Ecological Intensification When Maize is Not the Primary Crop

By Eros Francisco

Today in Brazil, the most common way to grow maize is as a 2nd crop after soybean harvest.

This cropping system evolution has also brought research, since the year 2000, on most beneficial cover crop species that can fit as intercrop with maize.

Such cropping system intensification raises questions about needed adjustments to N management for both high yield and improved soil quality

Maize has traditionally been grown worldwide as a primary crop during the summer to provide grain for both human and animal nutrition. In temperate regions, no other crop is grown after the maize harvest in the fall, but in some tropical or subtropical regions of the world maize can be grown throughout the entire season with minimal limitation, and be a secondary crop within a cropping system.

In Brazil, the amount of land devoted to growing maize in the summer (1st crop) was about 92% of the total area planted to maize until the year 2000. Generally, in the southern region, maize was seeded early in the spring and harvested by the end of the summer when a winter crop (wheat, oat, or barley) was sowed. In recent decades, farmers of the Midwest region began to grow maize more intensively in the fall, as a 2nd crop following soybean harvest. Today, the land planted to 1st crop maize is only 60% of its historic high of the mid 1980s (**Figure 1**). In the 2016 season, 2nd crop maize occupied 66% of the total 15.9 million (M) ha planted to maize, and represented 62% of Brazil's total maize production (66.7 M t; Conab, 2016). Francisco et al. (2014) have described the latest changes that have occurred in Brazilian soybean cropping systems to result in this shift to growing maize as a 2nd crop.

Commonly, farmers have grown 2nd crop maize alone, but recent crop and soil management research is revealing benefits of intercropping maize with cover crops, either legumes or grasses. Some benefits are related to soil quality, such as better aggregation, increased soil organic carbon and water holding capacity, more N availability via indigenous fixation with legumes, and others. Cropping system benefits include higher nutrient cycling, better weed control, land use intensification, nematode control, and so on. But for many farmers, the most beneficial outcome of intercropping maize with grasses is to have a pasture for grazing after maize harvest, which has allowed them to integrate grain and beef production in the same area.

The Global Maize Project (GMP) has two sites in Brazil. Field trials have been carried out for more than six years and are located in the states of Paraná and Mato Grosso, which well represent regional cropping systems where maize is not the primary crop. **Table 1** summarizes the components of both studies. In the south region (Paraná), the crop rotation is generally composed of wheat or black oat in the winter and soybean or maize in the summer, whereas in the Midwest region (Mato Grosso) maize is grown in the fall as a 2nd crop after soybean harvest.

The alternative under evaluation, proposed as the ecological intensification (EI) in each region, was to introduce legumes

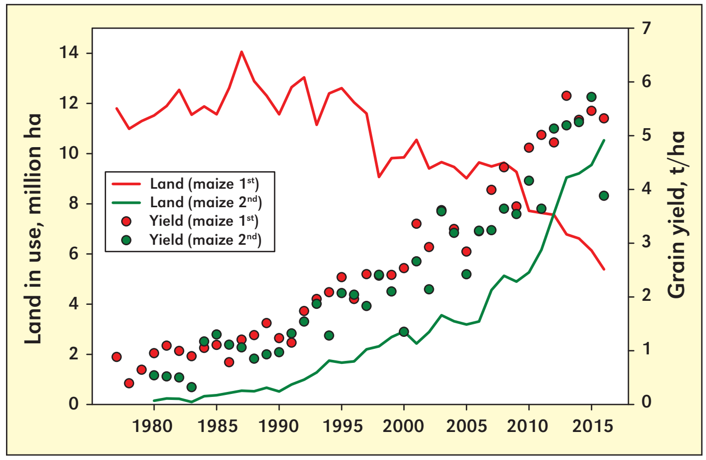

Figure 1. Historical use of land and yield of 1st and 2nd maize crops in Brazil. Source: Conab (2016).

Abbreviations and notes: N = nitrogen; C = carbon. IPNI Project GM-18; GM-19.

Table 1. Treatments under evaluation with maize in the states of Paraná and Mato Grosso, Brazil.

