# Understanding Nitrogen Transformations and Cycling for Sweet Corn Production in Sandy Soils[1]

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## Introduction

In Florida, sweet corn represents 10% of the total vegetable production value (Fla. Agri. Stat. Bulletin 2009) and was ranked fourth in total value ($174 million) and third in acreage (50,100 acres) during the 2010–2011 season (NASS 2012). Sweet corn crops grown on sandy soils depend on proper nitrogen (N) fertilizer inputs and management. Because sandy soils have low water and nutrient-holding capacities and Florida experiences high rainfall periodically, optimizing fertilizer use efficiency for sweet corn production is challenging. A plan that incorporates social, environmental, and economic considerations can help farmers produce sweet corn sustainably. To produce profitable crops while minimizing impacts on the environment, farmers must understand farm nutrient budgets. This document provides educational material about nitrogen budgets for growers, UF/IFAS Extension educators, and farm management advisers. This document stresses best management practices (BMPs) and will help farmers identify the major sources and sinks of N related to sweet corn production in sandy soils.

## Managing Nitrogen in Florida's Sandy Soils for Sweet Corn Production: Major Concerns

Managing N in sandy soils is crucial because N is highly susceptible to leaching. Leaching is a major agronomic, environmental, and economic concern for growers.

- *Agronomic*—High N losses can deplete nutrients and significantly reduce crop growth and yield.
- *Environmental*—N lost via leaching can contaminate groundwater and drinking water supplies.
- *Economic*—As fertilizers become a bigger part of corn production input costs, replacing lost N becomes more expensive.

Managing N losses requires quantifying the N sources and sinks in the fields. Once the N sources and sinks are identified and quantified, farmers can adopt management strategies to minimize losses, increase yield, and maximize profit while protecting the environment. Improving N use efficiency for crop production is particularly important for farms in areas with an impaired (i.e., polluted/degraded for its intended use) water body and where a basin management action plan will require BMPs. Understanding the N budget will help growers select and adopt the most effective BMPs.

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# Nitrogen Budget: Definition and Examples

A nitrogen budget is a summary of imports and exports of N for a given system (Shober et al. 2011; Prasad et al. 2015). A nitrogen budget can help a farmer understand the sizes of various N pools, gains, and losses to the environment. (An example of an N budget for potato was presented by Prasad and Hochmuth (2014) at http://edis.ifas.ufl.edu/ss614.)

A budget is considered "in balance" if inputs and outputs are equal. If inputs are greater than outputs, there is surplus of N in the system. Surplus of N may mean money is being wasted on excessive fertilizer (an economic concern) and that there is a higher risk of N leaching into groundwater (an environmental concern). If output is greater than input, then there is a deficit of N in the system (Oenema, Kros, and de Vries 2003). This deficit could take the form of N deficiency in the crop or a loss of N from the production system. Overall, the N budget represents the efficacy of N management practices on a farm growing sweet corn and can guide the farmer in adopting appropriate BMPs or making changes to current management practices.

# Preparing the Nitrogen Budget

A nitrogen budget for sweet corn requires accounting for the inputs and outputs of N involved in sweet corn production. Depending on the ease of data collection, the N budget can be calculated by simply measuring the difference between the amount of N applied as fertilizer and the N exported off the farm in the marketable ears. This type of N budget is known as a *farm-gate budget*, which estimates the percentage of N input exported from the farm (i.e., out through the farm gate) but does not explain how much N was lost to the environment. (Hochmuth and Bennett [2011] presented a farm-gate budget for phosphorus in the context of growing watermelon in Florida [available at http://edis.ifas.ufl.edu/ss547].)

A more detailed N budget is the *soil system N budget,* which is prepared by accounting for all the possible inputs and outputs of N in the sweet corn production system (Table 1). The materials and methods associated with collecting this data and developing a soil system N budget require high scientific expertise and are beyond the scope of the present fact sheet. However, interested readers may refer to Prasad (2014) for detailed information.

The soil system N budget is highly informative since it not only provides information on the N uptake efficiencies or recoveries within the plant but also quantifies the pools of N losses. Additionally, the soil system N budget estimates the amount of N that is recycled back into the soil through roots, stubble, and other plant parts that are left in the field after harvest. The plant residues decompose and become a part of the soil organic matter pool and slowly supply N for the following crops.

