The Global Maize Project: What Have We Learned?

By Luís Prochnow and T. Scott Murrell

Overall, average grain yield in ecological intensified (EI) systems surpassed farmer practice by nearly 1 t/ha.
If such an increase were extrapolated to all maize-growing areas of the world, an estimated 160 million (M) t of additional grain would be produced every year, representing about a 15% increase in world production.
Besides the increase in yield, improvement in nutrient use efficiency (NUE) was proved possible under EI in several circumstances.

Historically, the global average yield for maize has been increasing steadily over time. Since the 1960s, yields have been improving at a rate of 65 kg/ha/yr (**Figure 1**; FAO, 2017). In terms of the world's total maize grain production, it had been increasing at a steady rate of 10 million (M) t/yr until 2004, after which it shifted to a steeper line of 31 M t/yr (**Figure 2**). As is also shown in Figure 2, this shift in production closely follows the most recent trend line for maize harvest area expansion. Prior to 2007, global maize area had been increasing at a rate of 0.9 M ha/yr. Since 2007, maize area has been increasing at the more rapid pace of 4.7 M ha/yr. The United States, China, and Brazil have contributed to the majority of this area expansion, and in 2014 these three countries accounted for 47% of world's maize production.

These global trends clearly show that recent, rapid increases in maize production are associated more with the expansion of maize growing areas than with rapid increases in yield. One of the goals of EI, however, is to increase yields on existing lands, so there is much work yet to do.

Around the world there is a continuous debate over whether resources for research should be allocated more toward basic research or practical agronomic aspects. Those that understand the complexity of agriculture realize that both are needed. Good practice can only advance if basic aspects are understood, making new and effective techniques available for the field. In short, basic research creates the opportunities for higher yield and higher production, but the results from such research must be tested and integrated into field operations.

It seems logical that a great contribution to the reduction of yield gaps and improved efficiency in maize would come from testing the most advanced techniques made available by in-the-field research like EI, and comparing these results to what farmers are achieving. The objective question here would be: "*Is research pointing out alternatives that are better in terms of yield, efficiency, and profitability, than what farmers are presently using?*" The International Plant Nutrition Institute (IPNI) is a global organization with, among other things, a mandate to help farmers produce more with improved efficiency and greater profitably. The Global Maize Project (GMP) was implemented by IPNI to help answer the above practical question. This is facilitated by our presence in the most important agricultural regions of the world.

It is important to note that by concept the set of treatments reflecting EI and farmer practice (FP) are not fixed in time. They may change according to new possibilities coming from research (maybe added to EI) or from changes implemented in average practices used by farmers in the region (maybe added to FP). As an example, if a new maize hybrid was proven to be a great option for the region, it can be incorporated into the EI set of practices to be tested in conjunction with what else recent science suggest might be the best alternatives. As a moving set of practices, in regions where EI yields more than FP, with time, the yield gap between these two treatments would ideally narrow (**Figure 3**). This narrowing would indicate that farmers are adopting the EI management practices on their own farms. This of course would be facilitated by setting good programs to educate farmers about the benefits of EI (Satyanarayana et al., this issue).

As discussed in the different chapters of this issue of *Better Crops*, we have learned a lot with the GMP in various regions. Measuring the impacts (Norton et al., this issue) of EI and FP, and all combinations of different treatments around the globe, made it possible to have clear ideas on how to produce maize

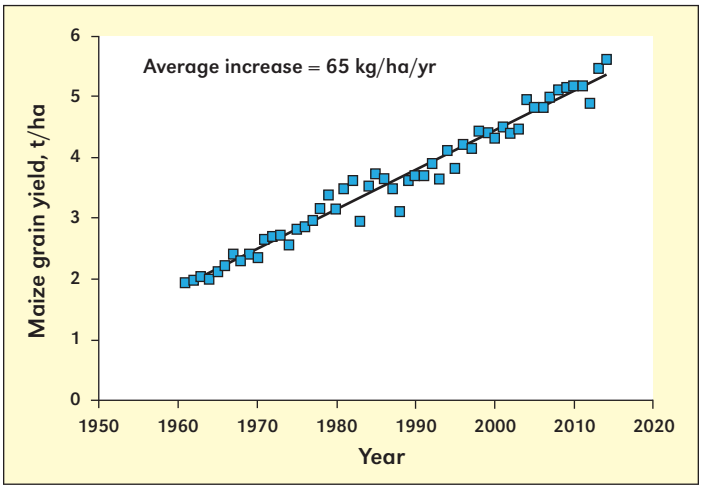


Figure 1. Trends in global average maize grain yield over time (FAO, 2017).