#	Description	Crop sequence† Spring/summer	Fall/winter	N applied to maize, kg N/ha
	Paraná			
1	Farmer practice	Soybean (1) Maize (2)	Wheat (1) Black oat (2)	0, 70, 140, 210
2	Farmer practice + silage production	Soybean (1) Maize (2)	Barley (1) White oat (2)	
3	Ecological intensification	Soybean (1) Maize (2)	Black oat (1) Forage pea†† (2)	
	Mato Grosso			
1	Farmer practice	Soybean	Maize	0, 35, 70, 110
2	Farmer practice + cover crop	Soybean	Maize+*Brachiaria*†††	
3	Ecological intensification	Soybean (1) Soybean (2) Maize+*Brachiaria* (3)	Maize+*Brachiaria* (1) Sunn hemp†††† (2) *Brachiaria* (3)	

† Number in parenthesis represent year in the crop sequence.
†† *Pisum sativum* subsp. *arvense* (L.) Asch. and Graebn. ††† *Brachiaria ruziziensis* Germ. and C.M. Evrard.
†††† *Crotalaria spectabilis* Roth and *Crotalaria ochroleuca* G. Don.

Table 2. Grain yield, N removal, and performance indicators of maize in response to the ecological intensification of the cropping system in two regions of Brazil.

#	Description	Grain yield t/ha	N removal kg/ha	PNB[†] kg/kg	PFP[††] kg/kg
	Paraná				
1	FP	11.05 b	144 b	0.96	99 b
2	FP+Silage	10.98 b	143 b	0.97	99 b
3	EI	12.15 a	169 a	1.13	108 a
msd[§]		(0.44)	(19.5)	(0.65)	(5.2)
	Mato Grosso				
1	FP	7.40	116	2.20	133
2	FP+CC	7.14	113	2.12	129
3	EI	6.96	109	2.08	128
msd		(0.72)	(19.5)	(0.37)	(15.4)

[†] Partial nutrient balance: kg nutrient removed/kg nutrient applied. [††] Partial factor productivity: kg grain/kg nutrient applied. [§] Minimum significant difference. Means represent the average of all N tested rates (0, 70, 140, and 210 kg N/ha in Paraná and 0, 35, 70, and 105 kg N/ha in Mato Grosso), and followed by the same letters do not differ by Tukey test (p<0.1).

into the system to increase N availability via biological fixation and serve as a positive factor for N use efficiency, as well as to intercrop a type of grass with maize to add more crop residue for the purpose of increasing soil C content. Also, adjustments in N supply were required to fulfil the cropping system demands, so a response curve of N rates was added as a split plot factor. All other nutrients were equally and adequately applied.

Yield and Nutrient Use Efficiency

The insertion of forage pea into the EI cropping system in Paraná significantly increased grain yield of maize by more than 1 t/ha, as compared to the farmer practice (FP) system (**Table 2**). It also supported higher N removal and benefited N use efficiency of the system. EI produced higher partial factor productivity (PFP; 108 kg grain/kg N applied), which represented a 9% increase compared to FP. The amount of N removed in EI was higher, as well as the partial N balance (PNB), indicating that the system is adequately supplying N to the crop. The intermediate system tested (FP plus silage production) performed similarly to FP.

Another positive effect of EI was noted in maize yield response to N application. **Figure 2** presents maize yield and N performance indicators in response to N rates among cropping systems in Paraná. No response of yield to N applied was observed in EI, while a significant and positive response to N rates was shown in FP. On average, grain yields obtained with 140 kg N/ha and 210 kg N/ha were equal and higher than observed with 70 kg N/ha and control (no N applied), while PFP and PNB performed differently in each rate showing decreasing values with increasing N rates. Due to the high amount of N supplied by forage pea fixation, maize yield in EI was significantly higher for the control (2.6 t grain/ha greater) and at the lowest N rate tested (1.8 t grain/ha greater), as compared to FP, respectively.

On the contrary, growing a legume crop (sunn hemp) in

E. Francisco/IPNI Image

Aerial view of Global Maize Project site in Mato Grosso, Brazil.

