Nutrient Movement in a 104-Year-Old Soil Fertility Experiment

Charles C. Mitchell*, Gobena Huluka, Dennis P. Delaney, Auburn University, AL
Kipling S. Balkcom, USDA-Soil Dynamics Lab, Auburn, AL

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Alabama's Cullars Rotation Experiment (circa 1911) is the oldest soil fertility experiment in the South. Each year K deficiencies are observed in the "no K" treatments on 5 different crops as is shown left on cotton in early August. The experiment was placed on the National Register of Historical Places in 2003. It was on this site where "cotton rust" was first diagnosed as a K deficiency in the late 1880s.

ABSTRACT

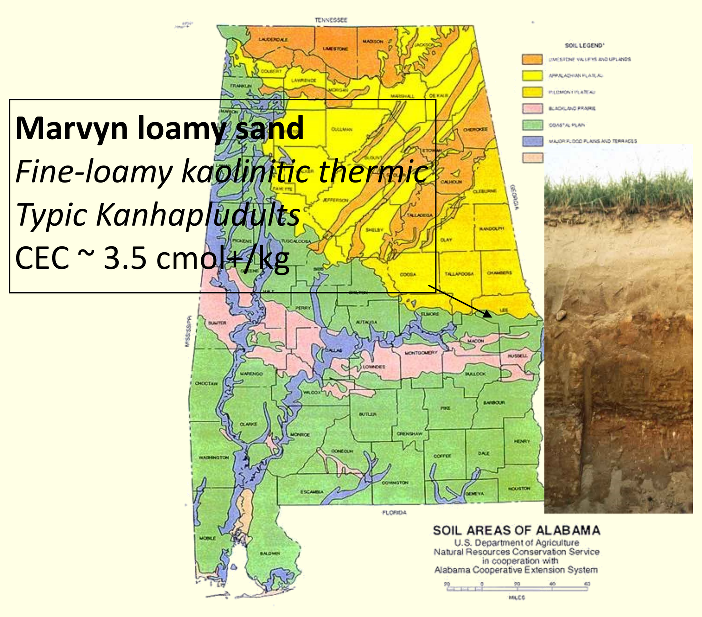
Alabama's "Cullars Rotation" experiment (circa 1911) is the oldest, continuous soil fertility experiment in the southern U.S. Treatments include 5 K variables, P variables, S variables, soil pH variables and micronutrient variables in 14 treatments involving a 3-yr rotation of (1) cotton-winter legumes, (2) corn-wheat, and (3) soybean. Each fertility treatment is replicated 3 times. The soil is a Marvyn loamy sand (Fine-loamy, kaolinitic, thermic Typic Kanhapludults) typical of the Gulf and Atlantic Coastal Plain region. Core samples were taken to 100 cm in 1986 and again in 2013 to monitor nutrient (primarily K) accumulation and movement under long-term cropping and fertilization. Potassium application rates ranged from 0 to 335 kg K ha^{-1} per 3-yr rotation. Although maximum K accumulation in the surface horizon of these low CEC soils (CEC~3.5 cmol kg^{-1}) was only about 50 mg exchangeable K kg^{-1}, exchangeable K accumulation decreased with depth in all treatments. Where no sulfate-S has been applied, K accumulation was significantly higher at all soil depths to 100 cm. Extractable P, Ca, Mg, and soil pH have also been monitored with depth.

OBJECTIVES

To measure and document nutrient movement under long term fertilization and cropping and compare recent values to similar measurements taken 25 years earlier.

HISTORY & METHODS

The Cullars Rotation experiment began as one of over 200 on-farm, soil fertility experiments initiated by the Alabama Agricultural Experiment Station in 1911 in order to determine the effects of added nutrients on crop yield. This experiment was on the farm of Mr. J.A. Cullars of Auburn, Alabama, thus its name. Alabama Polytechnic Institute (now Auburn University) purchased the farm from the Cullars family in 1934, and the experiment has been continued, with some modifications in fertilizer rates, since it began.



Crop rotations on the three tiers (blocks) of the Cullars Rotation have always been:

