"Latinoamérica unida protegiendo sus suelos"
XIX CONGRESO LATINOAMERICANO DE LA CIENCIA DEL SUELO
XXIII CONGRESO ARGENTINO DE LA CIENCIA DEL SUELO
Mar del Plata, Argentina – 16 al 20 de abril de 2012
contribuciones@congresodesuelos.org.ar

INTRODUCTION TO ECOLOGICAL INTENSIFICATION AND THE GLOBAL MAIZE PROJECT OF IPNI

Murrell, T. S.[1]
[1]Director, Northcentral U.S. *International Plant Nutrition Institute (IPNI)*. E-mail: smurrell@ipni.net. 1851 Secretariat Dr., West Lafayette, IN, EE.UU.

ABSTRACT

The Global Maize project is an interdisciplinary, international research effort with an overall objective of creating local, ecological intensification practices for maize production that increase yields at a faster pace than current farmer practices. This paper outlines common, general research protocols for the project and discusses the infrastructure that is being developed to ensure data can be appropriately combined from all locations for statistical analyses and model development and calibration.

INTRODUCTION

Ecological intensification (EI) is a term that was developed by Cassman (1999) and defines a production system that satisfies the anticipated increase in food demand while meeting acceptable standards for environmental quality. Unlike past high yield efforts, EI focuses not only on production, but also on profitability, sustainability, and creating a favorable biophysical and social environment.
Production goals for EI are based on potential yield. Potential yield is the "maximum yield that could be reached by a crop in given environments, as determined, for example, by simulation models with plausible physiological and agronomic assumptions" (Evans and Fischer, 1999). A crop growth model that was developed for the express purpose of simulating maize yield potential is Hybrid-Maize (Yang et al., 2004). The goal for production settings is for attainable yield to be within 80% of potential yield.
In 2009, the International Plant Nutrition Institute initiated a project called Global Maize. The Global Maize project is an interdisciplinary, international research effort with an overall objective of creating local, EI practices for maize production that increase yields at a faster pace than current farmer practices (FP). Such improvements are needed to meet demands for environmental improvement and security of feed, fiber, food, and fuel supplies. This paper describes the common elements of the project used at each location.

HYPOTHESES

There are two primary null hypotheses being tested in the Global Maize project for each dependent variable measured:

1. No difference exists between EI and FP treatment means for a given maize crop
2. No difference exists between rates of change in EI and FP treatment means over time

MATERIALS AND METHODS

There are three types of experiments considered by the Global Maize project: A-Sites, B-Sites, and C-Sites. Each one is described below.

A-Sites are locations with experiments that test the two hypotheses listed above. They compare two management system treatments: 1) FP and 2) EI. Both of these treatments are at the whole-plot level. In some locations, additional split-plot treatments are included that are comprised of nitrogen (N) rate and/or timing combinations that allow N response to be quantified.

B-Sites are locations investigating various components of the EI management system but are not directly comparing EI to FP. Practically, these are experiments that already exist at research stations that isolate certain factors to test their impacts on maize production. They are not funded by the Global Maize project, but their information is used to inform the decion-making process of creating the set of management practices used in EI.

C-Sites are locations utilizing omission plots to quantify the relative importance of specific nutrients as they interact with non-limiting levels of other nutrients. The Global Maize project considers the following nutrient combinations in the basic omission plot design: current farmer fertilization practice (FFP); ample N, phosphorus (P) and potassium (K) (or 3 other nutrients known to be limiting at the particular location); ample PK (-N); ample NP (-K); ample NK (-P); and no NPK (nutrient check).

Maize measurements at A-Sites and C-Sites consist of grain yield. A-Sites include additional measurements based on protocols developed for a large on-farm research effort in Asia (Witt et al., 2006). Plant samples comprised of at least 6 whole plants cut at soil level are collected at the R6 growth stage (physiological maturity). Plants are separated into grain, cob, and stover and anayzed for dry matter and nutrient content. Total nutrient uptake of the above-ground dry matter is calculated from the sum of nutrient uptake in each of the three partitions. Grain yield is also measured at harvest from center rows of each experimental unit. Calculations of nutrient use efficiency are based on those enumerated by Snyder and Bruulsema (2007) and include partial factor productivity and partial nutrient balance at all locations. At locations where split plots have been incorporated into the design that contain various N rates including a check (0 N applied), additional efficiency calculations are agronomic efficiency and apparent crop recovery efficiency.

Soil measurements at A-Sites are taken following the protocols developed for GRACEnet, a large, spatially distributed experiment in the U.S. conducted by the Agronomic Research Service of the United States Department of Agriculture (USDA-ARS, 2011). Soil samples are taken at the following depth increments: 0-5, 5-10, and 10-20 cm. Each sample is analyzed for soil organic carbon (C), soil inorganic C, particulate organic matter C, soil bulk density, total N, extractable ammonium N, extractable nitrate-N, extractable phosphorus (P), extractable potassium (K), soil pH (water), electrical conductivity, and particle distribution.

