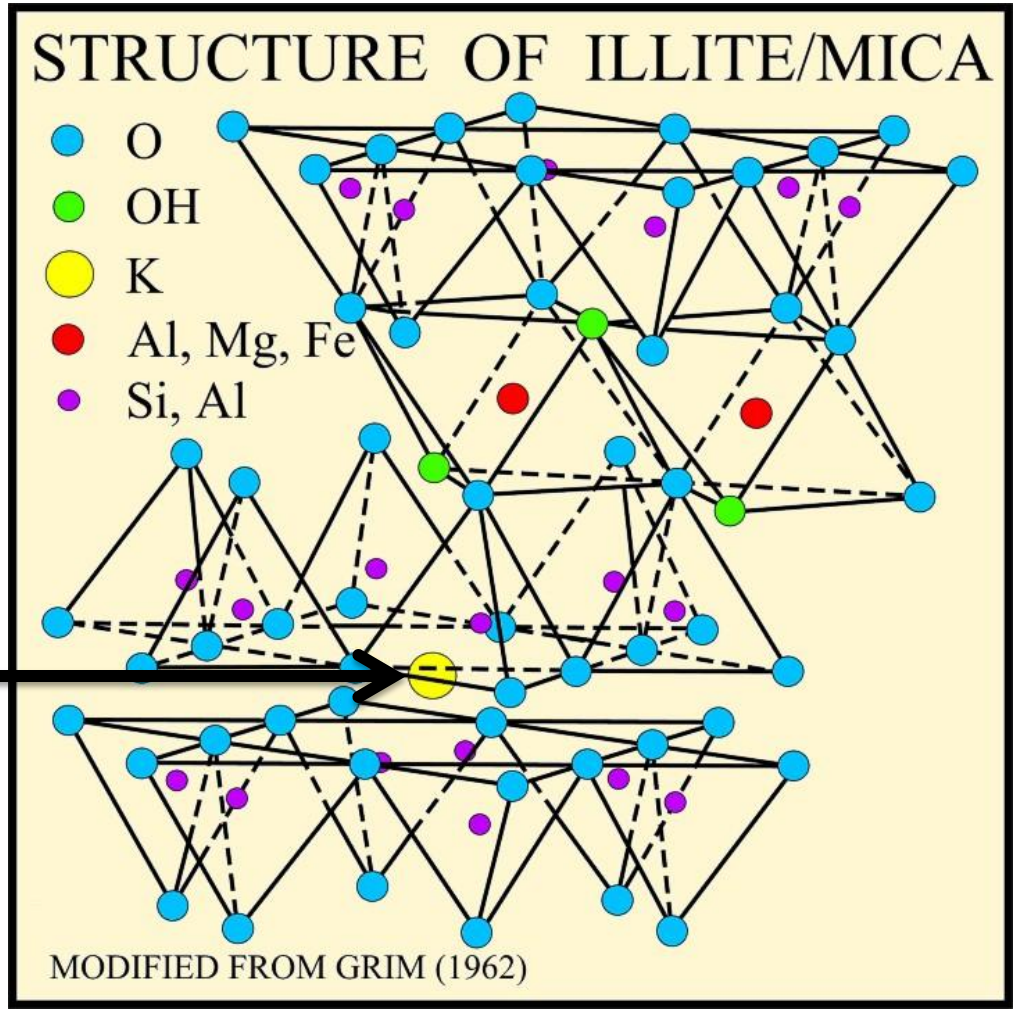
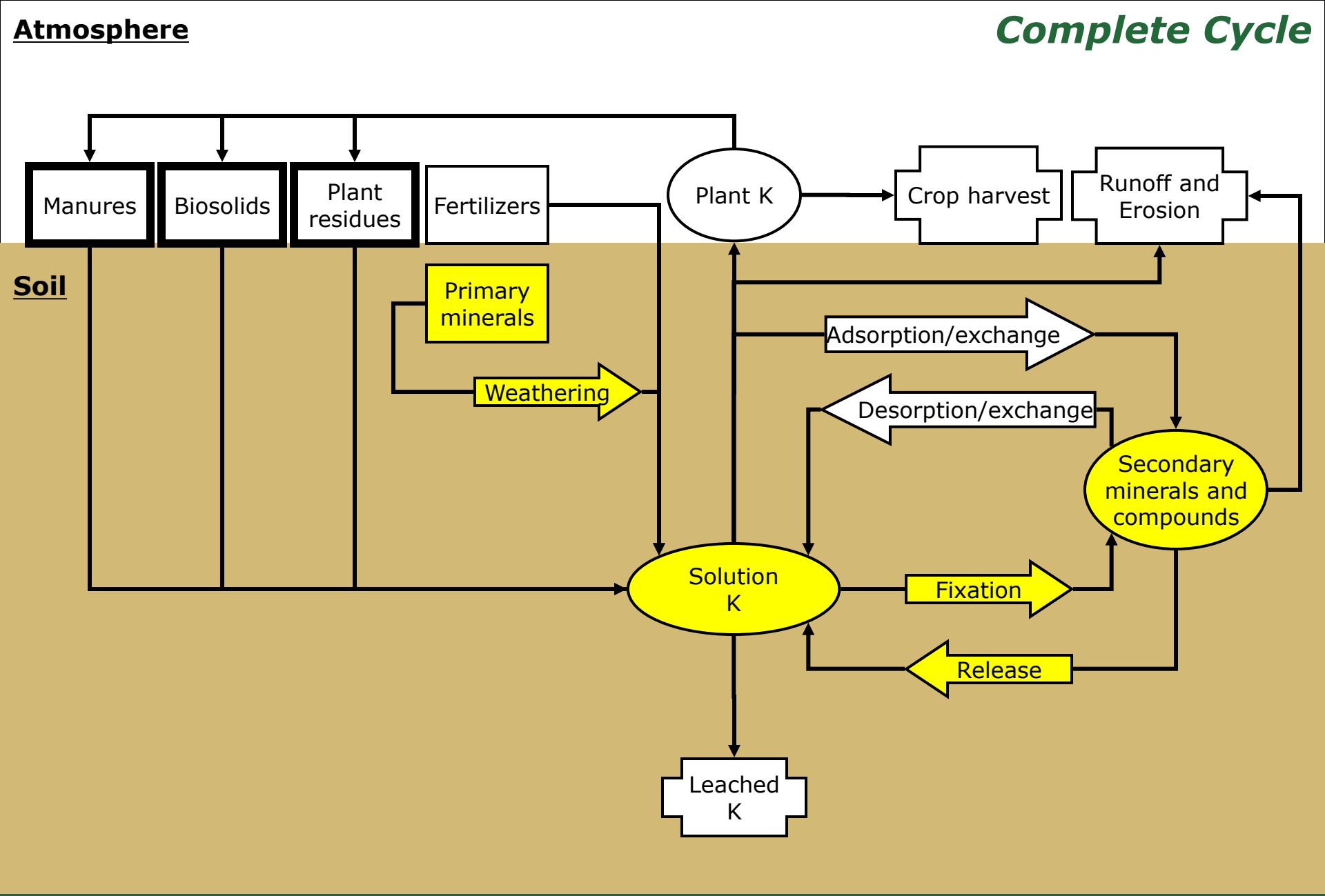


Image available at: http://pubs.usgs.gov/of/2001/of01-041/htmldocs/clays/illite.htm (verified 5 Jan. 2014).



Legend

Component | Organic input | Inorganic input | Output | Transformation | Cycle flow

Summary:
The K Sandwich

Mineral layer

Interlayer potassium

Mineral layer

Interlayer potassium is the “meat” of our discussion

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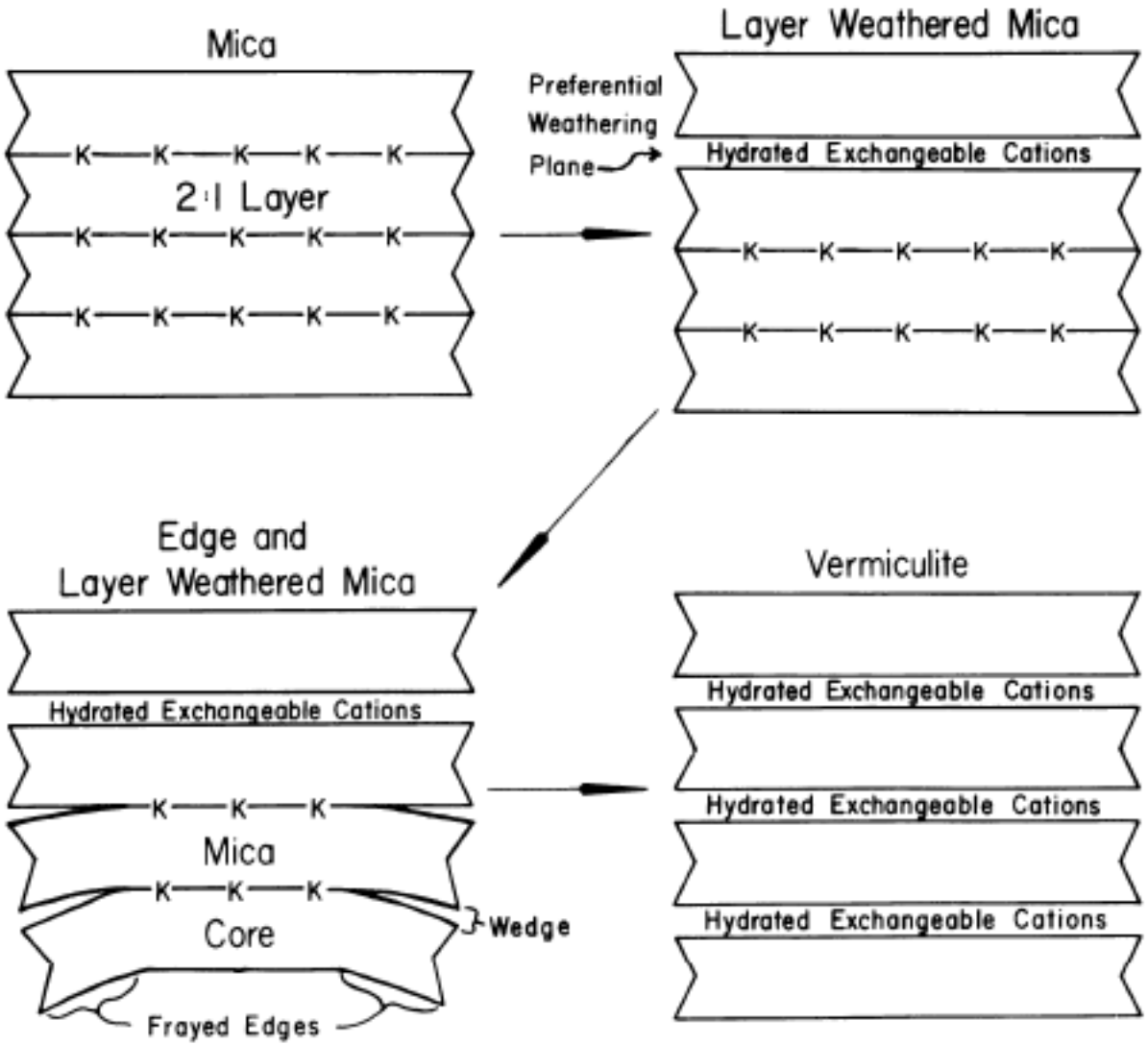
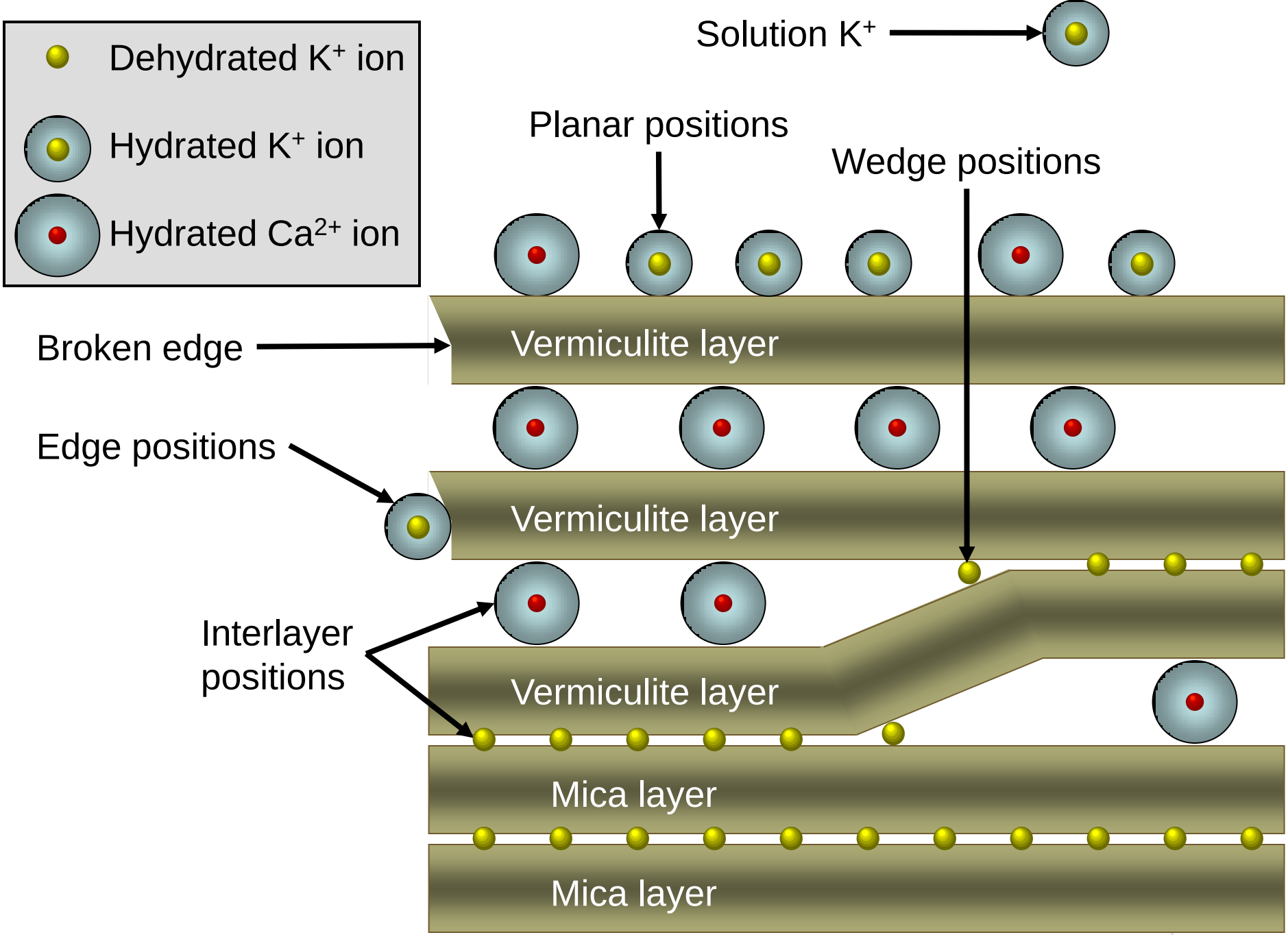
Mineral Transformations