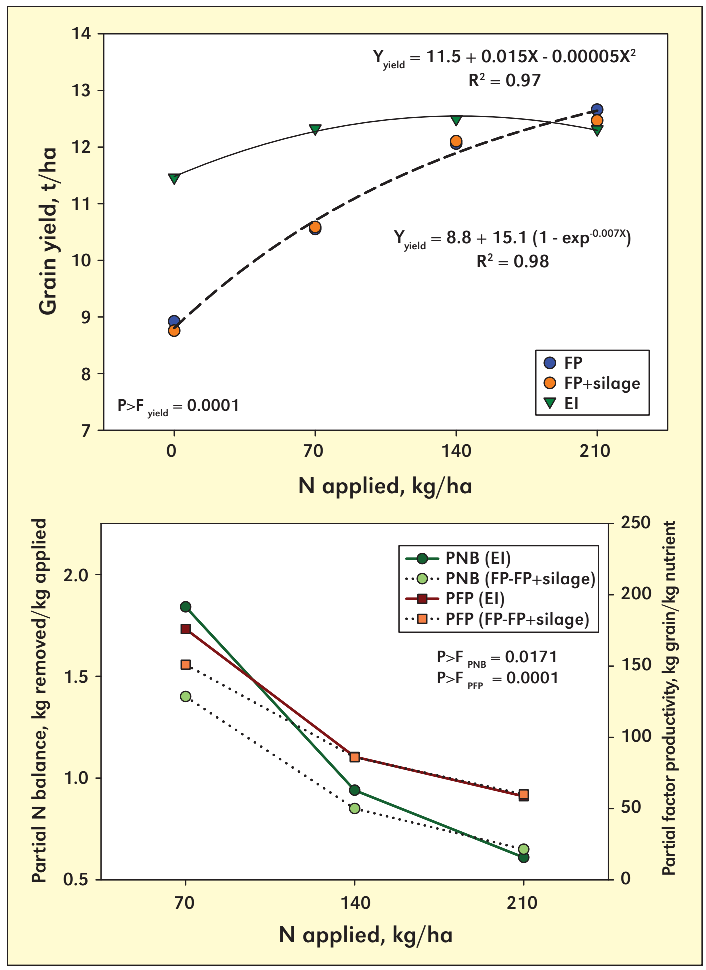

Figure 2. Maize yield (upper) and nutrient performance indicators (lower) in response to N rates in Paraná, Brazil, according to cropping systems: farmer practices (PF), farmer practices plus silage production (FP+silage), and ecological intensification (EI). Partial nutrient balance (PNB): kg N removed/kg N applied. Partial factor productivity (PFP): kg grain/kg N applied. Average of 4 years.

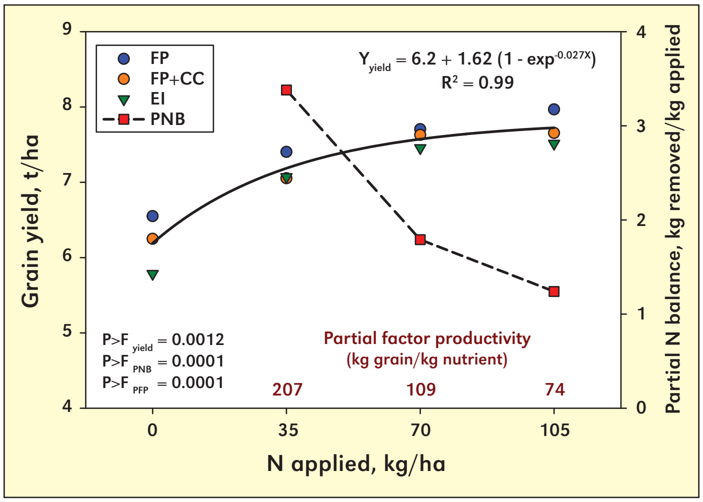

Figure 3. Maize yield and nutrient performance indicators in response to N rates in Mato Grosso, Brazil, according to cropping systems: farmer practices (PF), farmer practices plus cover crop (FP+CC), and ecological intensification (EI). Average of 6 years.