Daily weather data for A-Sites are collected from either instruments onsite or at nearby research stations. Data collected are minimum and maximum temperature, precipitation, total solar radiation, wind speed, and relative humidity.

The Global Maize project currenty has A-Sites in the following countries: Argentina, Brazil, China, Colombia, India, Kenya, Mexico, and the United States. C-Sites exist in these same countries, except for Argentina, Brazil and the United States.

At each A-Site, potential yield, as modeled by Hybrid Maize, is being compared to the yield attained by the EI treatment. The difference is termed the “yield gap” and represents the additional quantity of yield that may reasonably be attained with further management improvements.

DISCUSSION

Results from individual locations in Latin America are provided in the presentations accompanying this introductory paper and will not be discussed here. Instead, this paper focuses on challenges encountered in running a project of this scope and the approaches IPNI is implementing to address them.

The project was initiated under the current staffing structure of IPNI. This structure consists of regional directors and deputy directors who cooperate with scientists in well-defined geographic regions that follow political boundaries. These personnel were and still are responsible for providing some administrative and technical oversight and for identifying scientists willing to participate in the project.

IPNI has not previously attempted to disseminate common research protocols or data standards across its regions. At the initiation of the project, a statistician was contracted who could provide technical guidance on experimental designs. At each center, IPNI staff and cooperating scientists had their own ideas for incorporating A-Site treatments into local experiments. Expertise in experimental designs was therefore needed to ensure that local variations did not compromise the possibility of a meaningful and appropriate conglomerate analysis across all locations. The statistician remains an integral part of the project as the focus of most immediate need shifts from experimental design to statistical analyses.

As the project has progressed, needs for greater technical expertise in specific areas of the project were identifed. This awareness led to the concept of “Technical Leads.” Technical Leads are scientists and technically-trained personnel outside of IPNI who have recognized expertise in certain subject areas essential to the Global Maize project. Currently, Technical Leads exist or are being recruited in three major areas: 1) statistical analysis and modeling, 2) data sharing and standardization, and 3) data collection protocols (Figure 1).

The Global Analysis Group is primarily responsible for conducting appropriate statistical analyses and for running crop simulation models. Needed expertise in statistical analysis has already been discussed. Expertise in modeling is needed to further calibrate Hybrid Maize to the specific conditions encountered at each research location as well as to ensure that the model is being run appropriately. For this reason, a key member of the model’s development team was asked to participate in the project.

The Global Data Group is tasked with data reporting and archiving. This group is still being formed and IPNI is currently bringing together parties with similar needs and interests. Data standards have been used within other research groups and in some cases have been made publicly available (ICASA, 2012). Data standards are needed not only to ensure consistent reporting of data and metadata from the Global Maize project but also to ensure reuse of the data by other interested parties outside of the project. The intent is to make all data publicly available eventually so that others can use them in their investigations. A key part of this effort is data archiving – storing and recording data in such a way that it is accessible and useful in the long-term, as technologies, terminologies, and methodologies change.

The Global Measurements Group has the primary function of ensuing that data collection follows project protocols. If local revisions to the protocol are needed, the Technical Leads in this group can evaluate how or if such revisions affect the data collected and if they can be appropriately merged with data from other locations. Procedural details of each measurement are the focus of this group.