Mica Weathers to Other Minerals

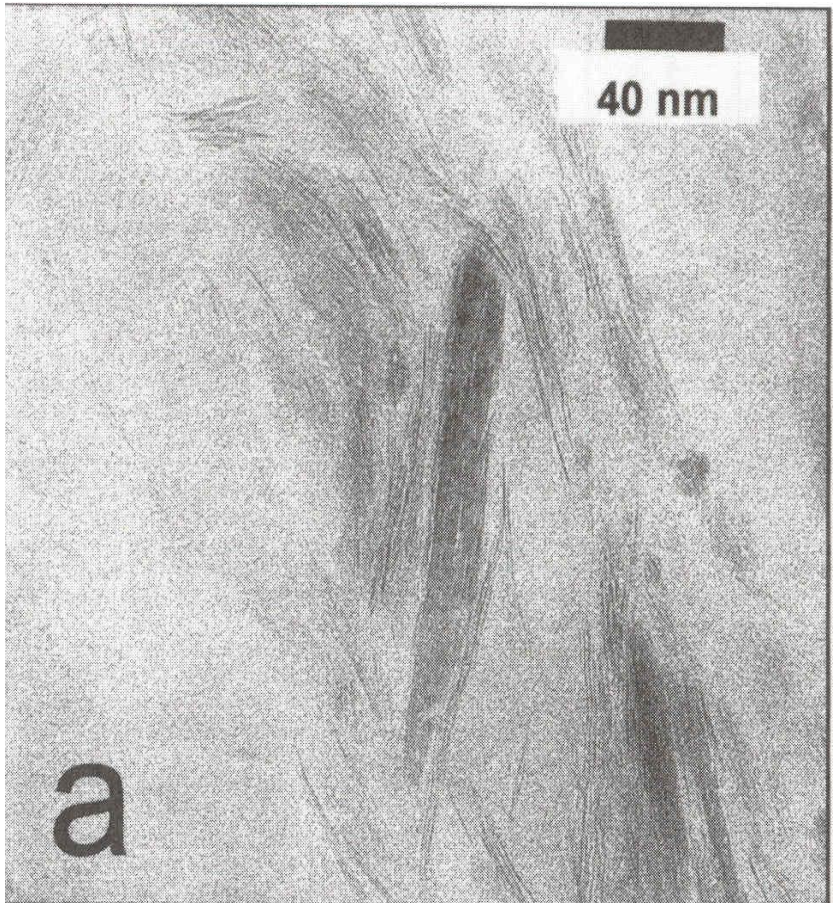


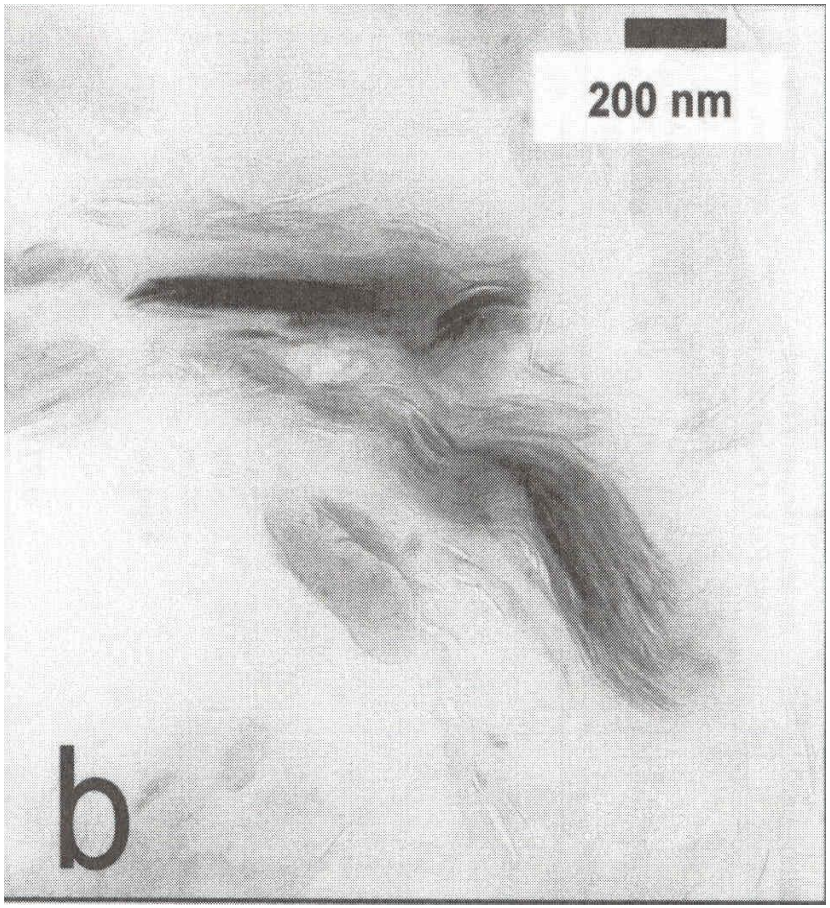
Fanning, D.S. V.Z. Keramidas, and M.A. El-Desoky. 1989. Micas. p. 551-634. *In* J.B. Dixon and S.B. Weed (eds.) Minerals in Soil Environments. 2nd ed. SSSA, Madison, WI..



Rich, C.I. 1968. Mineralogy of soil potassium. p. 79-108. In V.J. Kilmer, S.E. Younts, and N.C. Brady (Eds.) The role of potassium in agriculture. ASA, CSSA, SSSA, Madison, WI.

Transmission Electron Micrograph Shows “Feathering” of Mineral Edges

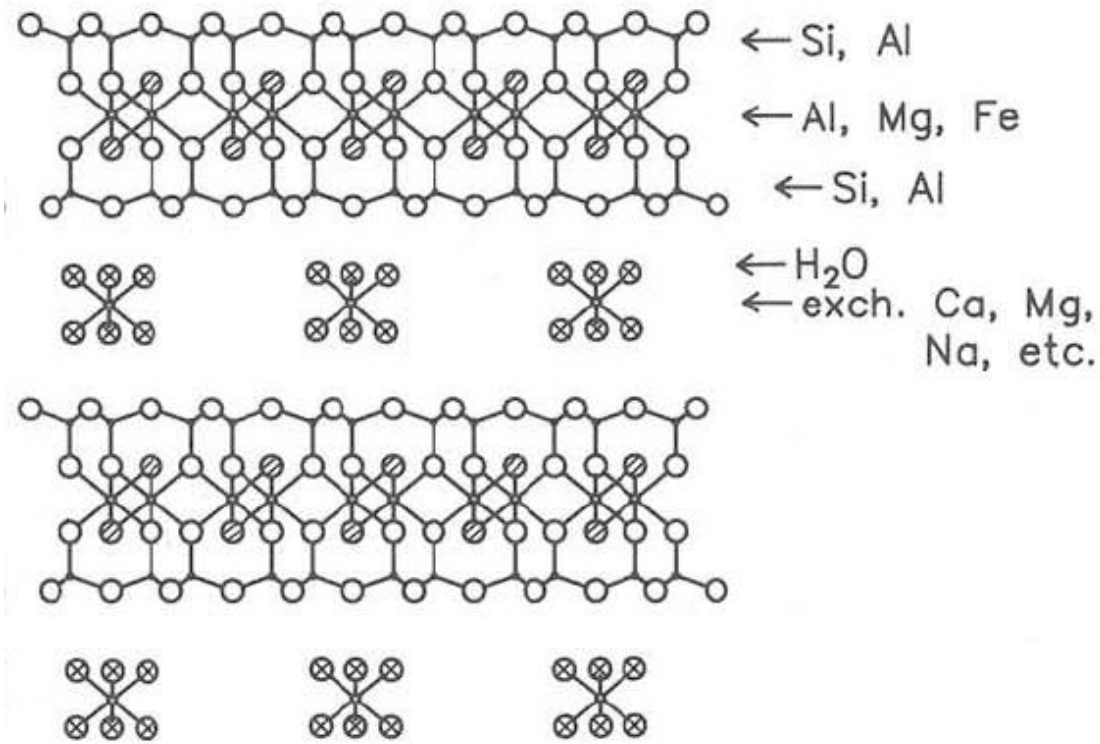




B. Joern, Purdue Univ. (personal communication)

Vermiculites and Smectites
(Swelling minerals)

- Interlayer cations in vermiculites and smectites are hydrated (have water around them) and are exchangeable
- Vermiculite has a higher layer charge than smectite



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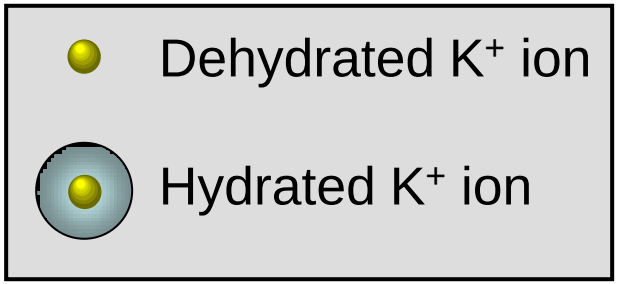
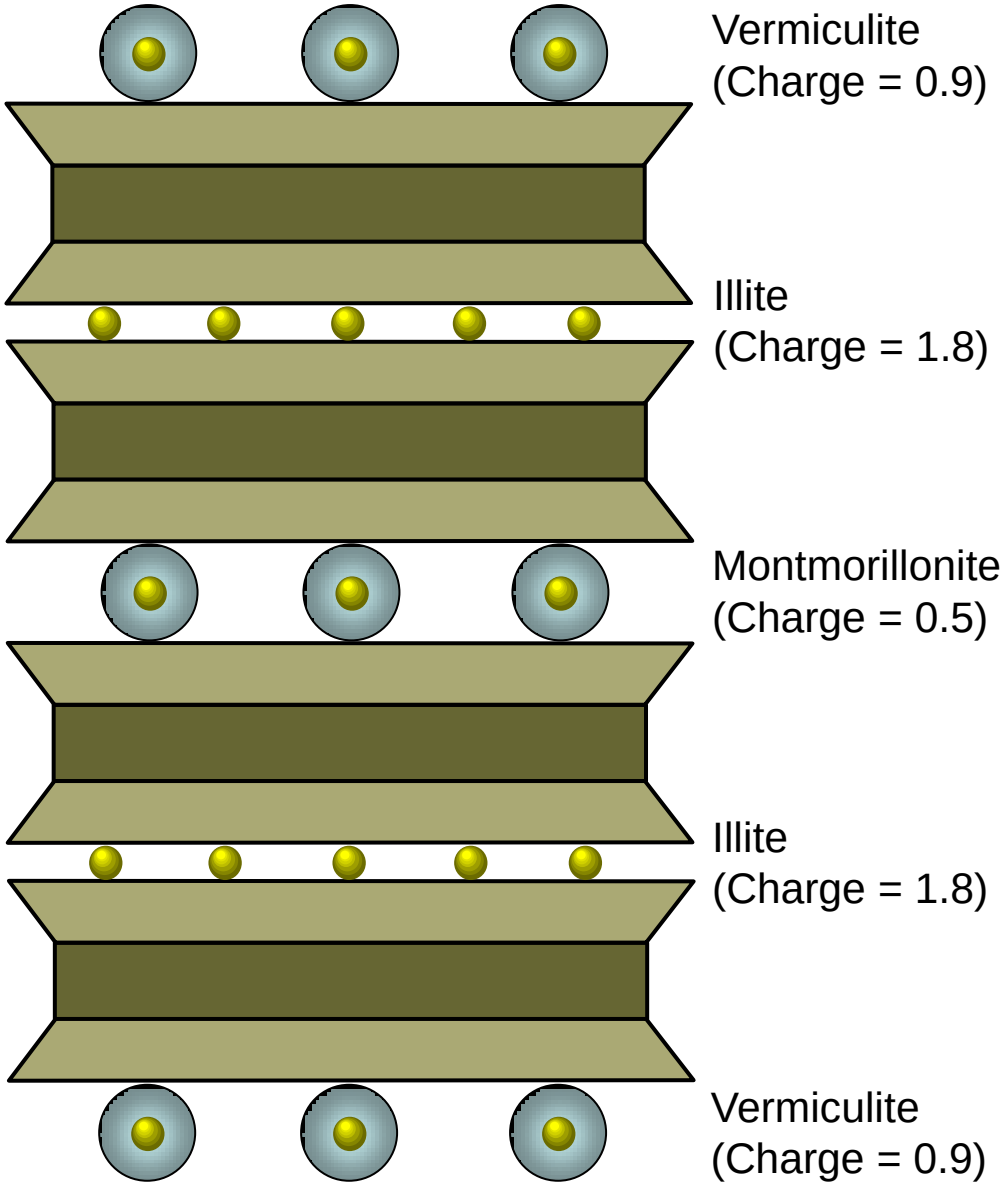
Illite
(Non-swelling mineral)