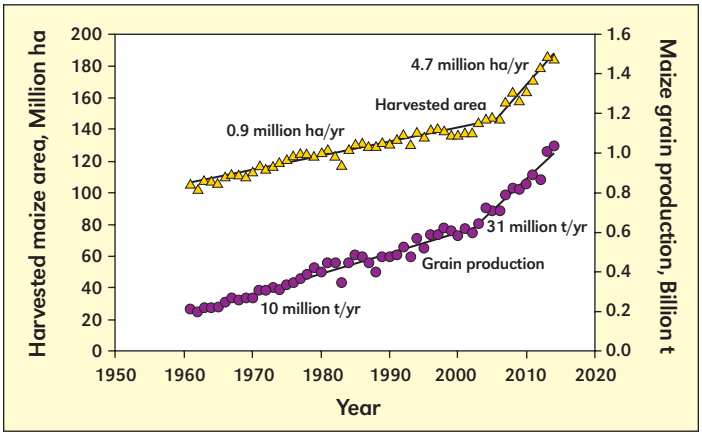


Figure 2. Trends in harvested area and total maize grain production over time (FAO, 2017).

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium.

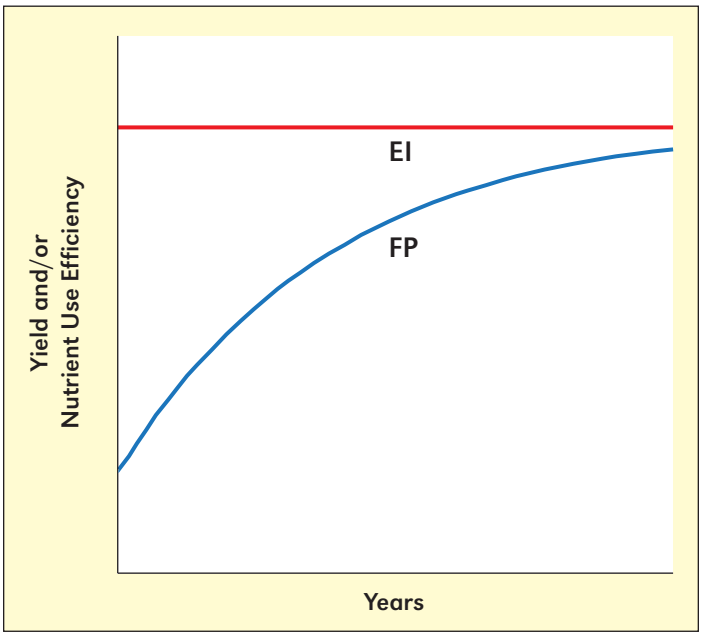


Figure 3. Conceptual goal for closing the yield and/or nutrient use efficiency gap between EI and FP, which would translate into farmers adopting the recommendations from EI.

better in regions where yield gaps are narrow (Murrell et al., this issue) or wide (García et al., this issue). For example, it was possible to see that management changes incorporated into EI practices improved net return in the majority of sites in Minnesota, USA, a region already recognized as having high yields and narrow yield gaps. Also, it was possible to confirm high yield increases in Sub-Saharan Africa, South Asia, and Argentina, regions recognized by models and yield gap analysis (Grassini et al., this issue) as having wide yield gaps. In some of these sites an improvement on nutrient use efficiency was also observed.

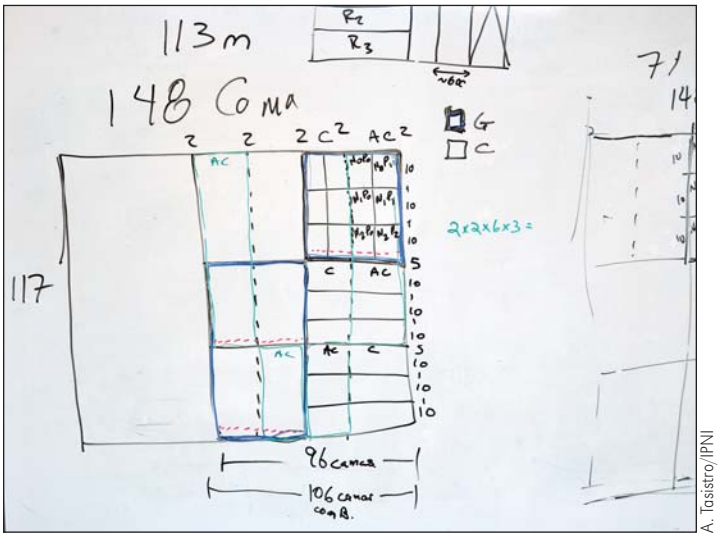
In China, the GMP found very interesting results. Optimized planting density, reduced fertilizer N rate, and better application time maintained crop grain yield and improved significantly nutrient use efficiency (Zhao and He, this issue). For example, agronomic efficiency, which measures how much grain yield has increased per unit of N applied, was 32% lower in FP than in EI. This is important information for a country needing to improve the use of nutrients in its agriculture to improve the environment and to address new legislation to be implemented in the near future.