Table 1. Major inputs and outputs of a soil system nitrogen budget

| | Nitrogen Inputs | Nitrogen Outputs |
|---|---|---|
| | 1. Initial mineral* N present in soil before planting<br>2. Nitrogen supplied through mineralization of soil organic matter and crop residues | 1. Mineral N in the soil at harvest |
| | 3. Inorganic N present in irrigation water and total amount of water applied during the growing season | 2. Total** N present in plant parts - root, stalk, leaves, and ear |
| | 4. Wet (inorganic N in rainfall) + dry atmospheric deposition | 3. Environmental N losses |
| | 5. Nitrogen supplied through inorganic or organic (e.g. animal manure) fertilizers | a) Leaching loss |
| | | b) Volatilization loss |
| | | c) Denitrification loss |
| | | d) Runoff loss |
| Total | Σ Inputs | Σ Outputs |
| Balance = ΣN inputs – ΣN outputs | | |
| *Mineral N or inorganic N is a sum of $(NO_X - N) + (NH_4 - N)$ | | |
| **Total N is sum of organic plus inorganic N | | |

# Interpreting the Nitrogen Budget: Examples

The following examples show how to interpret the N budget. The hypothetical data used in the example, though realistic, are for illustration purposes only.

## Farm-Gate Budget

Let us assume that a farmer growing sweet corn applied a total of 240 kg $ha^{-1}$ N. If the average N concentration was 2% in the ear tissue (which includes cob, husks, and kernels) and average dry weight of ears was 3,874 kg $ha^{-1}$, then the total N uptake in the ears was 78 kg $ha^{-1}$ N (see Equation 8 for calculation). As a result, of the total N applied (240 kg $ha^{-1}$) by the farmer, only 35% of N was exported from the farm in the sold ears. The fate of the remaining 65% of N is unknown in this type of budget. A limitation of this type of budget is that it does not explain what portion of the N in the crop came from fertilizer and what portion was contributed by soil organic matter or other N sources such as rainfall or irrigation water. Thus, a farm-gate budget serves as a record book of N imports (as fertilizer) and exports (as sold products) for the farm.

## Soil System Budget

Let us use the values given in Table 2 for calculating the soil systems budget. The data presented in Table 2 would require considerable time and resource investment for sample collection and analysis, such that these data would probably be derived from research studies on a farm. For our discussion we will focus on what can be learned from this type of budget.

Table 2. Illustration of a soil system budget for sweet corn

| Nitrogen Inputs | kg $ha^{-1}$ | Nitrogen Outputs | kg $ha^{-1}$ |
|---|---|---|---|
| 1. Initial mineral* N present in soil before planting | 25 | 1. Mineral N in the soil at harvest | 15 |
| 2. Nitrogen supplied through mineralization of soil organic matter and crop residue | 20 | 2. Total** N present in plant parts | |
| 3. Nitrogen (if present) applied through irrigation water during the growing season | 15 | a) Root | 18 |
| 4. Atmospheric deposition of N (wet +dry) | 3 | b) Stalk | 36 |
| 5. Nitrogen supplied through inorganic or organic fertilizers | 224 | c) Leaves | 43 |
| | | d) Ear | 78 |
| | | e) Stubble | 14 |
| | | 3. Environmental N losses | |
| | | a) Leaching loss | 40 |
| | | b) Volatilization loss | ? |
| | | c) Denitrification loss | 0 |
| | | d) Runoff loss | 0 |
| Total | 287 | | 244 |
| Balance = N inputs – N outputs | 43 | | |

*Mineral N or inorganic N is a sum of ($NO_x$ – N) + ($NH_3$ – N)
**Total N is sum of organic plus inorganic N

The data in Table 2 shows the total amount of N that went into sweet corn production amounted to 287 kg $ha^{-1}$ N, of which 224 kg $ha^{-1}$ N was supplied through fertilizers, the remaining 63 kg $ha^{-1}$ N from non-fertilizer sources. The N contribution from non-fertilizer sources comprised 22% of the total N input (see Equation 1). The non-fertilizer sources of N are considered *variable sources of N inputs* because the amounts of N contributed by each are highly variable and change over time. The total plant N uptake was 189 kg $ha^{-1}$. Thus, the N use efficiency of this system was 66% (see Equation 2). However, the fertilizer-use efficiency was 84% (see equation 3). The amount of mineral N left in the soil after the plant harvest was 15 kg $ha^{-1}$ N. This leftover N in the soil accounted for 5% of the total N input. This leftover N can be credited to next season's crop as an *N credit* (see Equation 4) provided the N is not lost before planting via leaching due to heavy rainfall.

