Coffee–Forage Intercropping is a Sustainable Production System for Brazil

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Cover crop forage grown under the coffee plant canopy serves as an important biomass source, which is proving effective at protecting this agro-ecosystem while improving the use of N.

Brazil is the world's largest producer of both arabica (*Coffea arabica* L.) and robusta (*Coffea canephora* Pierre ex A. Froehner) coffee species. The two species are cultivated on an estimated 2.3 million ha in Brazil with an average of 2.1 to 3 million tons of coffee processed each year.

Coffee grows in the extensive tropical region of Brazil characterized by two main seasons, the rainy season (from September to April) and a dry season (from May to September). In Brazil, the crop is largely grown under full-sun growing conditions, which is different from other large coffee-growing areas like Central America where the crop is commonly planted within a shaded agroforestry system.

Water is commonly limited in perennial plants grown under full-sun, tropical conditions, and it is important to minimize water loss from surface runoff and evaporation. Evapotranspiration varies from 3 to 5 mm per day (i.e., 3 to 5 L water/m^2/day). Soils are highly weathered with kaolinite and oxides present in the clay fraction. The dominant presence of these clay minerals limits soil water retention capacity to less than 0.5 mm per cm of soil (i.e., 0.5 L/m^2/cm).

Forages like *Urochloa decumbens*, *Urochloa ruziziensis*, and more recently, *Urochloa brizantha* are being intercropped on Brazilian plantations to accomplish the goals of protecting soil from the impact of torrential rainfall that is common in the tropics and reducing soil heating due to exposure to the sun.

A coffee–forage intercropping system contributes to the goal of improving water availability, especially during the first six to eight years of establishment, when the plants are only exploiting a fraction of the total area. For example, the presence of 3 t/ha of biomass increased soil moisture by 49% when compared with amounts measured without biomass addition (unpublished data).

Forage biomass can increase water infiltration and reduce the speed of surface runoff, which both contribute to less soil loss by water erosion. Further, the temperature of soil surfaces (5 cm depth) often do not exceed 35°C. This is far less than 50°C temperatures that are commonly observed on exposed soil surfaces, leading to root system stress and even root death.

In addition to protecting the soil, forage biomass can also increase fertilizer N recovery in its role as a cover crop. Nutrients absorbed from the soil volume through forage root growth in inter rows are recycled within the cropping system. Around 3 t/ha of forage biomass could provide the equivalent of 24 to 92 kg N/ha with a low release by decomposition of biomass under the coffee canopy (Pedrosa, 2013).

Despite the numerous advantages of forage cultivation in a coffee-forage system, producers can often justify resisting its adoption due to misperception of yield-robbing nutrient, mainly N, competition. In crop systems in which there is input of fresh biomass, there is commonly an increase in availability of oxidizable C as a energy source for microorganisms and this decomposition immobilizes soil N (or releases N) depending on the C:N ratio of the added biomass.

Addition of biomass with a C:N ratio above an equilibrium of 33:1 results in N immobilization due to the incorporation of the C source into the soil microbial biomass. Biomass C:N ratios below this equilibrium will increase soil N, since the supply exceeds microbial demand (**Figure 1**).

Coffee plantations harvest forage biomass with a shredder, which distributes the biomass over the desired area. Biomass residue input commonly ranges between 3 and 5 t of dry matter/ha/yr. During every forage harvest/spreading operation, biomass nutrients taken from a region where coffee plants


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Coffee-forage (*Urochloa* sp.) intercropping system.

Abbreviations and notes: N = nitrogen; C = carbon.

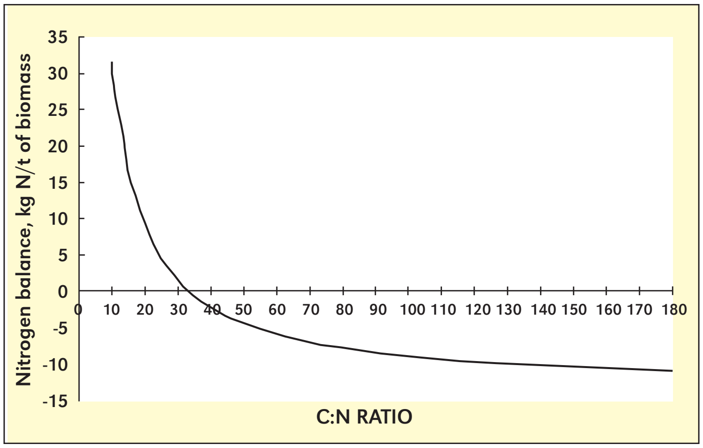

Figure 1. Impact of forage biomass on soil N balance with increasing C:N ratio (from Cantarella, 2007).