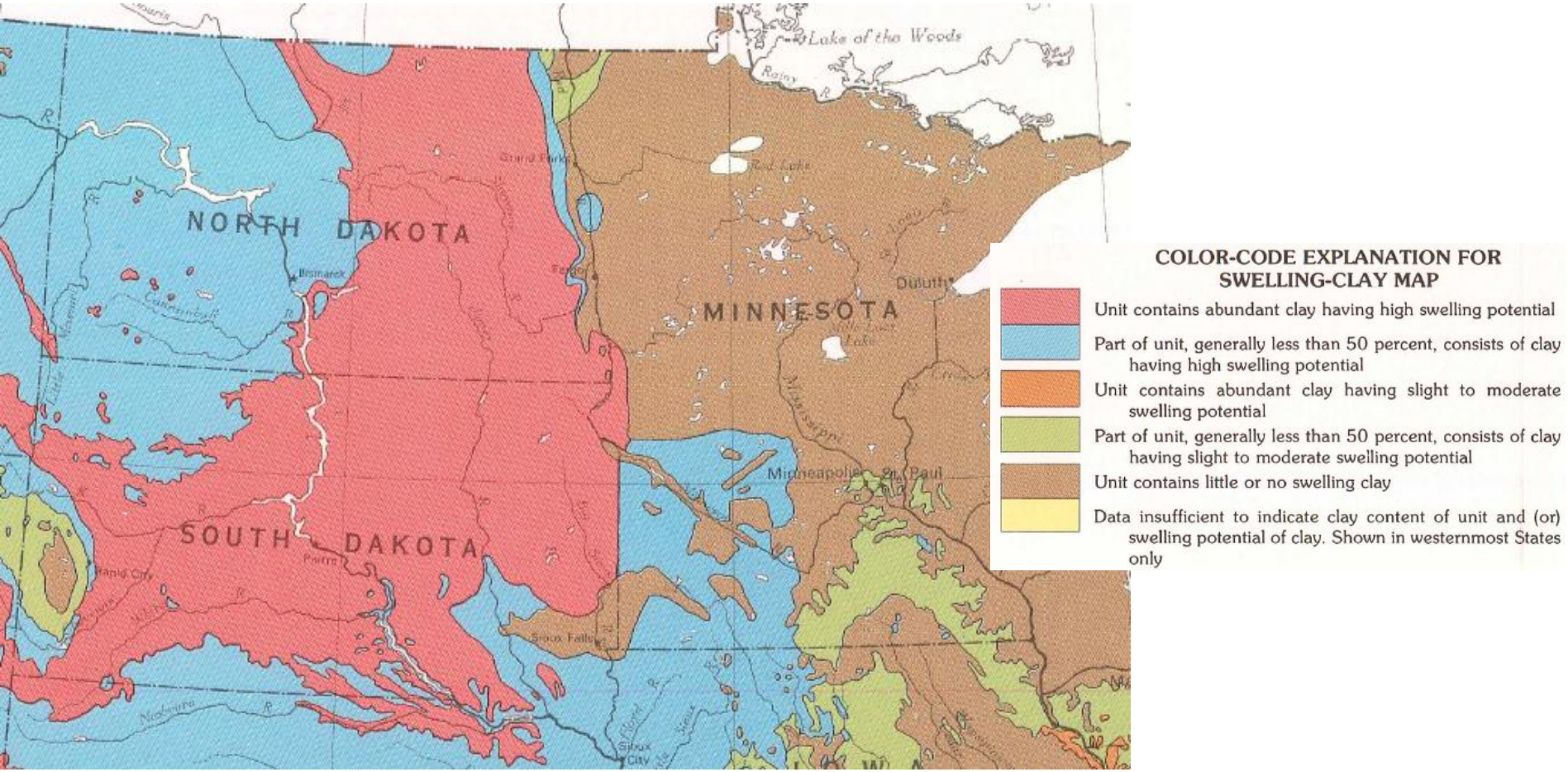
- Illite often occurs interlayered with smectite (I-S crystals)
- Percentage of illite in I-S crystals varies





Meunier, A., B. Lanson, and D. Beaufort. 2000. Vermiculitization of smectite interfaces and illite layer growth as a possible dual model for illite-smectite illitization in diagenetic environments: A synthesis. Clay Minerals 35:573-586.

USGS Swelling Clays Map



Olive, W.W., A.F. Chleborad, C.W. Frahme, J. Shlocker, R.R. Schneider, and R.L. Schuster. 1989. Swelling clays map of the conterminous United States. Miscellaneous Investigations Series Map I-1940. USGS, Washington, DC. Available at http://pubs.er.usgs.gov/publication/i1940 (verified 5 Jan. 2014).

Mineral Transformations Summary

- Pure mineral phases are not common
- Interstratification is common, and Illite-Smectite (I-S) interstratification exists in many Midwestern agricultural soils

Note: To see how mineralogy affects K behavior, go to "K Budgets and Soil Test Changes"

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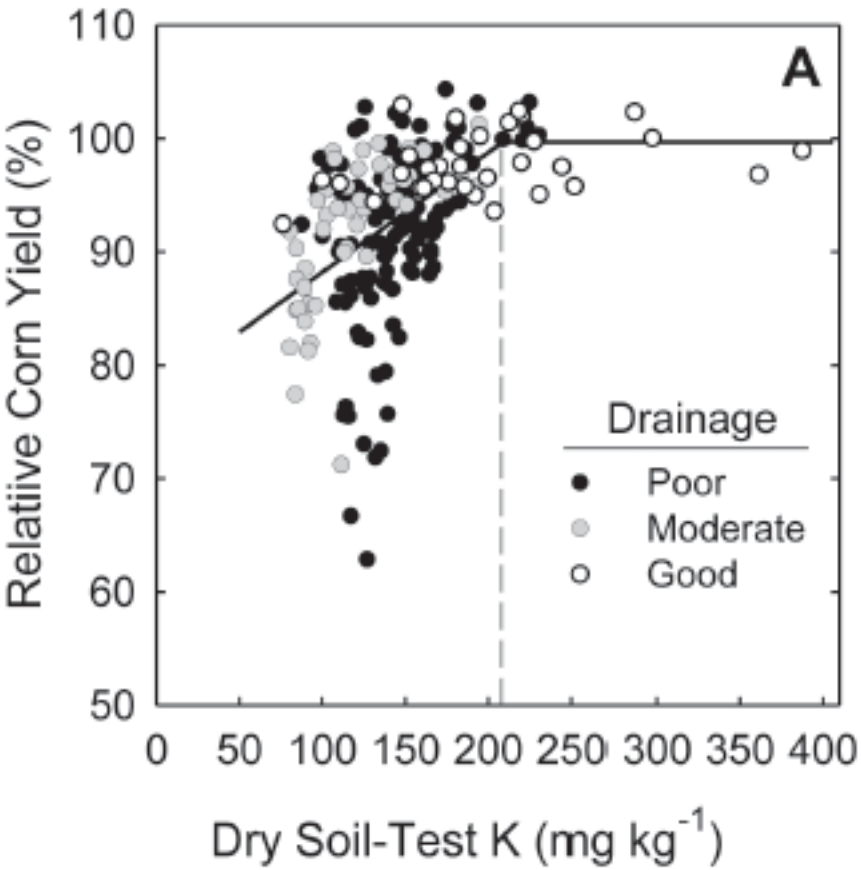
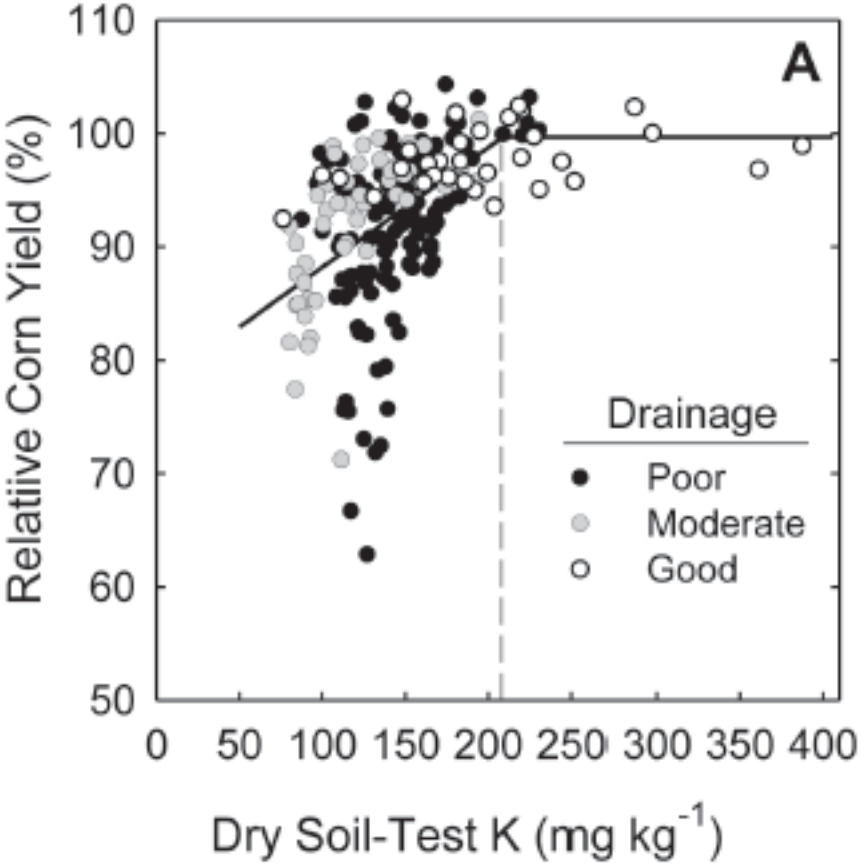
The Moist K Test

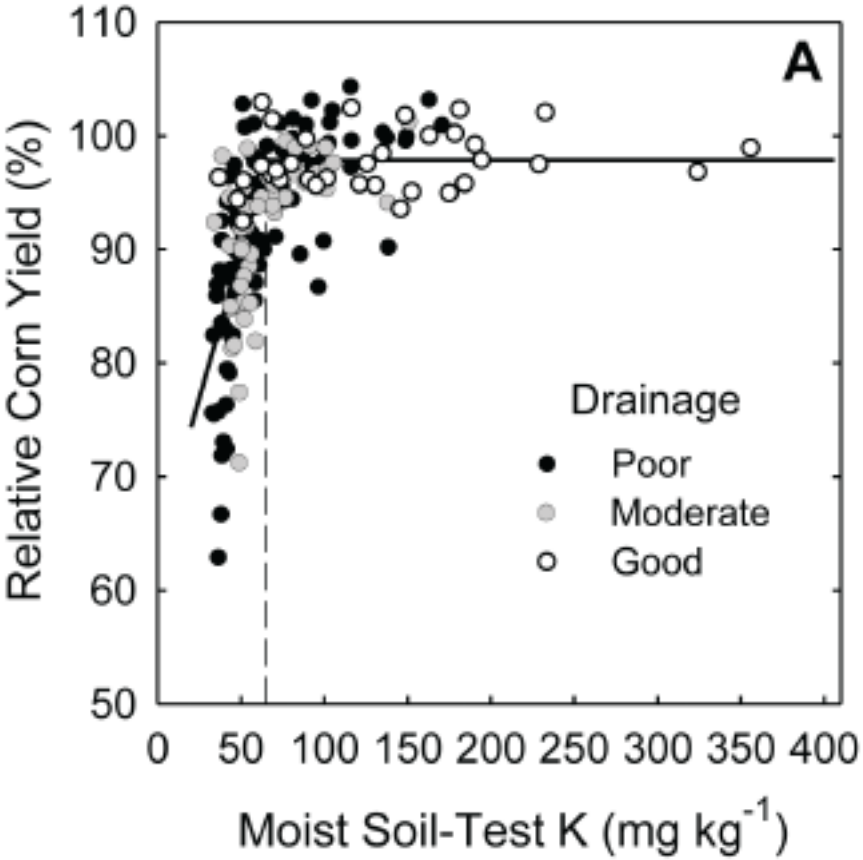
Moist vs. Dry Sample Preparation Affects Soil Test Calibration Relationships



Barbagelata, P.A. and A.P. Mallarino. 2013. Soil Science Society of America Journal 77:318-327.

Moist vs. Dry Sample Preparation Affects Soil Test Calibration Relationships

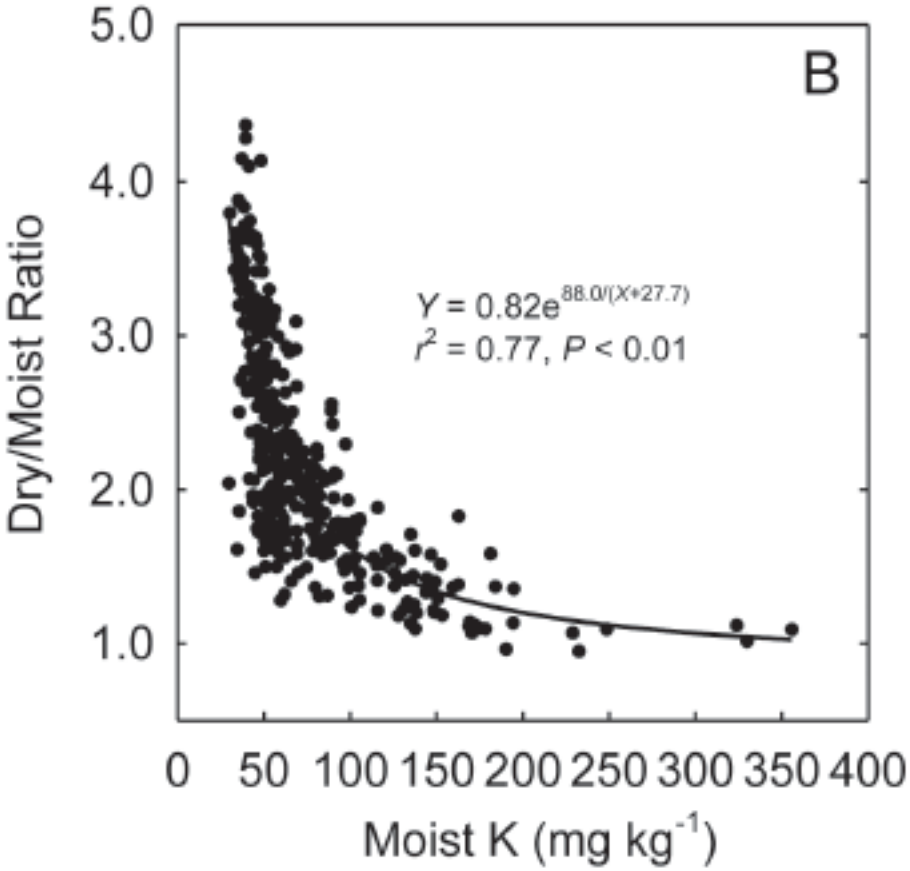




Barbagelata, P.A. and A.P. Mallarino. 2013. Soil Science Society of America Journal 77:318-327.