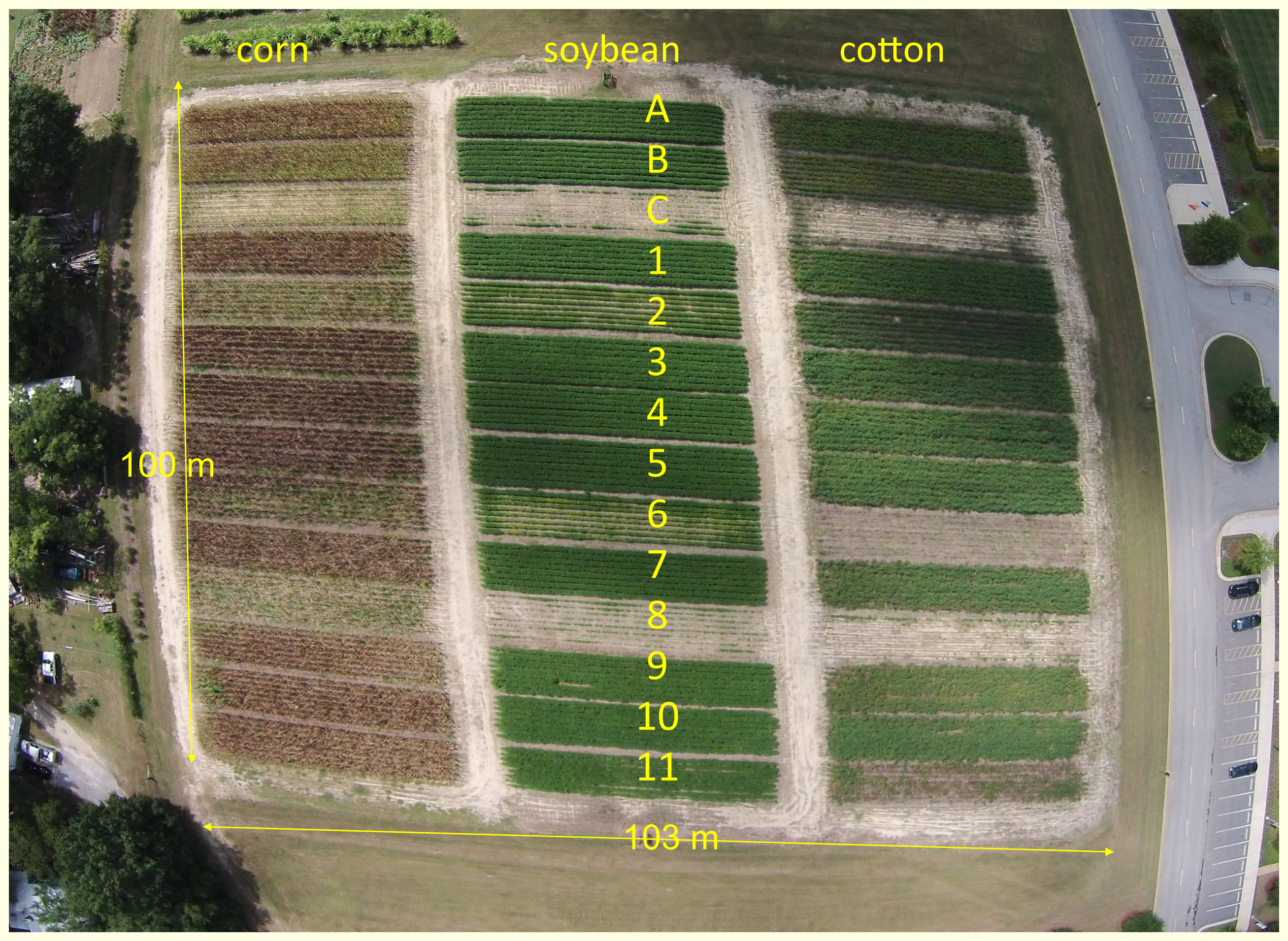
(1) **cotton** followed by a winter legume cover crop (crimson clover and/or vetch);

(2) **corn** followed by a small grain (currently **wheat**); and

(3) **soybean** after the wheat is harvested for grain.

Average annual rainfall at the site is 1346 mm (53 inches). The site is not irrigated. Before 1997, all crops were planted using conventional tillage e.g., moldboard plowing, disking, and cultivation to control weeds. In 1997, all soil disturbance was stopped, and all crops are planted using high residue management, no-till and chemical weed control. An in-row-subsoiler or paratill to a depth of 36 cm is used prior to planting cotton and corn. Plow layer soil samples have been routinely taken from all plots since 1954. In the winter of 1987, K variable treatments were sampled to a depth of 100 cm to monitor K accumulation and movement. All plots were sampled again to 100 cm during the winter of 2013. Samples from the 2013 sampling were analyzed for pH_w, Mehlich-1 extractable P, K, Mg and Ca, neutral normal ammonium acetate extractable cations, and non-exchangeable K.

* *Extension Agronomist-Soils & Professor, Dep. Crop, Soil & Environmental Sciences, Auburn University, AL 36849-5412. Email: mitchc1@auburn.edu*



Aerial image of the Cullars Rotation experiment taken 5 Sep. 2014. Numbers and letters indicate traditional treatment identifications that extend across all three tiers. The three tiers are the crop rotations. Plots 1-11 were started in 1911 and plots A, B and C were added in 1915.