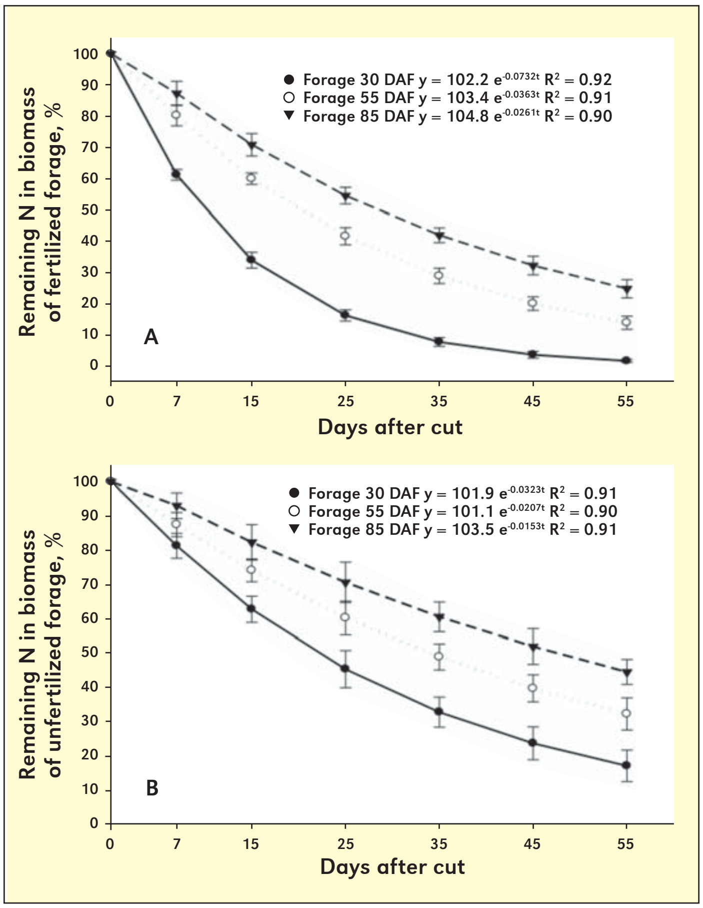

Figure 2. Nitrogen release from forage biomass fertilized (A) and unfertilized (B) with N, cut at 30, 55 and 85 days after fertilization (DAF) (from Pedrosa et al., 2014).

explores a low volume of soil due to crop formation stage, are transferred to the coffee canopy zone that is highly explored by coffee roots. After each forage harvest, a proportion of the forage root system dies, leaving channels or stable biopores that contribute to rain infiltration and oxygen exchange within the soil profile. A forage harvest/spreading operation done at 30 and 45 day intervals has been demonstrated to not immobilize significant N supplies to coffee since the biomass C:N ratio is maintained below 35:1 (Pedrosa et al., 2014).

When evaluating biomass it is important to know the half-

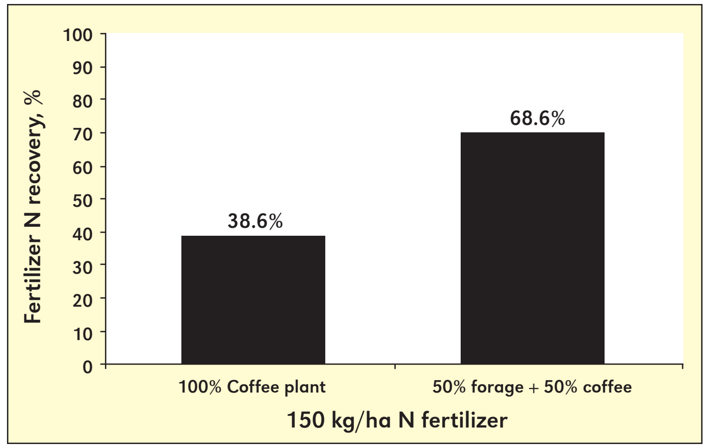

Figure 3. Recovery (%) of ^{15}N in coffee applied via fertilizer. Application of 150 kg N/ha in coffee plant (100% of the dose) and application of 75 kg/ha in coffee plant (50% dose) and 75 kg/ha in forage grass (50%), which is cut and deposited in coffee plant canopy (unpublished data).

life time for its residue decomposition—the time required to decompose 50% of the biomass applied. This also applies to rate of N released from the biomass. An example of the release of 50% of N present in biomass due to both forage fertilization and cutting time is shown in **Figure 2**. Forage N fertilization increased the rate of its biomass decomposition with 50% of the N released within 10 days (cut 30 days after N fertilization), 20 days (cut 55 days after N fertilization) and 30 days (cut 85 days after fertilization). In comparison, forage not receiving N (the most common situation) released 50% of N present over 20, 35 and 55 days under the same three cutting intervals.

Many coffee-forage intercropping system advantages have been observed in coffee field areas in Brazil. Field research to assess N balance due to biomass C:N ratio and fertilizer N recovery, through ^{15}N isotopic technique for this system, is now underway. Preliminary results indicate that there is an increase in the order of 30% in the efficiency of N fertilization in this system (**Figure 3**).

Summary

Forages can recover around 85% of fertilizer N applied and then release this N during residue decomposition under the coffee canopy, which is then readily absorbed by the coffee crop. Early results highlight the sustainability of this coffee-forage intercropping system due to its conservation of water, soil and N. BC

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