Dry/Moist Ratio and Critical Level

- At lower soil test K levels, dried samples produce higher readings than moist samples
- At or above the critical level, the two methods of preparation produced the same results



Barbagelata, P.A. and A.P. Mallarino. 2013. Soil Science Society of America Journal 77:318-327.

Summary:
Moist K Test

- Critical soil test levels are lower
- Variability appears smaller, but what about relative differences?
- Differences in moist and dry values decrease exponentially as the critical level is approached

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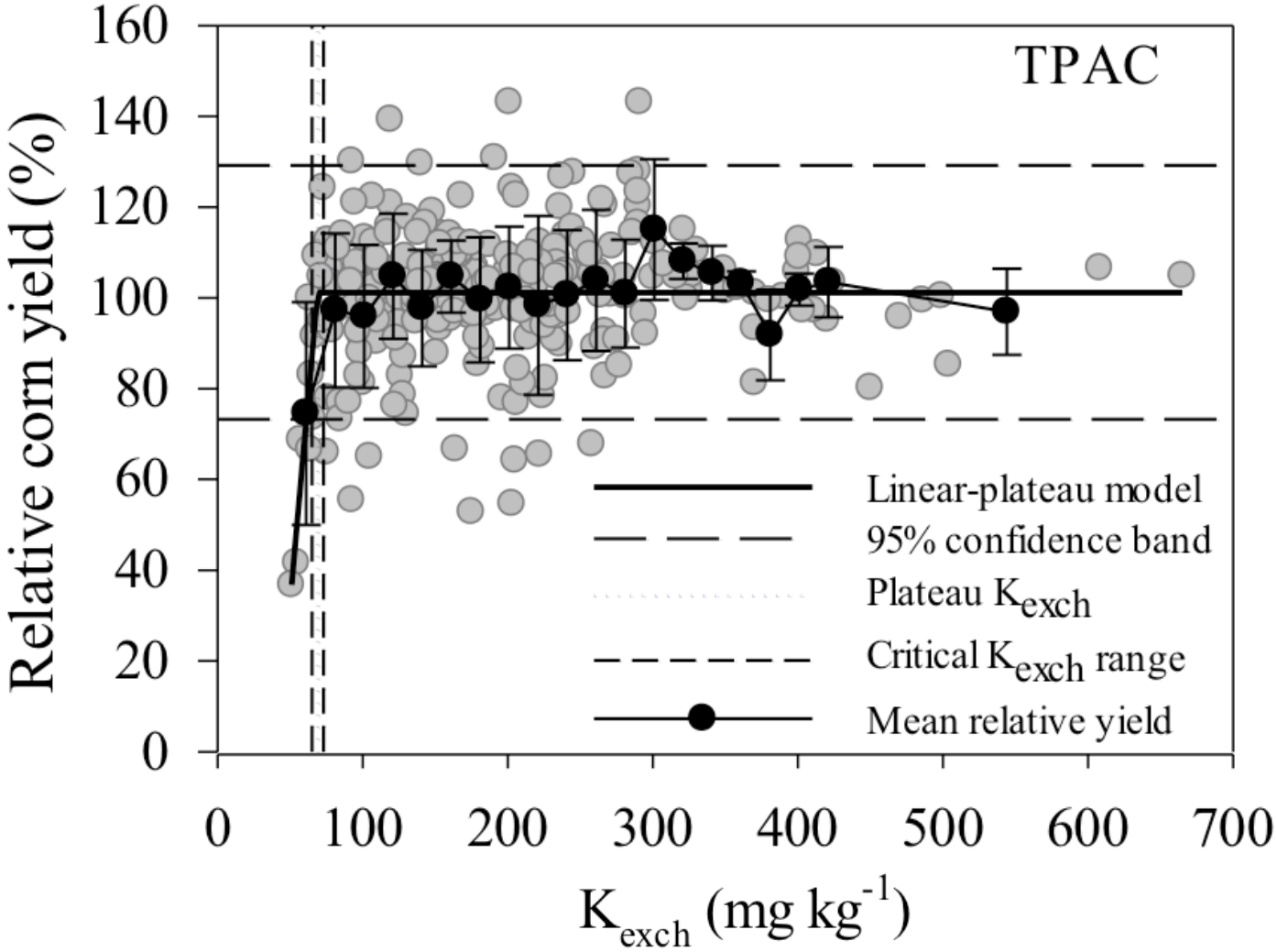
Site-Specific Soil Test K Calibration

Soil Test vs. What the Plant "Sees"

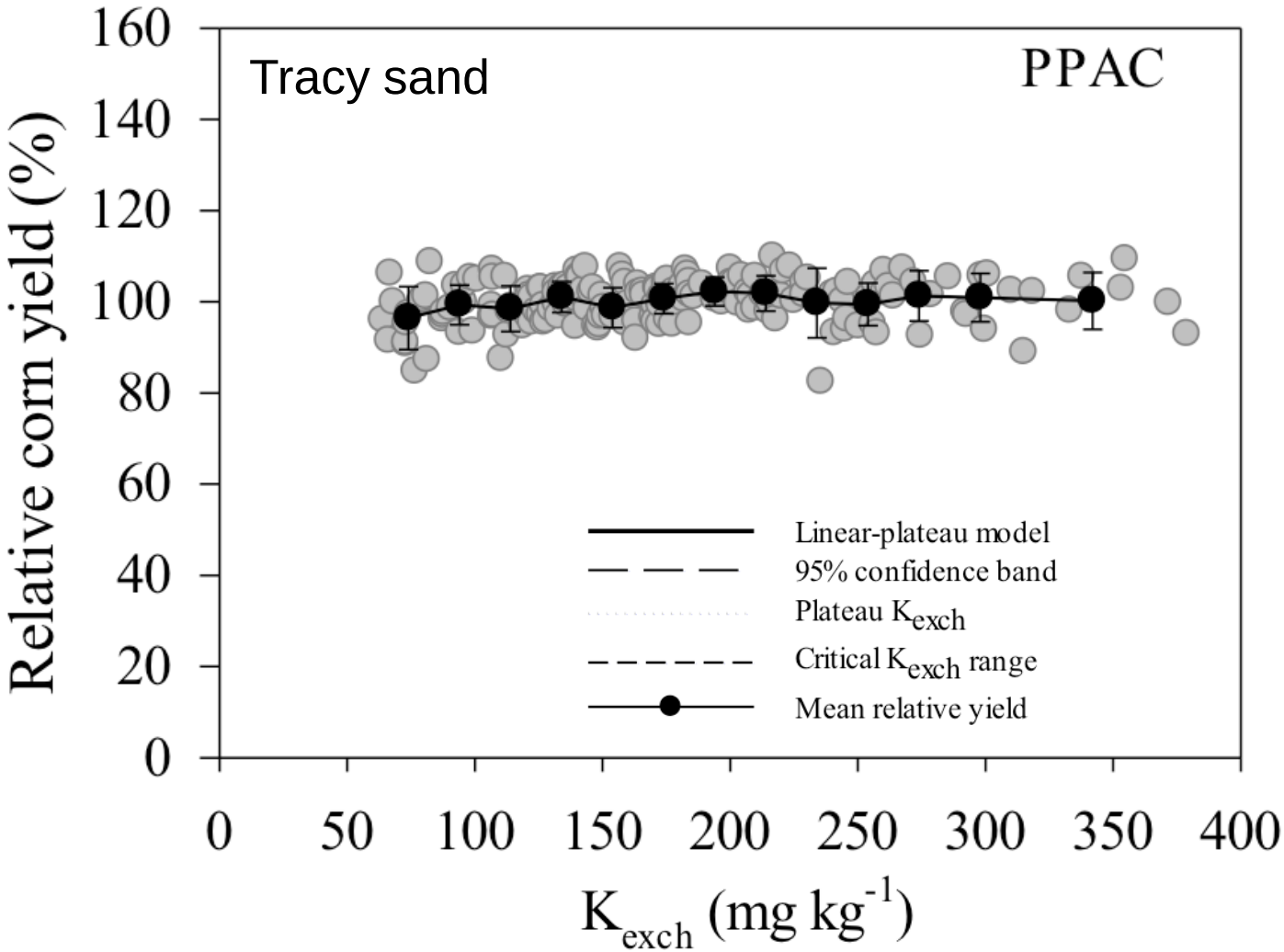
- Newly summarized studies are showing that a soil test may not be well related to the fertility the plant "sees" at specific sites.
- Long-term research at Purdue showed that soil testing was a poor indicator of fertility at 3 out of 5 sites where corn was grown in long-term fertility experiments.

Example of a location where lower soil tests are associated with lower soil fertility



R.Navarette-Gonchozo. 2013. Personal communication (Purdue University)

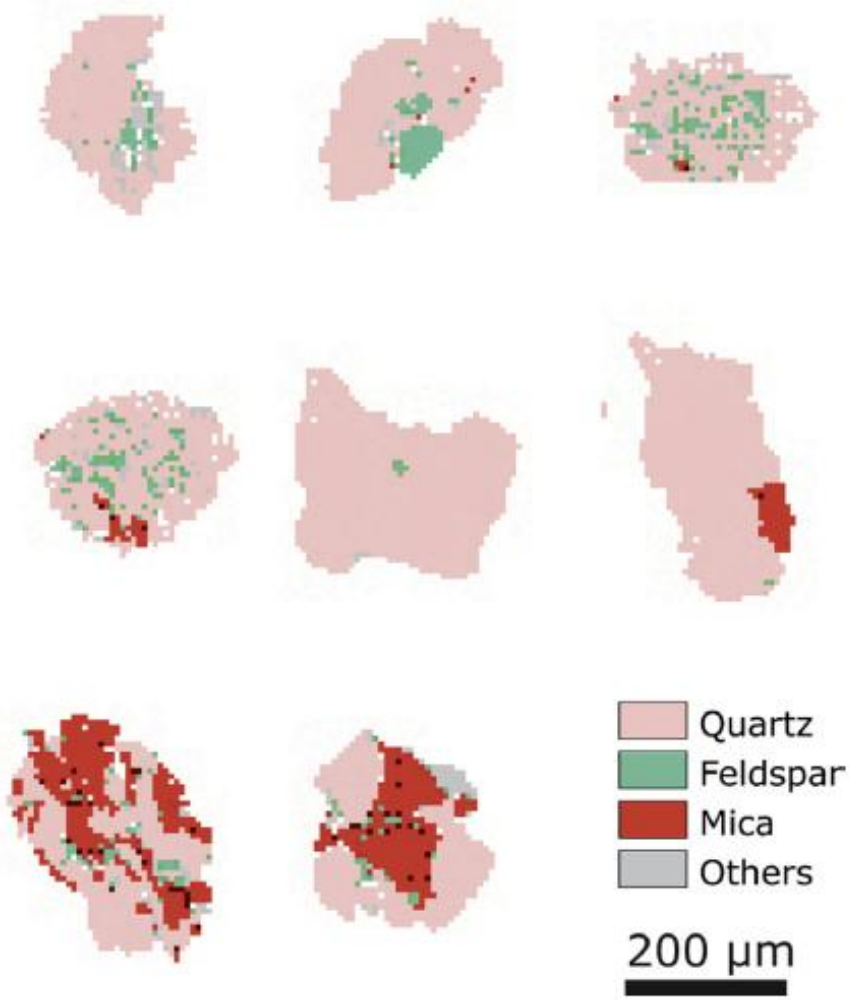
Example of a location where lower soil tests are not associated with lower soil fertility



R.Navarette-Gonchozo. 2013. Personal communication (Purdue University)

Fine Sand Particles Can Have Mineral Inclusions

- Fine Sand (100 – 250 µm)
- Individual quartz grains contained inclusions of
  - Feldspar
  - Mica
- May help explain why some sands seem to have an adequate supply of K



Meyer, M.C., P. Austin, and P. Tropper. 2013. Quantitative evaluation of mineral grains using automated SEM-EDS analysis and its application potential in optically stimulated luminescence dating. Radiation Measurements 58:1-11.

Summary
Site-Specific Soil Test K Calibration

- Different sites may have different critical levels and levels of crop responsiveness
- New studies showing mineral inclusions in sands may indicate why some coarse textured soils may not be as responsive as expected

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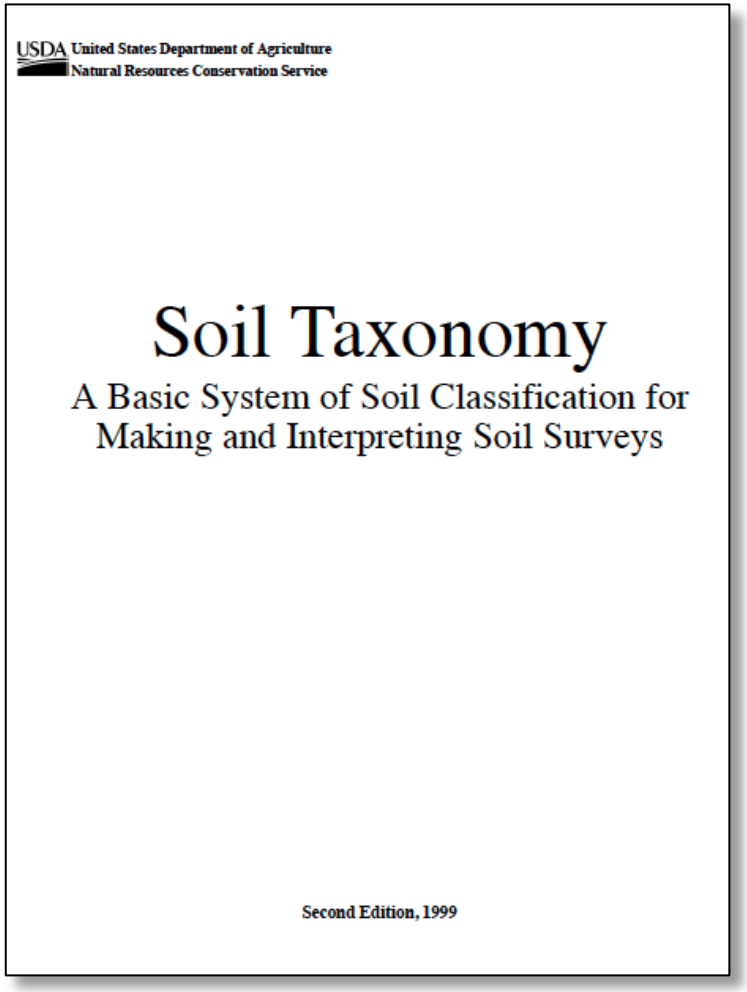
Obtaining Mineralogical Information from Soil Surveys

Soil Taxonomy

ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Taxonomy/tax.pdf

Mineralogy Classes
(p. 825 – 827)

- Smectitic
  (> 50% smectite by weight)
- Illitic
  (> 50% illite by weight)
- Vermiculitic
  (> 50% vermiculite by weight)
- Mixed
  (other)


USDA United States Department of Agriculture
Natural Resources Conservation Service

Soil Taxonomy

A Basic System of Soil Classification for Making and Interpreting Soil Surveys

Second Edition, 1999

https://soilseries.sc.egov.usda.gov/osdname.asp

Official Soil Series Descriptions

USDA-NRCS Soil Survey Division

View by Name

DIRECTIONS

The following entry field may be used to retrieve an Official Soil Series Description or a Series Extent Map. If you enter a complete series name, buttons to choose the Official Soil Series Description or Series Extent Map of the series name will be displayed. If you enter an incorrect or incomplete series name, the best-matched series names will be displayed for your selection.

