# Potassium Balance on Sloping Lands as Affected by Farming Systems

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**This study assessed the available soil K balance under five different farming systems in southern Guizhou from 2000 to 2004. The negative impacts of traditional down slope cultivation were quantified relative to improved systems. Cash crop hedgerows can be highly effective in controlling soil erosion and preserving soil K.**

The susceptibility of K to leaching and the impact of K losses on degrading soil fertility and productivity has been well documented (Adisak et al., 2002; Fardeau et al., 1992; Johnston and Goulding, 1992; Kaddar et al., 1984; Nativ, 1992). On sloping lands, loss of K through soil erosion and runoff may be more serious. Besides rainfall and landscape type, improper tillage, incorrect fertilization, and cropping patterns are known to induce soil K loss by encouraging soil erosion. Recent use of integrated cash crop hedgerows has been proven successful in combating soil erosion in southwest China, but a detailed study on soil K balances is lacking. The objectives of this project were to study the differences in K dynamics as affected by farming systems, and to evaluate soil K balance under five different farming systems in southern Guizhou.

Researchers selected a 30 ha agricultural watershed located at Xinlong Township, Luodian County, Guizhou Province (E106°46', N25°26') with 6 ha of paddy rice and 24 ha of upland crops and fruits. Slopes vary between 11 to 24°. Soils are classified as red-yellow (Hapludalf), developed from Devonian and Cretaceous carbonaceous shale, dominated with quartzes, kaolin, and hydrous micas. The area lies in subtropical, monsoon climate zone with annual precipitation of 1,200 mm. Though rains are usually concentrated from April to September, drought spells often appear in summer and autumn. Corn, the local staple food crop, is widely grown on these slopes using a traditional, erosion-prone, down slope cultivation method.

The experiment used a randomized complete block design with five treatments and four replications (**Table 1**). All the treatments were grown across the slope except traditional farmers' practice (FP), which was grown down the slope. Two types of hedgerows were introduced, buckwheat + plum (AC1) and daylily (AC2). They were grown across the field with 5 m spacing between hedge belts (**see photo above**). The engineered terrace (ET) treatment copied the commonly used practice of reshaping fields into plots 6 m wide and 3 m in length, with 2° slope. All other treatments shared an initial slope of 17° and a plot area of 11 m × 6 m separated by a cement plate. Water tanks were built to receive runoff and sediment at the bottom of each plot.

**Two types of hedgerows,** buckwheat + plum and daylily, were grown across the field with 5 m spacing between hedge belts.

**Table 1.** Amount of runoff and available K lost as affected by different treatments.

| Treatment | Runoff, t/ha | Reduction vs. FP, % | Available K in runoff, kg/ha |
|---|---|---|---|
| Buckwheat + plum (AC1) | 1,996 a | 43.3 | 16.0 |
| Daylily (AC2) | 2,130 a | 39.5 | 14.8 |
| Engineered terrace (ET) | 2,315 ab | 34.2 | 19.2 |
| Balanced fertilization (BF) | 2,756 b | 21.7 | 19.7 |
| Farmer's practice (FP) | 3,519 c | - | 23.1 |

Different letters mean significant at 0.05 levels, respectively

Soil samples taken prior to the experiment determined basic soil physiochemical properties. The soil was acidic with a pH of 5.7 and the mechanical composition was 70.5% clay, 10.6% silt, and 18.8% sand. Soil samples were taken before seeding and after harvesting to analyze available K and slowly-available K using the methods as described by Knudsen et al., 1982.

Fertilizers included 270 kg N/ha as urea (N = 46%), 105 kg $P_2O_5$/ha as single superphosphate ($P_2O_5$ = 16%), and 18 t farmyard manure/ha (N = 0.5%, $P_2O_5$ = 0.25%, $K_2O$ = 0.6% on a wet weight basis) for the FP treatment. The other treatments received 270 kg N/ha, 105 kg $P_2O_5$ /ha, 105 kg $K_2O$/ha as KCl ($K_2O$ = 60%), 6 kg Zn/ha as zinc sulfate (Zn = 23%), 1,950 kg burned lime/ha (CaO = 70%), and 18 t farmyard manure/ha. Except N, all the other fertilizers were applied as basal fertilizers prior to seeding corn. Nitrogen was split twice between corn seedling and earring stages.