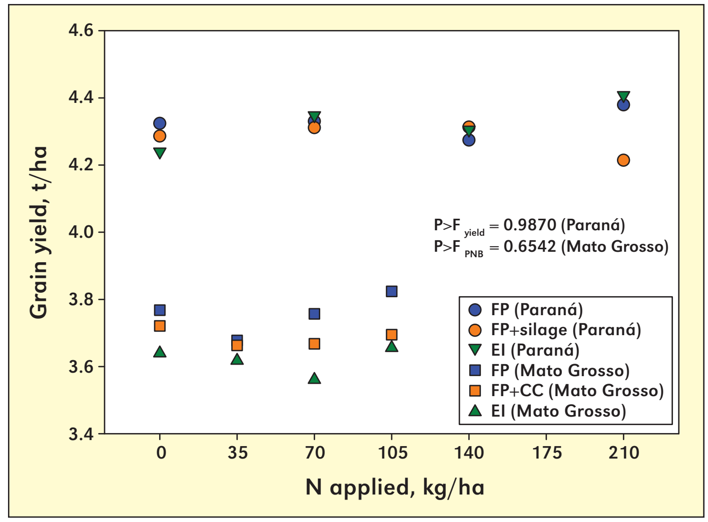

Figure 4. Soybean yield in response to N rates previously applied to maize in Paraná and Mato Grosso, Brazil, according to the cropping systems: farmer practices (PF), farmer practices plus silage production (FF+silage), farmer practices plus cover crop (FP+CC), and ecological intensification (EI). Average of 4 years in Paraná and 6 years in Mato Grosso.

the fall following soybean harvest as part of the EI treatment in Mato Grosso showed no benefit to maize yield, as in Paraná (**Table 2**). Despite no statistical significance, maize yield of EI consistently trended lower than FP, as well as the amount of N removed and the value of performance indicators. After six years of study, average maize yield of EI trended 0.5 t grain/ha lower than FP. Two possible reasons have been provided to explain this potential difference: 1) competition of *Brachiaria* grass intercropped with maize for water and nutrients, or 2) N immobilization by the higher amount of biomass added to the soil. Regarding the first reason, research results are showing that intercropping grasses with maize can reduce grain yield in a large range depending on the type of grass, time of seeding, use of herbicide, and weather conditions (Borghi and Crusciol, 2007; Ceccon et al., 2013). In this case, the reduction in maize yield caused by the association with *Brachiaria* grass was 0.26 t grain/ha on average (FP vs. FP+CC), which could not be overcome by growing sunn hemp for extra N in EI.

Figure 3 presents maize yield and N performance indicators in response to N rates among cropping systems in Mato Grosso. A significant response of all parameters to N rates was observed. All rates of N applied performed equally to increase grain yield as compared to control (no N application), while PFP and PNB performed differently in each rate showing decreasing values with increasing N rates. Grain yield was increased 16%, 23%, and 24%, respectively, with 35, 70, and 105 kg N/ha, as compared to control (no N applied).

Soybean grain yield was not affected by the cropping system nor by the rate of N previously applied to maize in both studies (**Figure 4**). In Paraná, grain yield of FP and EI showed a slight positive trend of increase with higher N rates, as compared to FP+silage, but no statistical difference was observed. In Mato Grosso, soybean grain yield of each cropping system was numerically higher with increasing N rates in the first three years of the study, but this trend was inverted later on, likely in response to higher maize grain yields observed with new hybrid. Also, soybean yield of EI was a bit less than FP indicating that more N may be required in the system to deal with higher amounts of C added via crop residues.

Summary

The use of performance indicators is an adequate way to compare the efficiency of different cropping systems in supplying crop nutrients. Values of PFP and PNB observed in Paraná showed that N use efficiency in EI was much higher than in FP, representing a possibility of saving resources while increasing grain yield. On the other hand, the performance of EI in Mato Grosso was not as expected and further investigation is necessary to understand the interaction of growing factors.

The weather conditions of fall/winter, such as precipitation and temperature, are crucial for growing cover crops that can positively affect the cropping systems. In regions where precipitation is accumulated in the summer time and short rains occur in the rest of season, like in Mato Grosso, the benefits of EI via use of cover crops can be suppressed.

Nitrogen is a key nutrient for high yielding maize, as shown in both studies, but its efficient use must be pursued in EI systems. The results presented above indicate that lower rates of N can be applied in Paraná when farmers decide to adopt EI. BC

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