Enter the Official Soil Series Description name you would like to view. Capitalization does not matter.

Fargo

Find Series | Clear Form

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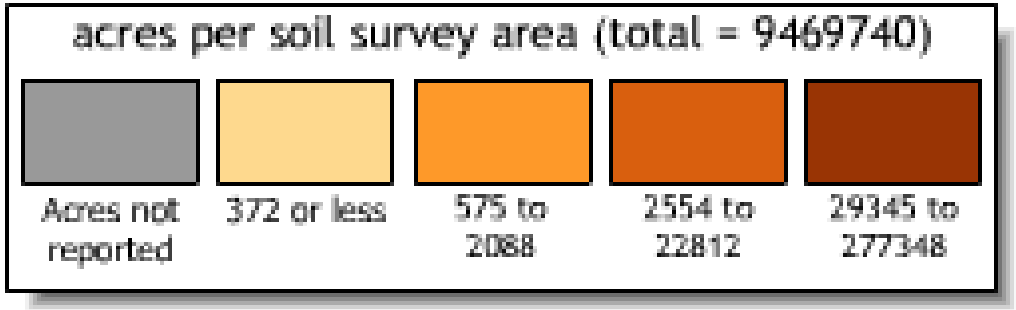
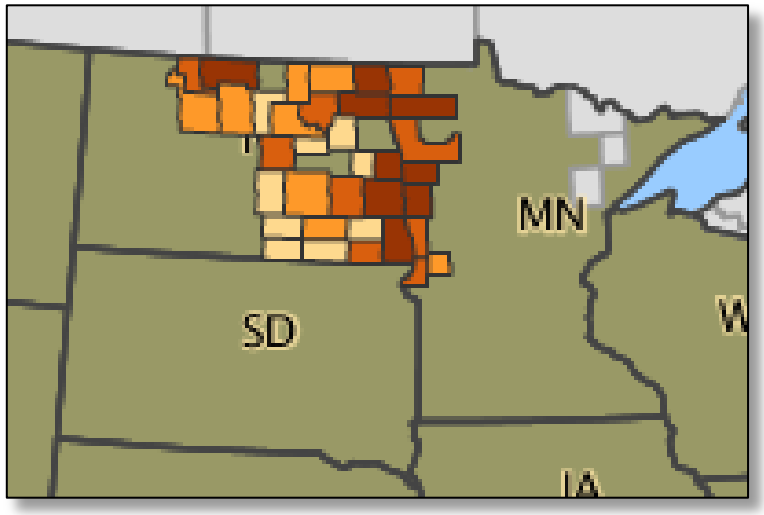


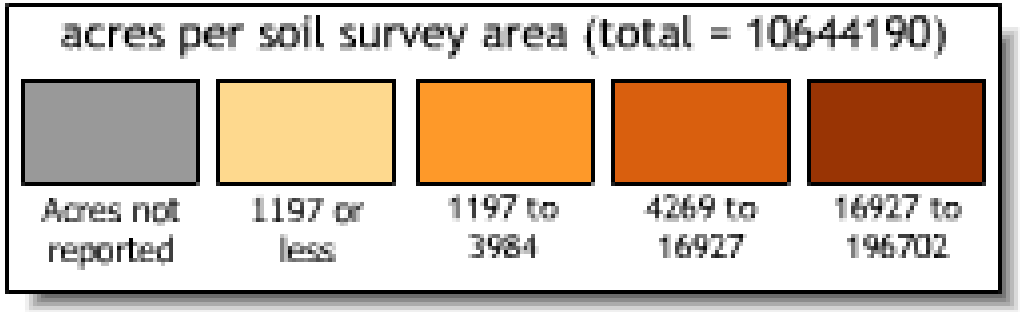


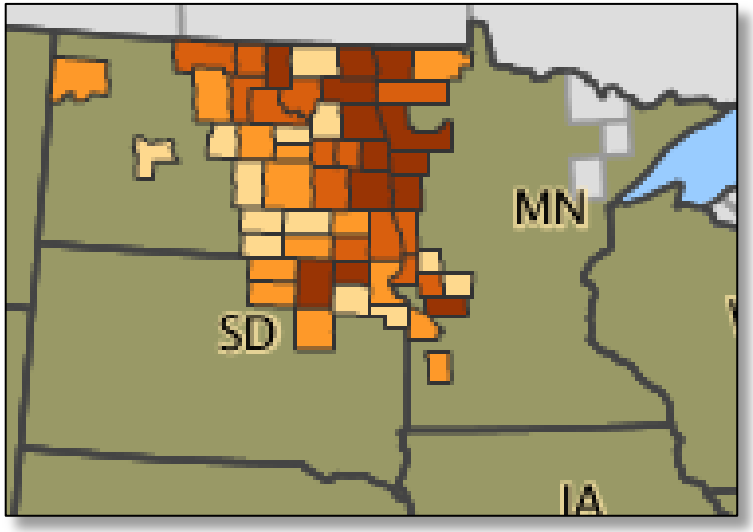
FARGO SERIES

The Fargo series consists of very deep, poorly drained and very poorly drained, slowly permeable soils that formed in calcareous, clayey lacustrine sediments. These soils are on glacial lake plains, floodplains, and gently sloping side slopes of streams within glacial lake plains. Slopes range from 0 to 6 percent. Mean annual air temperature is 42 degrees F, and mean annual precipitation is 19 inches.

TAXONOMIC CLASS: Fine, smectitic, frigid Typic Epiaquerts

family level designation: smectitic





BEARDEN SERIES

The Bearden series consists of very deep, somewhat poorly drained, moderately to slowly permeable soils that formed in calcareous silt loam and silty clay loam lacustrine sediments. These soils are on glacial lake plains and have slopes of 0 to 3 percent. Mean annual air temperature is 39 degrees F, and mean annual precipitation is 18 inches.

TAXONOMIC CLASS: Fine-silty, mixed, superactive, frigid Aeric Calciaquolls

family level designation: mixed

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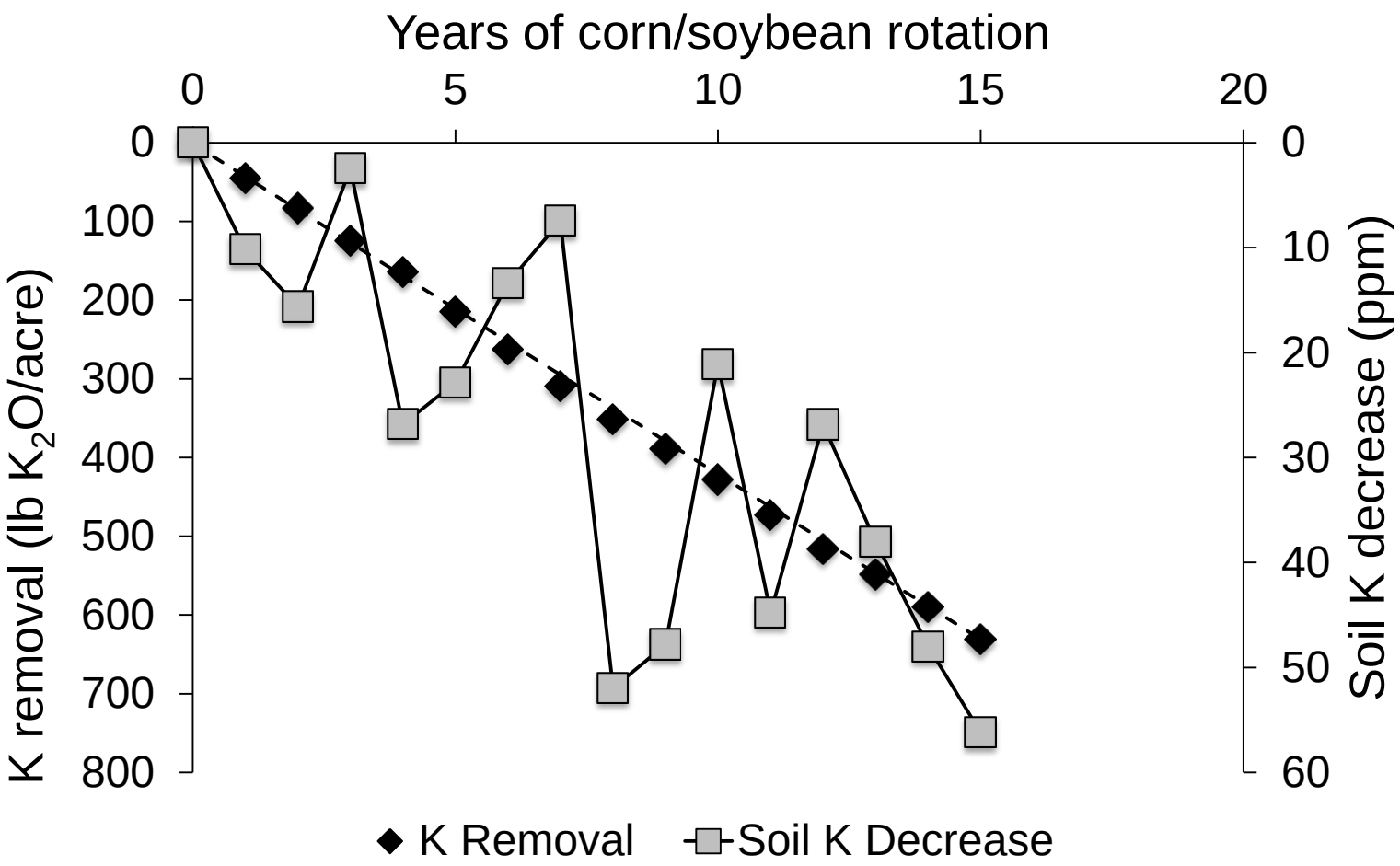
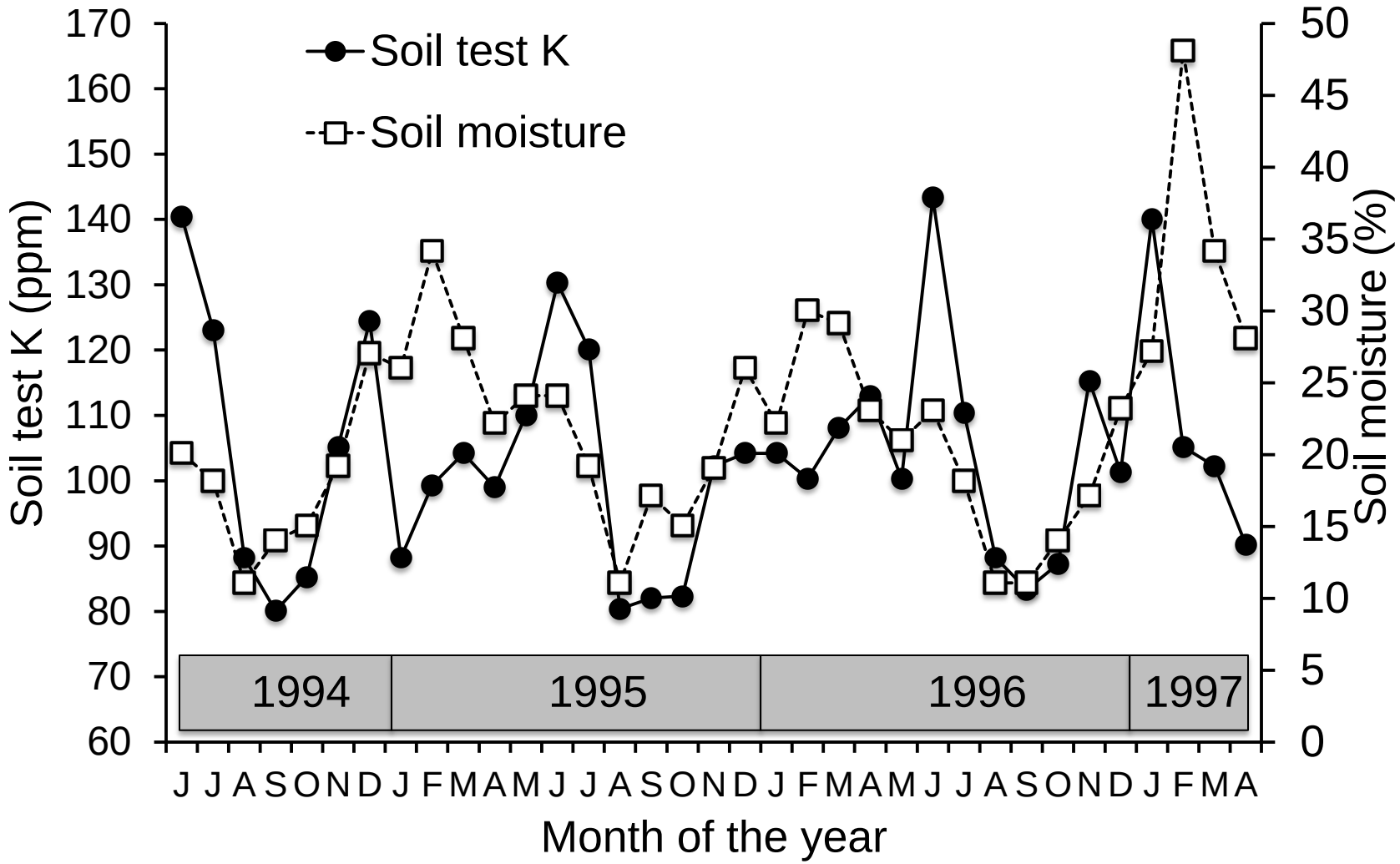
Variability in Soil Test K Response to K Budgets

Year-to-Year Variability Impacts Soil Test Response to Nutrient Budgets



Villavicencio and Mallarino, 2011. Personal communication

Possible Cause: Soil Moisture



Ebelhar et al. 1997. Personal communication. Soil test values are ammonium acetate extractable.