Treatments and Soil Test (0-15 cm)

Plot no.	Treatment*	Soil pH**	Mehlich-1 extractable nutrients*** P	K	Mg	Ca
			------------------- mg/kg			-------------------
A	No N/ + winter legume	6.1	VH 73	H 84	H 25	406
B	No N/ no winter legume	6.3	VH 65	H 72	H 17	263
C	No soil amendment	**5.1**	**VL 6**	**L 22**	**L 8**	**82**
1	Complete fertilization/ no winter leg.	6.1	H 41	M 60	H 50	243
2	No P	5.8	**VL 6**	M 60	H 23	176
3	Complete fertilization	6.1	VH 54	H 70	H 38	353
4	4/3 K	5.9	VH 87	H 82	H 45	513
5	Rock phosphate	5.9	EH 276	H 76	H 38	353
6	No K	6.1	EH 101	**L 18**	H 45	419
7	2/3 K	6.1	VH 68	M 57	H 41	402
8	No lime	**4.5**	VH 79	M 45	L 7	72
9	No S	6.1	VH 94	H 82	H 38	405
10	Complete fertilization + micronutrients (B, Zn, Cu, Mn)	6.1	VH 82	H 66	H 29	350
11	1/3 K	6.1	VH 65	M 36	H 39	330

*P rate = 112 kg P_2O_5/ha per 3-yr rotation as TSP
K rate = 302 kg K_2O/ha per 3-yr rotation as muriate of potash
Cotton N rate = 100 kg/ha in split applications
Corn N rate = 134 kg/ha in split applications
Small grain N rate = 67 kg/ha in February

**All plots except C and 8 are limed to pH 6.5 when pH drops below 5.8.
*** Soil test rating for cotton:
VL= very low; L = low; M = medium; H = high; VH = very high;
EH = excessively high

Ammonium Acetate versus Mehlich-1 Cations

The Auburn University Soil Testing Laboratory has used Mehlich-1 extractable P and cations since 1954. For the purpose of this study, we compared M1 and neutral normal ammonium acetate extract for K, Mg, and Ca for 218 samples and reconfirmed that the values are comparable for these weakly buffered, low CEC soils.

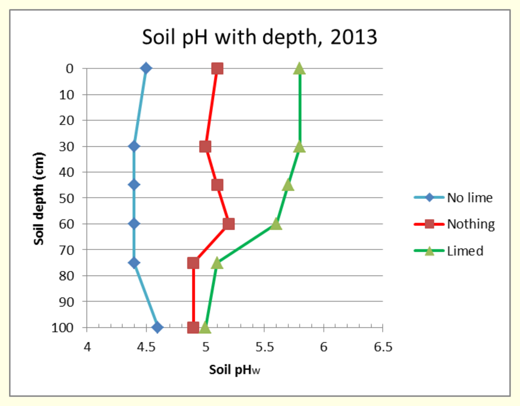
Potassium: $Y= 0.90X - 6.6$ $R^2= 0.96$

Magnesium: $Y= 0.87X + 4.96$ $R^2= 0.96$

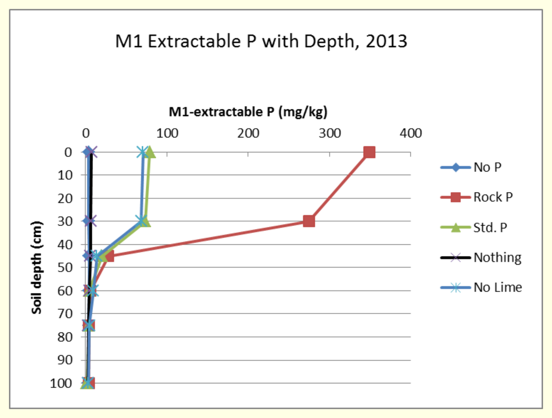
Calcium: $Y=0.83X + 82.5$ $R^2= 0.72$

Therefore, data presented are for Mehlich-1 extractable K only.