Of the total input in the N budget, we easily identified 71% N in the plant and soil (leftover N at the time of harvest) and 14% N lost via leaching, but we could not account for the remaining 15% of N (see Table 2). The unaccounted-for N (see Equation 5) was presumably associated with volatilization (i.e., vaporization) losses. Nitrogen is lost to the environment through leaching, volatilization, denitrification, or runoff; however, in Florida's sandy soils, leaching and volatilization N losses are most common (Prasad 2014). Although directly measuring leaching and volatilization losses requires high scientific expertise, the sum of these two losses can be estimated by subtracting the total N output from the total N inputs. Although this method provides an estimate of the N lost to the environment, it does not differentiate between leaching and volatilization losses of N.

The amount of N recycled back into the soil from the plant residues left in the field is another important part of this soil system N budget. In the present example, the marketable portion of a sweet corn plant is the ear. The remaining plant parts (such as leaves, stalk, stubble, and root) are left in the field for recycling and become part of the soil organic matter pool. Thus, 39% of the total N input was left in the soil for recycling (see Equation 6) whereas 27% N was exported off the farm as marketable ears (see Equation 7). It should be noted that the farm-gate budget overestimates the N exported from the farm: in the present example, the farm-gate budget estimated 35% of total N was exported from the farm whereas the soil system budget estimated 28%N was exported. The difference in the values arises because in the farm-gate budget, we counted the N from fertilizer only, but in the soil system budget we counted N from both fertilizer and non-fertilizer sources.

In summary, of the total N input for sweet corn production in sandy soils, 66% N was captured in the plants, 14% N was lost via leaching, and 5% N remained in soil after harvest. Of the 66% N that was captured in the plants, 27% N left the farm in the marketable ears, while the remaining

39% N stayed in the field for recycling and became part of the soil organic matter pool. The unaccounted-for N was 15% of the total N inputs, which was associated presumably with volatilization loss (denitrification losses, although they cannot be ruled out completely, are of less significance in sandy soils; these soils are not saturated or anaerobic and lack organic substrate and thus do not favor the denitrification reaction). The total environmental N loss (leaching plus volatilization) was 29%. Growers can use Table 3 and equations given below to draw similar conclusions for crop production in their farm.

# Conclusion

Nitrogen budgets are highly informative, effective tools for evaluating the N management in sustainable sweet corn production. Depending on the ease of data collection and the level of information required, either farm-gate or soil system N budgets can be prepared. High N recovery in the plants indicates less N loss and a sound N management practice, whereas low N recovery indicates poor crop performance, poor N management practice, and higher risk of N loss to the environment. Once the pools of N are quantified, farmers can implement management strategies to reduce losses, improve N efficiency, and achieve greater sustainability in sweet corn production.

Table 3. Performance indicators of a soil system nitrogen budget

| Parameters | % | Use |
|---|---|---|
| % N supplied from sources other than fertilizer | 22 | Equation 1 |
| Nitrogen use efficiency | 66 | Equation 2 |
| Fertilizer use efficiency | 84 | Equation 3 |
| % N that was left in soil at harvest (N credit) | 5 | Equation 4 |
| % N that was unaccounted for | 15 | Equation 5 |
| % N in stalk, leaf, and stubble left in the soil for recycling | 39 | Equation 6 |
| % N exported off the farm as sold ears | 27 | Equation 7 |

**Equation 1:** %N supplied through non-fertilizer sources = (amount of N from non-fertilizer source ÷ total N (fertilizer + non fertilizer sources)) × 100

**Equation 2:** N use efficiency = (Plant N uptake ÷ Total N inputs) ×100

**Equation 3:** Fertilizer use efficiency = (Plant N uptake ÷ Total N supplied through fertilizer) × 100

**Equation 4:** %N remaining in soil (N credit) = (mineral N present in soil at harvest ÷ total N input) × 100.

**Equation 5:** Unaccounted-for %N = 100 − (%N captured in plant + %N remaining in soil + %N lost via a known pathway such as leaching)

**Equation 6:** %N in plant residue left for recycle in the soil system = (N present in stalk + leaves + root + stubble) ÷ Total N inputs × 100

**Equation 7:** %N exported from farm as marketable ears = (N present in ears ÷ Total N input) × 100

**Equation 8:** Total plant N uptake (kg $ha^{-1}$) = (%N in tissue N × dry tissue yield weight kg $ha^{-1}$) ÷ 100

# References

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