Effect of Iron Reduction on K Fixation

Sample	Treatment	Fe^{2+} as a percent of total Fe	Fixed K
		(%)	(cmol(+) kg^{-1})
Smectite SWa-1	Unreduced	0.16	2.9
	Reduced	74.0	31.5
Smectite API 25	Unreduced	5.8	3.0
	Reduced	66.8	25.3
Fithian Illite	Unreduced	25.4	135.7
	Reduced	60.8	89.8

Under reducing conditions:
- smectites “fixed” K
- illite released K

Shen, S. and J.W. Stucki. 1994. p.173-185. *In* J. Havlin and J.S. Jacobsen (eds.) Soil testing: Prospects for improving nutrient recommendations.

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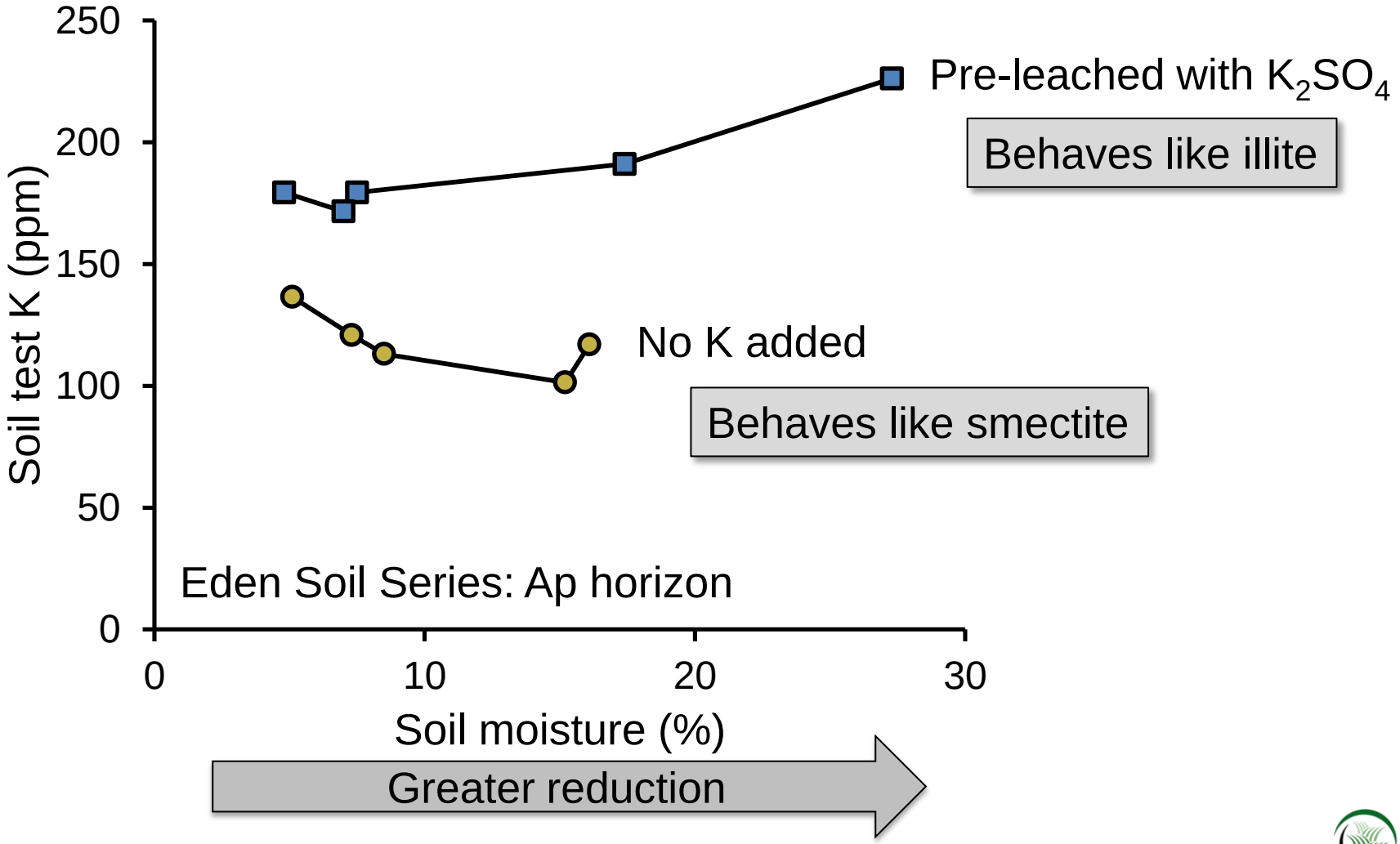
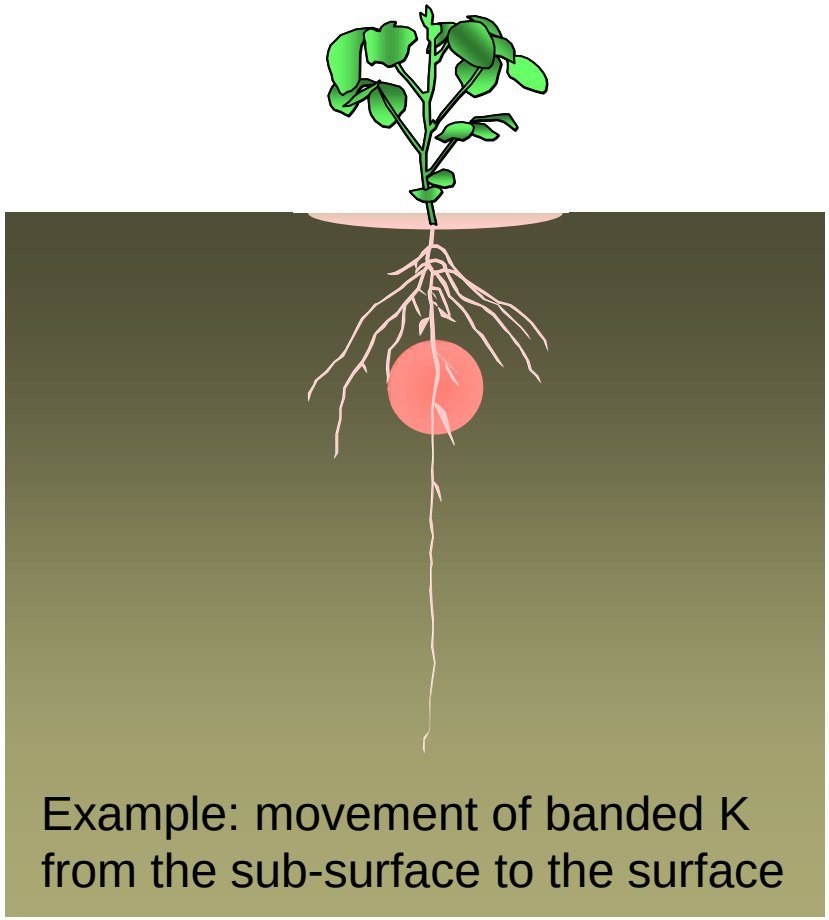
Interaction of Soil Moisture and K Addition



Dowdy, R.H. and T.B. Hutcheson Jr. 1963. Soil Science Society of America Proceedings 27:31-34.

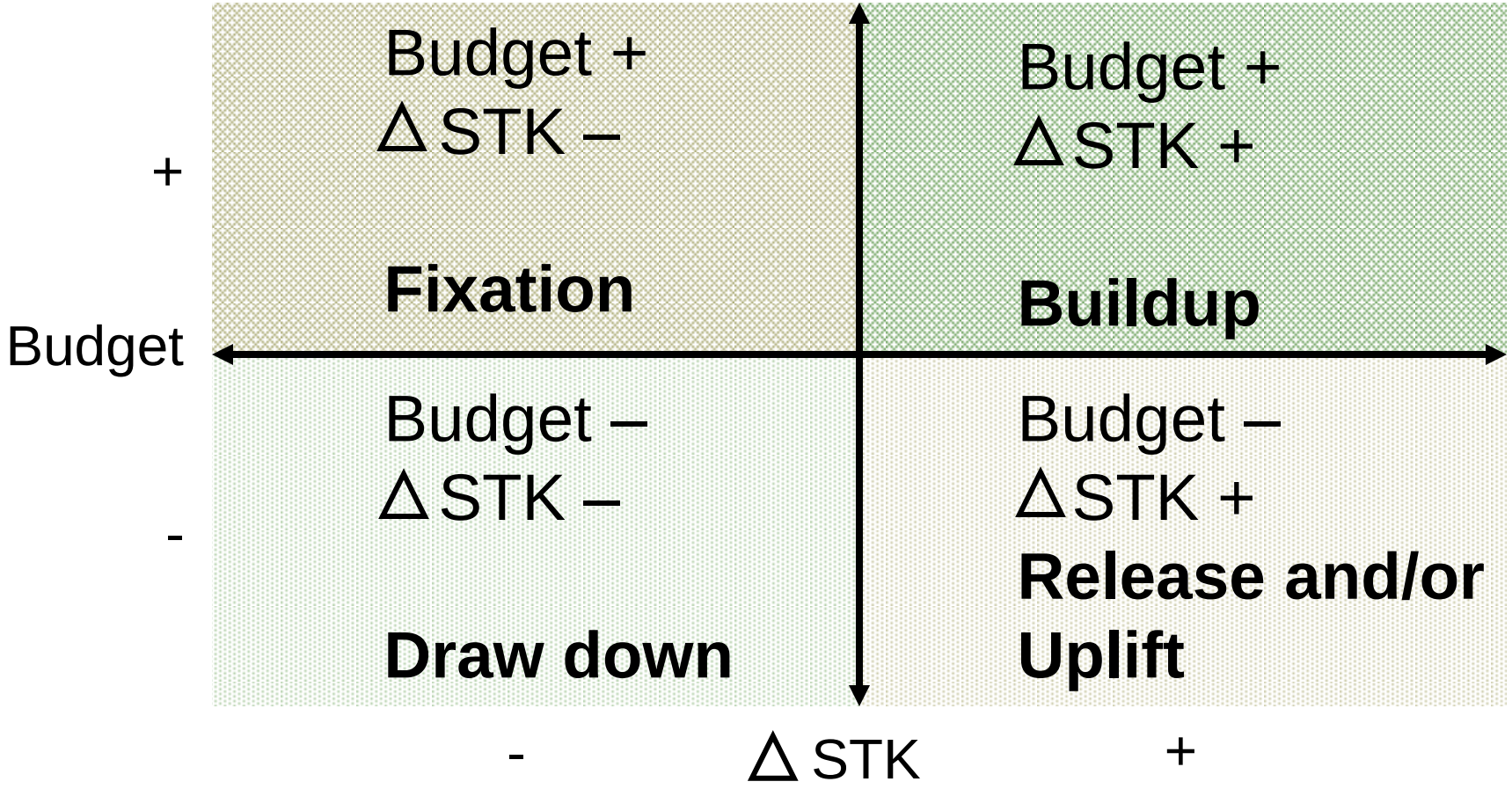
Possible Cause: Nutrient "Uplift"

- Nutrient uplift:
  Plants take up K from lower in the soil profile. This K is then deposited at the soil surface after maturity as K is leached from the residue.
- Even though soil fertility declines with crop removal, uplift may keep such changes from being detected

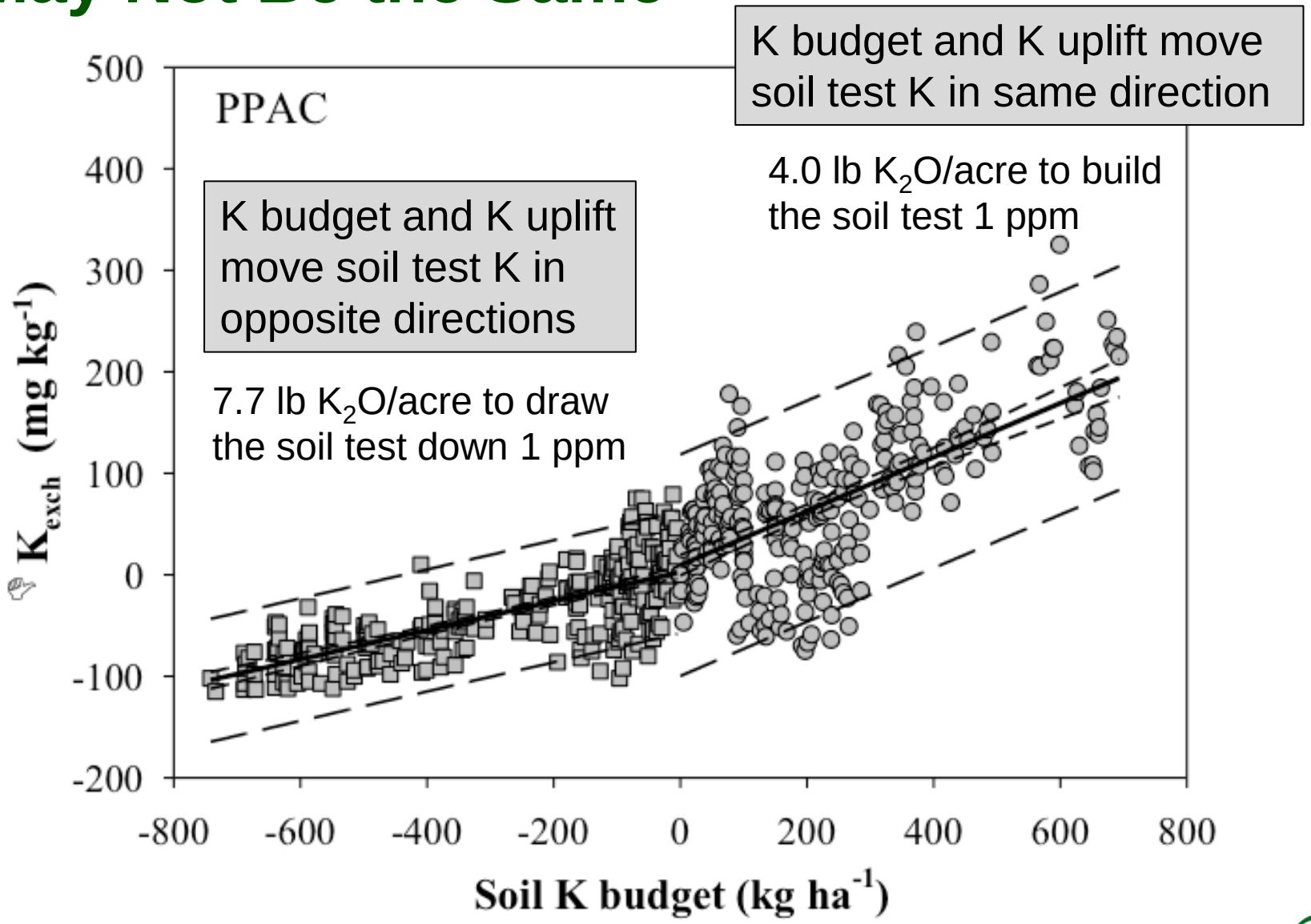


Jobággy, E.G. and R.B. Jackson. 2004. Ecology 85:2380-2389.