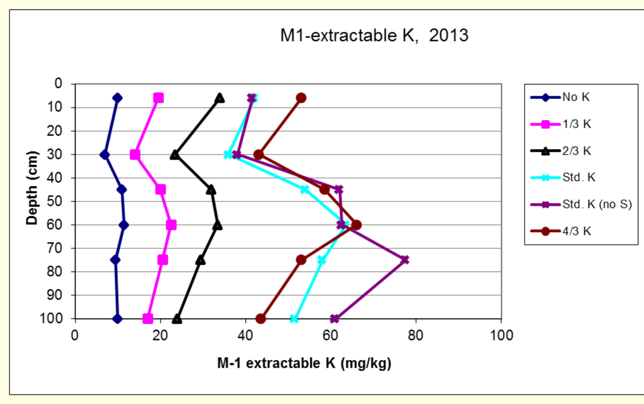
RESULTS

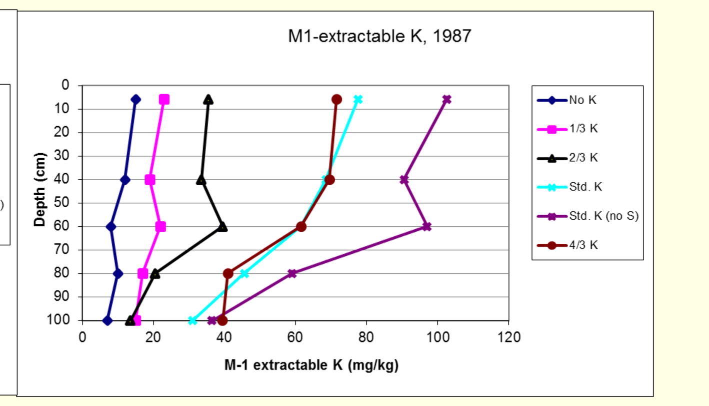


Ground, agricultural limestone is applied periodically to maintain the surface pH_w 5.8 to 6.5. Limestone has been surface applied since 1997 but has had some effect to a depth of 60 cm. The "No Lime" treatment (plot 8) is fertilized which accounts for the lower pH compared to the "Nothing" treatment (plot C).

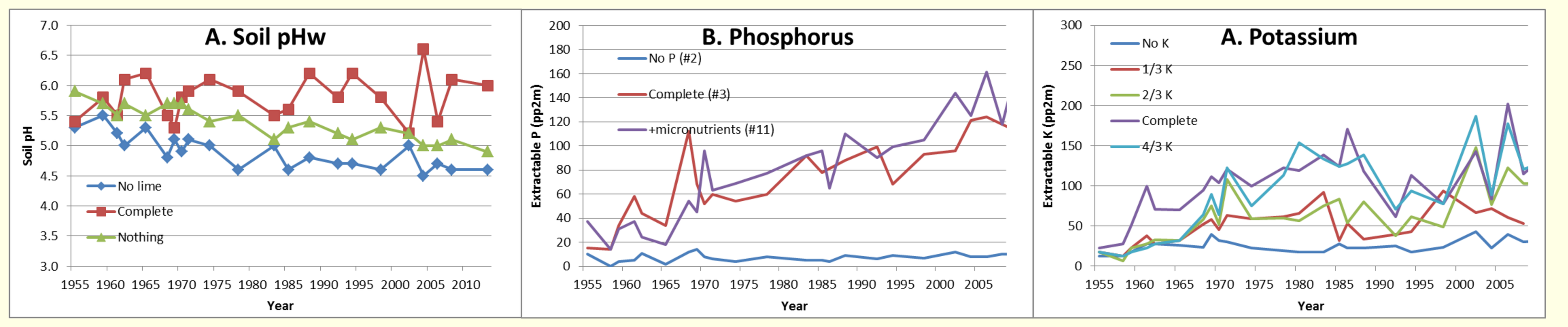


Soil P has not moved below 40 cm in this well drained, soil. Treatment/plot no. 5 received 1350 kg ha^{-1} ground phosphate rock per 3-yr rotation until 2002. All other treatments received only 112 kg P_2O_5 ha^{-1} per 3-yr rotation. Today, all plots receiving P are well above the critical M1 P concentration for most crops of 25 mg P/kg.





Potassium accumulation and movement corresponds to the rate applied. Higher K tends to accumulate throughout the profile where no S as gypsum has been applied. The most dramatic change in the 25 years since the 1987 sampling was in the magnitude of exchangeable K in the upper 60 cm. The only changes that might have affected this was the switch to no-till with in-row subsoiling in 1997 resulting in greater rainfall infiltration and less runoff and an overall increase in crop yields resulting in greater K removal.



The above figures illustrate the changes in soil pH_w and M1 extractable P and K in selected treatments since soil samples have been tested on a regular basis beginning in 1955. Values are for the Middle Tier only.

SUMMARY

The historic "Cullars Rotation" experiment (circa 1911) provides a unique opportunity to examine the classic accumulation and movement of nutrients, especially K, in a weakly buffered soil typical of the Atlantic and Gulf Coastal Plain region. This experiment also provides unique teaching and extension opportunities because of the dramatic nutrient deficiencies exhibited by 5 different crops during the course of a year. Differences in extractable or exchangeable K to a depth of 1 m closely followed K rate applied but limited by the low CEC of this soil. Where no S as gypsum has been applied, more K accumulated in the upper horizons. Less total K was found throughout the profile in 2013 as compared to samples taken in 1987, 25 years earlier. This is presumed to be due to higher K removal by crops (higher yields) and greater water infiltration due to conservation tillage.

ACKNOWLEDGEMENTS

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