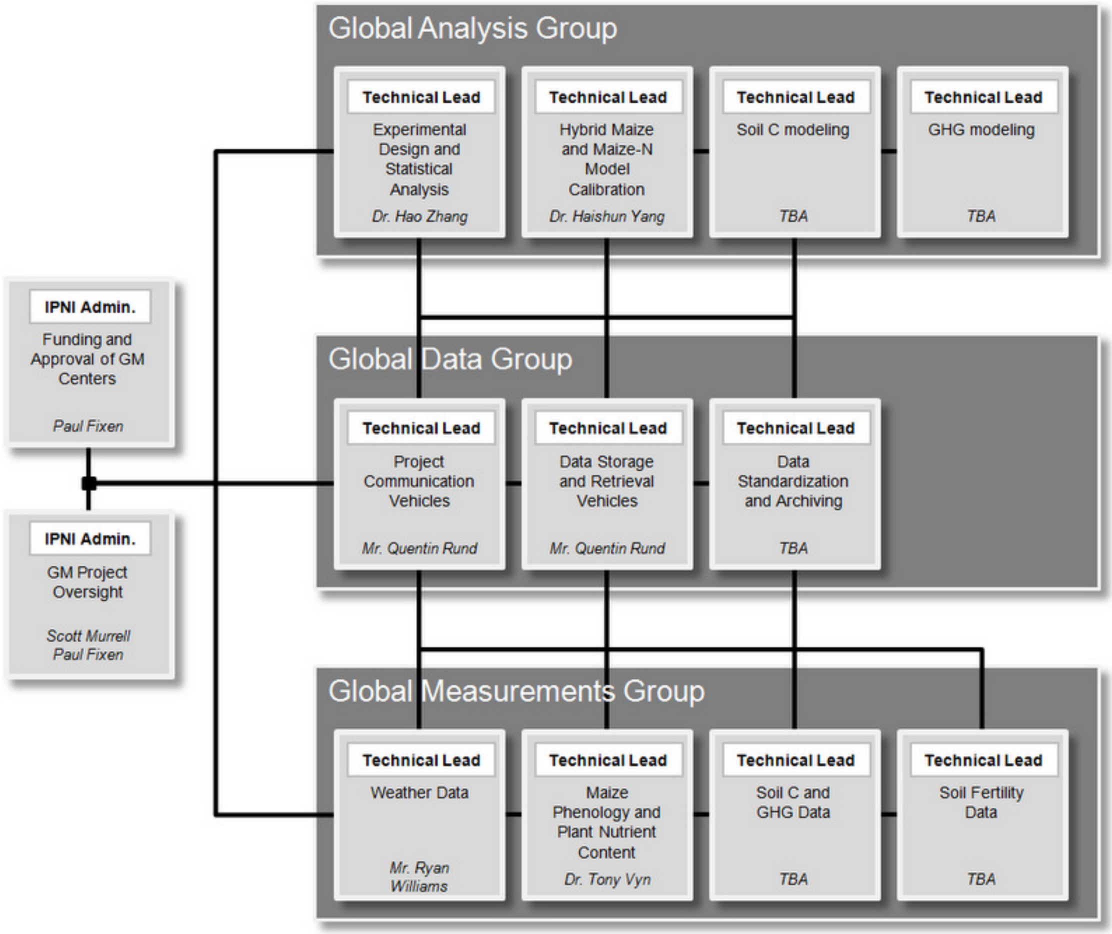

Figure 1. Structure of the technical leads within the IPNI Global Maize project (TBA designates positions that are currently being considered for addition)

Figure 2 shows the overall goal of the combined efforts of these three groups working with IPNI staff and local scientists at each location. Data of appropriate quality are collected and recorded at each center using common protocols. These data are then housed both locally and centrally for access. Data collected in a central location will be curated, using methods developed by the library sciences to ensure data are accessible, understandable, and useable for a long time into the future. These archived data can then be used by others wanting to conduct modeling and statistical research (upscaling), both within as well as external to the Global Maize project. Findings from such analyses can then be used to develop approaches that improve maize management locally. As can be seen from this discussion, the Global Maize project is in the midst of substantial infrastructure development, as are the institutions with which IPNI is partering.

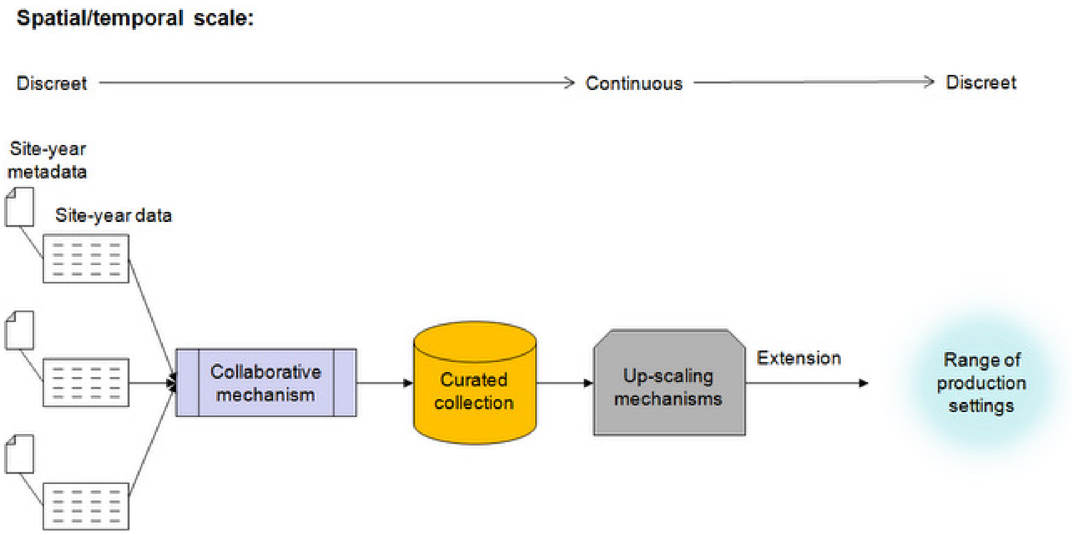

Figure 2. Process model for collection, collaboration, curation, use, and extension of data collected from the IPNI Global Maize project.

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