Possible Influences of K Fixation and Release on Soil Test K Response to K Budgets



Buildup and Drawdown Buffer Capacities May Not Be the Same



R.Navarette-Gonchozo. 2013. Personal communication (Purdue University)

Summary:
Soil Test Response to K Budgets

- There can be large variability in soil test K levels between sampling times
- Given a high enough frequency of sampling over time, soil tests do reflect K budgets
- Major factors contributing to variability:
  - The effect of soil moisture on K fixation and release
  - Nutrient uplift over time

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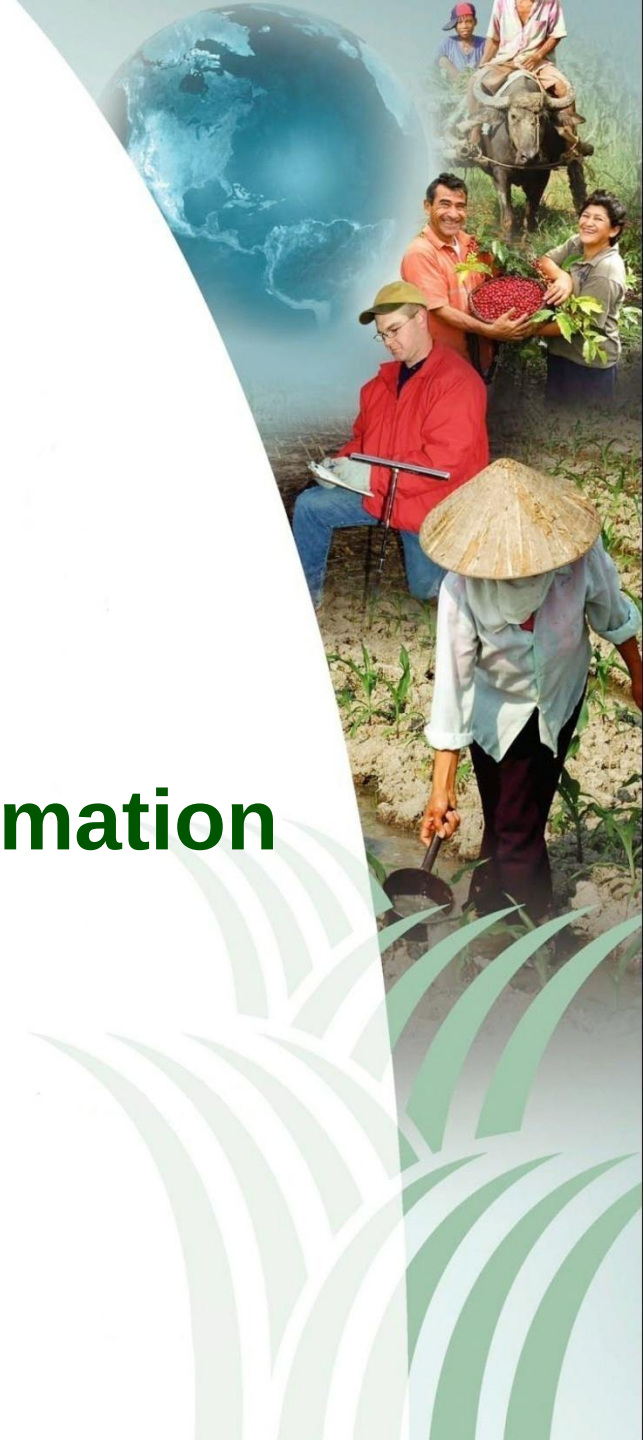
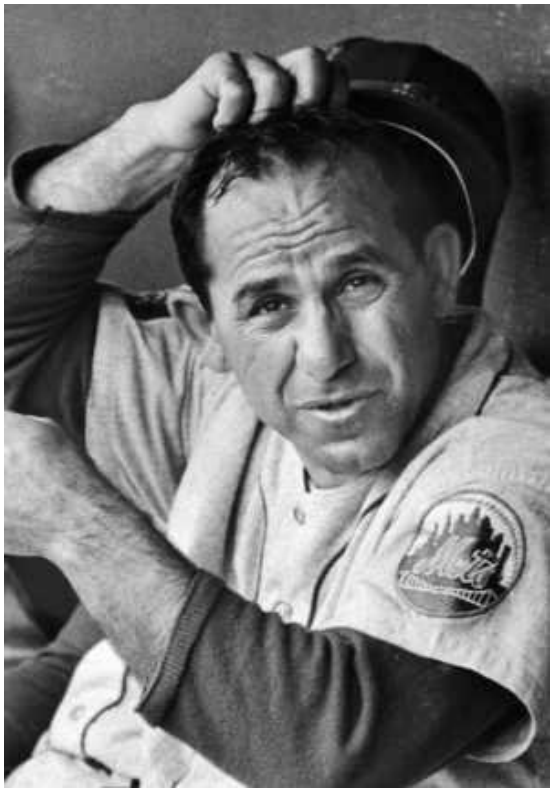


Augmenting Soil Test K Information

Visual Indications of K Deficiency

“*You can observe a lot by watching.*”



-- Yogi Berra

What K Does In Plants

Potassium is involved in:

- Regulating water pressure in plant cells, affecting cell extension, gas exchange, and movement of leaves in response to light
- Activating enzymes that help chemical reactions take place
- Synthesizing proteins
- Adjusting pH within plant cells
- Increasing carbon dioxide fixation during photosynthesis
- Transporting chemical compounds within the plant
- Balancing electrical charges in various parts of plant cells

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K Deficiency in Corn

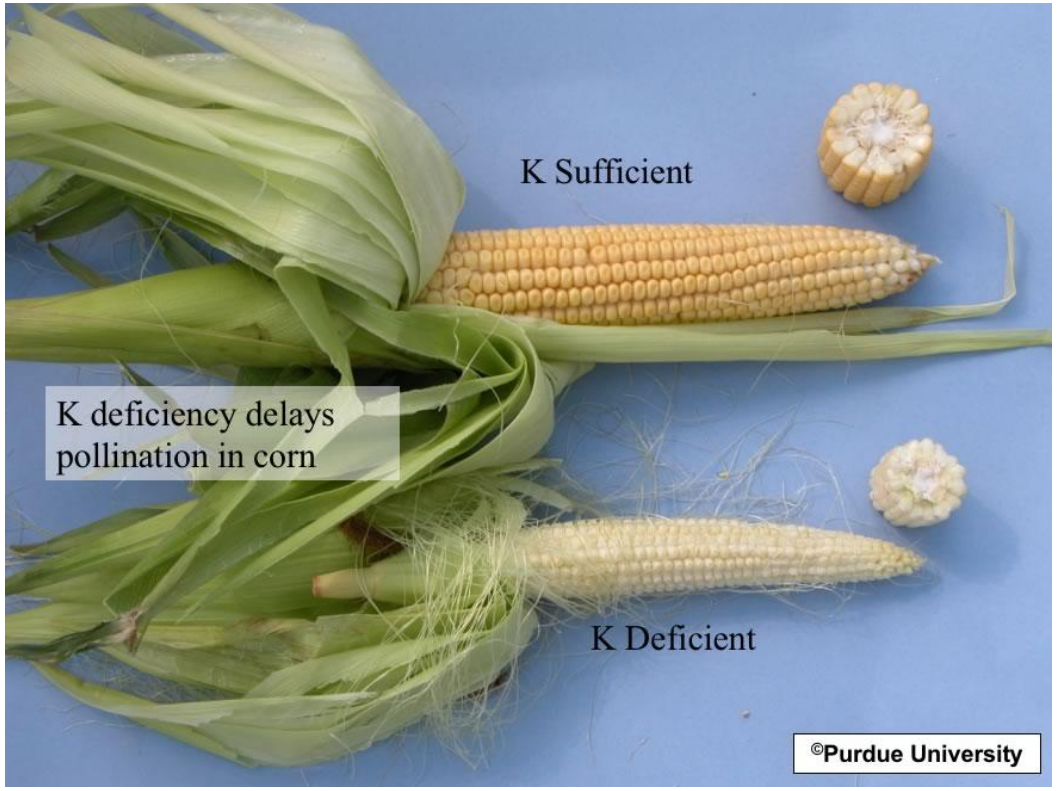
- Marginal yellowing, leading to necrosis
- Reduces amount of leaf area that is photosynthetically active
- Reduces the quantity of carbohydrates manufactured

Photo: L. Murrell, Lance Murrell Consulting

Hoffer, G.N. 1941. Deficiency symptoms of corn and small grains. p. 55-98. *In* G. Hambridge (ed.) Hunger Signs in Crops. American Society of Agronomy and the National Fertilizer Association, Washington, D.C.

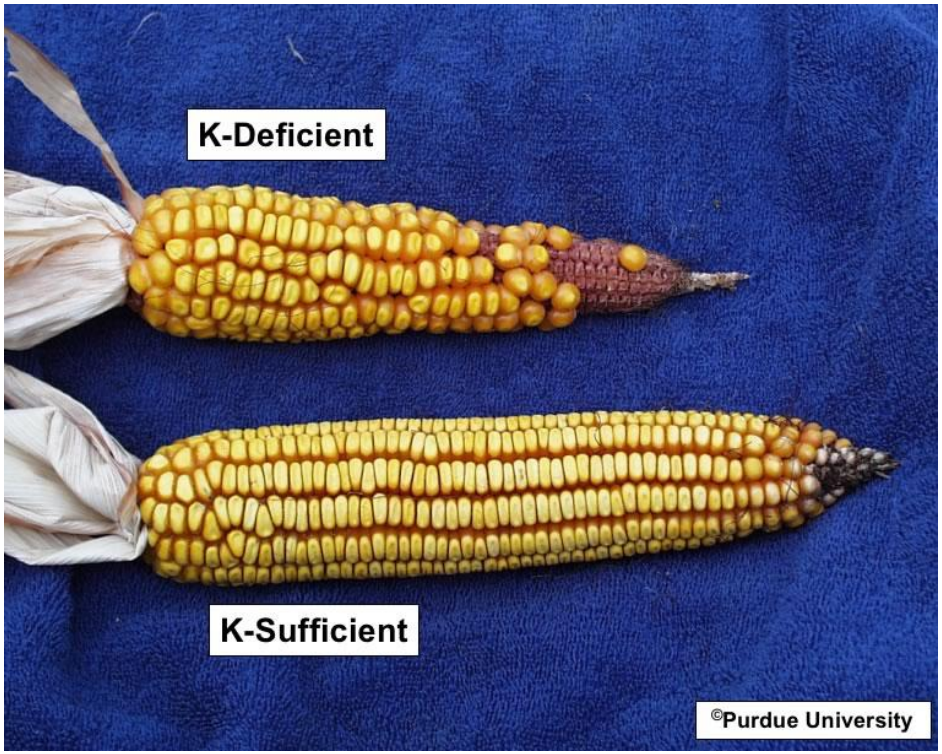
K Deficiency in Corn

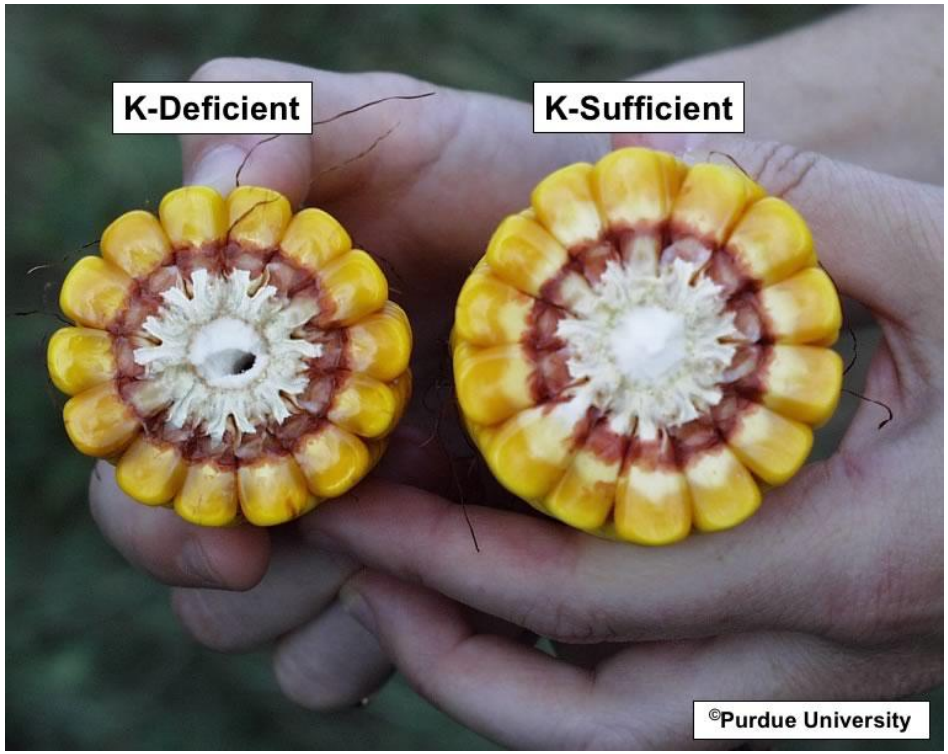
- Delays rate of growth
  - stunted plants
  - delayed pollination and maturity



Hoffer, G.N. 1941. Deficiency symptoms of corn and small grains. p. 55-98. *In* G. Hambridge (ed.) Hunger Signs in Crops. American Society of Agronomy and the National Fertilizer Association, Washington, D.C.