Corn biomass and seeds, daylily flowers, and buckwheat were collected from each plot to determine yield and nutrient uptake. Rainfall data was recorded using a local meteorological station. Soil loss and runoff from the plots were collected and measured manually after each rain event. Soil loss was estimated from sediment samples taken from the final sus-

**Abbreviations and notes for this article:** K = potassium; N = nitrogen; P = phosphorus; KCl = potassium chloride.

**Table 2**. Potassium balance in topsoil before planting and after harvesting.

| Treatment | K in top soil before planting, kg/ha | | | K in top soil after harvesting, kg/ha | | | Balance, kg/ha | |
|---|---|---|---|---|---|---|---|---|
| | Total | S.A. K[1] | Avail. K[2] | Total | S.A. K | Avail. K | S.A. K | Avail. K |
| AC1 | 49,974 | 659.4 | 155.5 | 49,755 | 353 | 208 | -306 | 52 |
| AC2 | 46,351 | 572.2 | 179.0 | 45,253 | 294 | 202 | -288 | 23 |
| ET | 46,542 | 604.0 | 179.6 | 48,971 | 349 | 203 | -255 | 24 |
| FP | 40,300 | 576.4 | 153.8 | 39,167 | 401 | 126 | -175 | -28 |
| BF | 45,469 | 651.3 | 154.8 | 47,219 | 369 | 153 | -282 | -2 |

S.A. K[1] = slowly available K; Avail. K[2] = available K.

**Table 3.** Available K balance on sloping land.

| Treatment | Additions, kg/ha | | | Removals, kg/ha | | | | | | Balance, kg/ha |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rain | Fertilizer | Subtotal | Corn grain | Corn stalk | Hedge crop | Runoff | Sediment | Subtotal | |
| AC1 | 3.5 | 176.8 | 180.3 | 12.1 | 42.8 | 32.7 | 14.8 | 4.5 | 106.9 | 73.4 |
| AC2 | 3.5 | 176.8 | 180.3 | 10.9 | 47.5 | 31.7 | 16.0 | 5.9 | 112.1 | 68.2 |
| ET | 3.5 | 176.8 | 180.3 | 10.4 | 31.4 | - | 19.2 | 5.0 | 66.0 | 114.3 |
| FP | 3.5 | 89.7 | 93.1 | 9.6 | 18.8 | - | 23.4 | 9.4 | 61.3 | 31.9 |
| BF | 3.5 | 176.8 | 180.3 | 12.2 | 56.7 | - | 19.7 | 6.4 | 94.9 | 85.4 |

pension of sediment collectors (Rowell, 1994). Soil and plant analyses were conducted in the Guizhou Soil and Fertilizer Institute, Guizhou Academy of Agricultural Sciences.

Results suggest that the best measure to conserve soil K is to control water losses. Hedgerow treatments were highly effective in controlling runoff compared to the BF and FP treatments (**Table 1**). No difference in runoff losses was observed between ET and BF or hedgerow treatments. Available K lost to runoff varied among treatments with the hedgerow treatments being lowest and farmers' practice highest.

Differences in slowly-available K between pre-planting and post-harvest were negative for all treatments (**Table 2**). Slowly-available K was reduced the most under AC1 > BF > AC2 > ET > FP. Available K decreased with FP, remained fairly constant under BF, and increased under the two hedgerow treatments and ET. A sum of the balances for slowly-available and available K after harvest resulted in the following order of K deficit: BF > AC2 > AC1 > ET > FP. While the order might appear surprising at first glance, if one considers evidence which follows on corn yield and hedgerow crop harvest, it is obvious that the reduction in soil K during the cropping season is most correlated to crop yield, or alternatively, K removal by corn. The high reduction in slowly-available K in the BF and hedgerow treatments is most likely a result of high available K demand by the corn and hedge crops. This demand necessitated a more rapid conversion of slowly-available K to available K.

The comparison of K additions and removals, as influenced by treatment, are provided in **Table 3**. All treatments contributed to positive balances. The highest K surplus occurred under ET and the lowest occurred under FP. The FP treatment supplied the lowest fertilizer K–only half the amount used in the other treatments–and was most susceptible to soil erosion and water loss. Farmers' practice had the lowest crop K removal, but this could not be offset by its low K input. The highly positive K balance under ET was a result of much lower crop K removal (i.e., low corn K removal and no hedgerow K removal) despite receiving the same fertilizer K input as the two hedgerow treatments.