Studies also confirmed that maize rotation with other crops can be of enormous value to some soil systems and to maize production. This was the case in Ponta Grossa, Paraná, Brazil, where the introduction of forage pea into the EI cropping system significantly increased grain yield and partial factor productivity (Francisco, this issue).

Applying precision agriculture (PA) to maize will be fundamental to seeking more production with lower environmental impact. PA tools and management strategies will help create the information-driven, evidence-based agricultural systems needed to meet its challenges (Phillips and Majumdar, this issue).

The results of the GMP and similar studies are creating an impact in different regions of the world. In a recent survey, IPNI collaborators pointed out important impacts. The following list is a compilation of that feedback:

- Forming a network of specialists through councils of maize experts discussing and deciding the type of deliverables needed in each region and how to conduct the experiments.
- The project has increased awareness of the concepts of EI (i.e., more grain with less environmental impact).
- The GMP is serving as a means to increase maize yield in different regions of the world. Although different experiments target different objectives, increasing maize yield around the world is a critical goal for ecological intensification. Overall, average grain yield increase in EI systems over FP was nearly 1 t/ha. If such an increase were extrapolated to all maize-growing areas of the world, an estimated 160 M t of additional yield would be produced every year, representing about a 15% increase in world production.
- Concepts of EI are serving as examples for researchers working with other crops, like rice, sunflower, cotton, sugarcane, and wheat. For example, scientists at Darwad and Ranchi, India, initiated work in different agro-climatic conditions following the concepts used in the GMP.
- GMP is creating a database of information that leads to improvements in fertilizer recommendations. A clear example is in Africa, where the Kenya Agricultural Research Institute is revising recommendations for maize.
- The project is serving to train students, crop consultants, and farmers around the world. Field experiments in some regions are serving as teaching tools. Field days take place in most GMP experiment sites to transfer what is being learned to those who need the information to improve farming practices. Both graduate and undergraduate students are involved and scientific work related to GMP will provide data for M.Sc. theses and Ph.D. dissertations in many different locations.
- GMP is increasing diversity in crop rotations. For example, in Mato Grosso, Brazil, soil and climatic conditions do not favor accumulation of soil organic matter. Here GMP research is looking into different cropping



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Early sketch of the layout of the Global Maize Project study conducted at the Norman E. Borlaug Experiment Station, Sonora State, México.

systems and testing their abilities to accumulate higher levels of soil organic matter to make the cropping systems more sustainable.

- GMP is facilitating expansion of maize production to some good potential areas. IPNI directors in India and Colombia pointed out this expansion. In India, collaborators claim that the area where maize is cultivated has already increased by 20% and maize is being planted instead of other less profitable crops.
- GMP is providing data that are already being used to create recommendations that are better suited to regions with high risk of insufficient rain. In Muguga, Kenya, GMP results are showing that lower rates of nutrients (about 50% of rates for maximum yields under irrigation) should be applied for higher efficiency under drought conditions, which are common in the region. Also in Kenya, results are raising awareness that more complete crop nutrition is needed, going beyond N and P to include K and micronutrients.
- The credibility of the GMP is increasing and is leading to associations with important key players at the political level. As an example, one of the IPNI directors in China pointed out that the research center in Shijiazhuang was recognized as a state agricultural environmental monitoring station.

It is evident from this survey that there are many benefits that have already emerged from this project that go beyond the specific results of the study itself.

Although we have learned a lot, more is needed. To accomplish economic, production, and environmental objectives, nutrient management will need to be better integrated with other management practices. What this project has demonstrated clearly is that changes to nutrient management practices alone are not sufficient to shift FP to EI. It takes a suite of management practice changes. Projects like the GMP, which make an effort to translate scientific findings into real farming operations, should be intensified wherever possible. The feeling is that although the GMP has proven it possible to significantly increase yields and/or NUE in different agro-ecological scenarios, one of the most important contribution of this project is highlighting that through a simple practical approach of testing what is best in science versus what farmers are actually using in the field, yield gaps can be quantified and approaches can be refined to narrow them. Once proven that a region-specific set of management practices called EI is better than FP, the project should continue to effectively transfer the technology to the field with a goal of closing that yield gap in the future. It cannot get much more practical and objective than this. BC

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References

Food and Agriculture Organization of the United Nations (FAO). 2017. FAOSTAT. Available at http://www.fao.org/faostat/en/#home (verified 14 Apr. 2017).