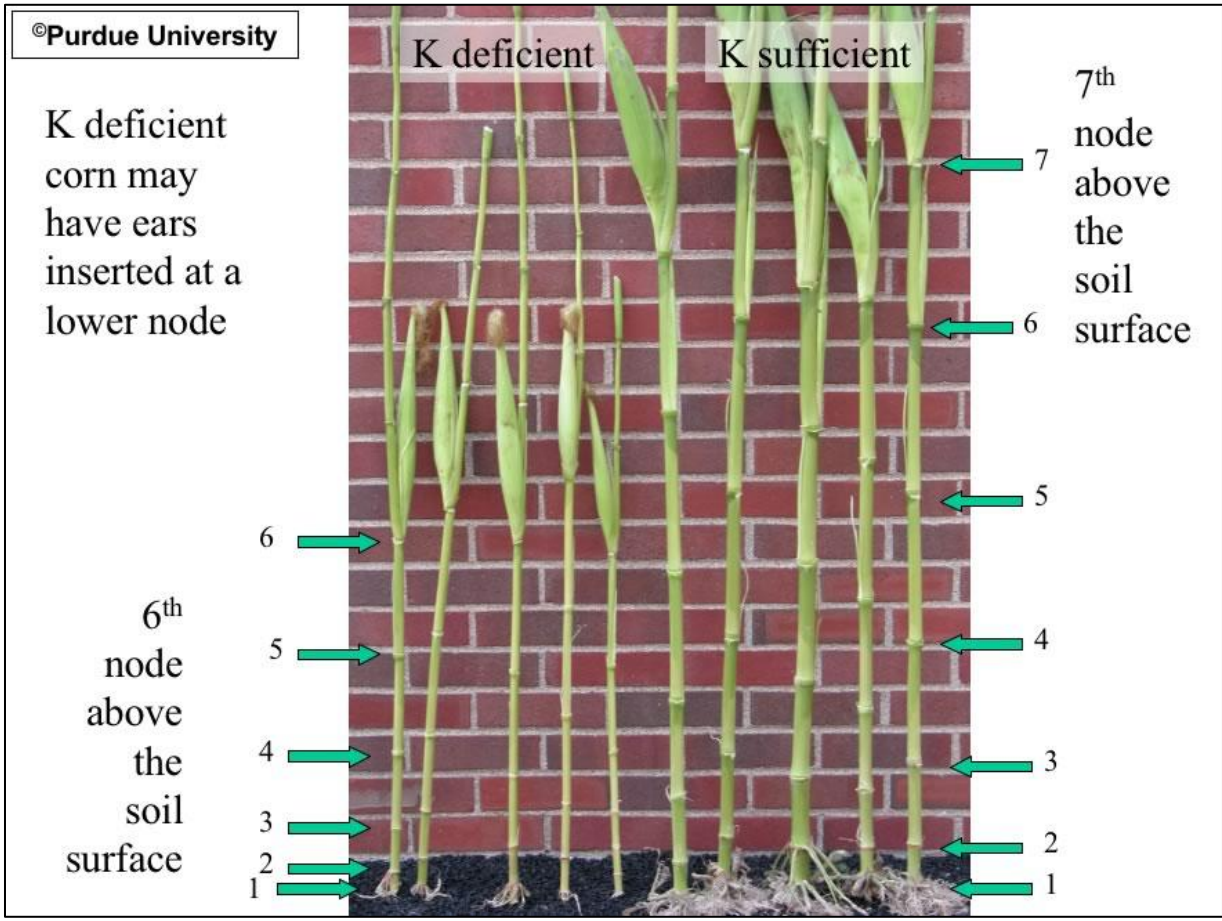
K Deficiency in Corn: Reduced Ear Diameter and Poor Grain Fill





K Deficiency in Corn

- Reduces cell extension
  - shorter internodes
  - ears lower to the ground
  - greater harvest losses



Hoffer, G.N. 1941. Deficiency symptoms of corn and small grains. p. 55-98. *In* G. Hambidge (ed.) Hunger Signs in Crops. American Society of Agronomy and the National Fertilizer Association, Washington, D.C.

K Deficiency in Corn

Photo: T.S. Murrell, IPNI

K Deficiency: Volunteer Corn in Soybean Resulting from Corn Harvest Losses the Previous Season

Photo: T.S. Murrell, IPNI

K Deficiency in Corn

- Iron compounds accumulate in the joints of corn plants
- Potassium thiocyanate, applied to plant tissue, makes the iron visible
- Accumulated iron disrupts translocation of photosynthate from leaves to roots

Photo: L.S. Murphy, PPI

Hoffer, G.N. 1941. Deficiency symptoms of corn and small grains. p. 55-98. *In* G. Hambidge (ed.) Hunger Signs in Crops. American Society of Agronomy and the National Fertilizer Association, Washington, D.C.

K Deficiency in Corn

- Increased susceptibility to stalk rot
- Increased chances for lodging
  - Smaller brace root system and cellular disintegration in brace roots
  - Cellular disintegration in lower part of the stalk

Photo: P. He, IPNI

Liebhardt, W.C. and J.T. Murdock. 1965. Effect of potassium on morphology and lodging of corn. 57:325-328.

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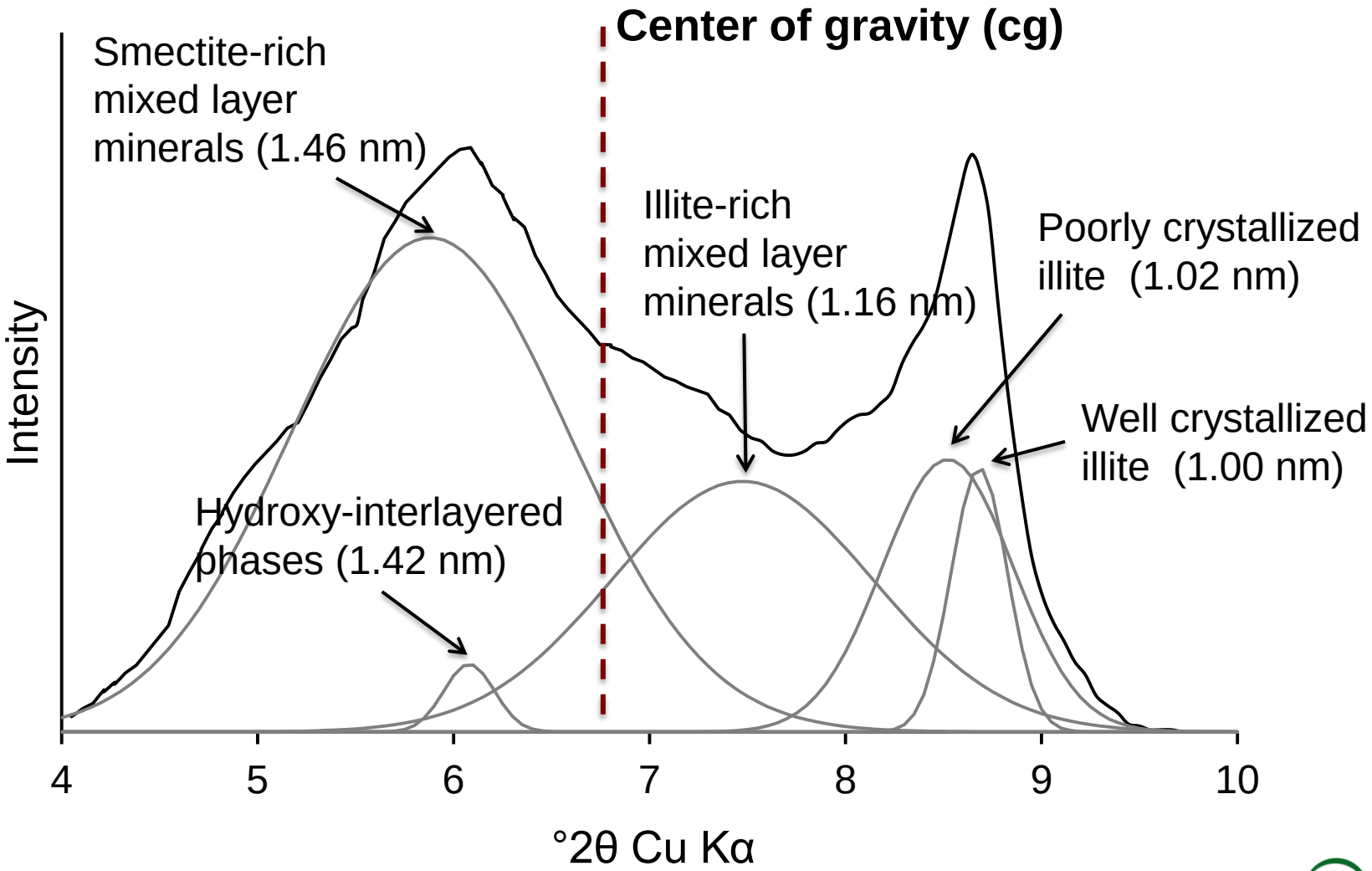
K Enrichment Impacts Mineralogy

“Center of Gravity” Concept:

Area-Weighted Average of Peak Positions



Barré et al. 2008. Plant Soil 302:213-220.

Cumulative K Budgets Used for Evaluating Changes in Mineralogy

Treatments	Total K applied	Total K removed	K budget
	---------- (kg K ha^{-1}) ----------		
0	580	4088	-3508
P	580	4771	-4191
K	5980	4478	1502
PK	5980	5030	950
0 init	0	3824	-3824
PK init	8090	4597	3493

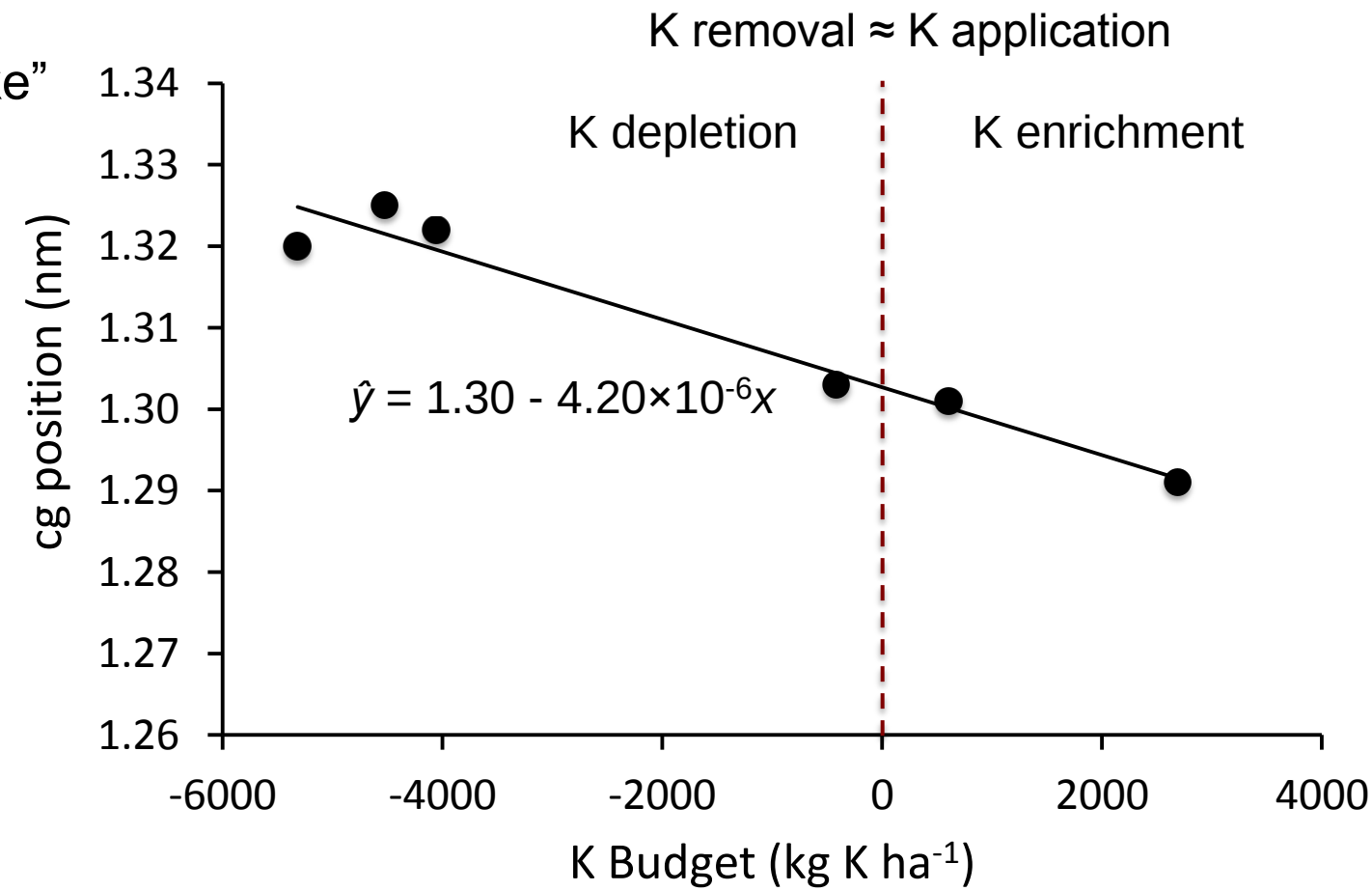
Experiment started in 1959 and lasted for 40+ years

Barré et al. 2008. Plant Soil 302:213-220.

Potassium Budgets Impact Mineralogy

More
"smectite-like"

More
"illite-like"



Barré et al. 2008. Plant Soil 302:213-220.

Summary:
K Enrichment Impacts Mineralogy

- K enrichment can cause interstratified illite-smectite (I-S) minerals to behave more like illite
- Enrichment can occur by:
  - K fertilization
  - Redistribution of K by the plant: moving K from lower in the soil profile to the soil surface, where it becomes more concentrated
- As soils dry, K is more likely to be “fixed,” lowering soil test K levels

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