Crop uptake was responsible for the majority (46 to 82%) of soil K removal – 31 to 60% remaining in corn stalks, 28 to 31% removed by hedge crops, and 10 to 16% translocated to harvested seed/grain. In all treatments, the majority of soil K removal was a result of growing corn (grain + stalk) which accounted for 46 to 72% of total K removal. Runoff was the main pathway for permanent available soil K loss, accounting for 14 to 38%, while soil erosion accounted for only 5 to 15%.

The FP led to the highest non-crop related K loss from sloping lands – losses to soil erosion and runoff accounted for 53% of total removal, or 35% of the total K input. In the two hedgerow treatments, K lost to soil erosion and runoff was limited to about 20% of total K removal and the remaining 80% was taken up by the corn and hedge crops – a remarkable demonstration of the effect of these hedgerows on minimizing soil nutrient losses.

Traditional farmers' practice was very susceptible to soil erosion and water losses. All treatments showed large reductions in slowly-available soil K due to crop removal. Available soil K increased within the two alternative hedgerow cropping systems and engineered terracing. Integrated practices which make proper use of K fertilizer, crop residue recycling, and soil conservation technology are key components to managing the region's soil K balance. BC

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Corn was planted following cotton from early March to early April at about 28,000 seed/A. Ammonium polyphosphate (11-37-0 or 10-34-0) was applied at 2.5 to 10 gal/A. In most trials, the recommended rate of 4 to 5 gal/A was compared to a no-starter control. Grain yield, silking date, and harvest grain moisture were determined, and plant development was monitored during the growing season (plant dry weight and/or plant height). Extractable soil P levels in the test area were considered high each year, according to analyses conducted by the LSU Agricultural Center Soil Testing Laboratory.

Average corn grain yields ranged from 124 to 204 bu/A. The in-furrow N-P starter fertilizer application significantly increased yield in 5 of the 15 trials and responses in these trials ranged from 8 to 25 bu/A, with an average starter response of 12.5 bu/A (**Figure 1**). No grain yield response to starter occurred in 9 of the 13 years evaluated. Phosphorus deficiency symptoms and starter responses were most common on the more coarse-textured soils. The largest yield response (25 bu/A) occurred on a sandy loam soil. These sandy, low organic matter, light colored soils are cold-natured. Plants on these soils are more susceptible to reduced early season P availability than on finer-textured soils. This probably accounts, to a large extent, for the low incidence of early season P deficiency symptoms and smaller yield responses to starter on clayey soils.

Although starter fertilizer increased yield in only one third of the trials, early season plant growth was increased in all trials. A typical plant growth response to starter is shown in **Figure 2**. Two rates of starter increased plant height from the early seedling to tassel growth stages, while starter N alone had little affect on plant growth. This confirmed that growth responses on sandy loam and silt soils are primarily due to the P in the starter, probably because of reduced P availability on the cold-natured soils.

Enhanced plant growth with starter hastened maturity, which was reflected in advanced mid-silk dates and lower harvest grain moistures. Starter fertilizer reduced mid-silk dates by 4 days when yield responses occurred and by 3 days when no yield response occurred (**Table 1**). Harvest grain moisture was 1% lower in trials with starter yield responses and 0.5% lower in trials with no yield response to starter. This could result in earlier harvest and lower drying costs, which may lead to higher net profit.

**Table 1.** Influence of starter fertilizer on average mid-silk date and harvest grain moisture in 15 trials on Commerce silt loam at the Northeast Research Station at St. Joseph, 1991 through 2005.

| Starter yield response | Number of trials | Mid-silk date No starter | Mid-silk date Starter | Harvest grain moisture, % No starter | Harvest grain moisture, % Starter |
|---|---|---|---|---|---|
| | | ------ DAP[1] ------ | | | |
| Yes | 5 | 73 | 69 | 17.1 | 16.1 |
| No | 10 | 72 | 69 | 18.7 | 18.2 |

[1]DAP = days after planting

Early rapid plant growth also hastens canopy closure, reducing weed development and the need for herbicides.

Planting from mid-March to early April and using starter fertilizer would help ensure consistent maximum corn yield production and minimal conflict with cotton production practices in both spring and fall. Since starter fertilizer such as ammonium polyphosphate can be applied with the same in-furrow application equipment currently used to apply fungicide and insecticides at planting, the only additional cost is the fertilizer expense. At current starter fertilizer prices of $1.65/gal, the application of 4 to 5 gal/A is relatively inexpensive insurance, especially on cold-natured, coarse-textured soils. BC

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