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Crop management based on field observations: Case studies in sugarcane and coffee

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ABSTRACT

For millennia farmers have continually improved their crop management and production practices through their observations and experience. More recently modern science and research methods based on controlled experiments became the most visible instrument of technological change in agriculture, nevertheless farmers continued to develop and implement new technologies based on their own observations made under commercial conditions. Modern information technology and social organization of producers make it possible to use operational research, which is based on the observation and analysis of operations so as to improve them, to manage crops better. The article describes two cases, coffee and sugarcane, in which observation of the results obtained by farmers, with the natural variation in the environment and the distinct management practices they apply can be used to determine site specific crop management practices. The basis of the methodology is to (a) obtain data from a series of cropping events that characterizes the conditions under which each crop is grown, how it is managed and how it performs under commercial conditions (*data capture*), (b) to manage and analyze the data in centralized databases (*data management and analysis*) and (c) make the information derived from the data analysis available to growers so that they can use it to make better informed decisions (*interpretation*). All aspects of the methodology depend on the *social organization* of the growers and the supply chain of which they form a part, and hence social organization is an integral part of the methodology.

The processes of characterization of the growing conditions, including both environmental and management parameters, the establishment of databases, the data analysis and interpretation, and mechanisms of interacting with producers are described with emphasis on the importance of social organization and farmers' groups. Examples are given of how this approach can be used to better understand the crop response to variation in the environment and management, and how this can be used by farmers to improve productivity and quality in two contrasting crops. The paper demonstrates that operational research can be used to evaluate farmers' experiences and to share that knowledge amongst them so as to improve their production practices in the context of their particular environment. It is suggested that the operation research approach is particularly effective in heterogeneous landscapes with perennial crops that have not been the subject of intense research. Furthermore operational research is effective in determining the crop response to variables that are not readily studied in small plots and in determining optimal combinations of multiple variables. Producers believe in the results obtained as there are none of the problems of scaling up from experimental plots to commercial conditions. It is proposed that the approaches described can readily be applied to other crop species.

1. Introduction

Since the first attempts by man to plant crops and domesticate livestock farmers have experimented, trying out new approaches

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to manage their crops and fields. Observations by farmers formed the basis for innovation in agriculture, with farmers selecting practices and technologies suitable for their particular conditions. From the middle of the 19th century modern science was increasingly applied to agriculture and the linear model, based on scientific research as the main driver, became increasingly important (Chambers and Ghildyal, 1985; Thompson and Scoones, 1994; Russell and Ison, 2000; Altieri, 2002; Marsh and Pannell, 2000). However, Hall (2005) and Hall and Dijkman (2006) have pointed out that innovation is an iterative and evolving process involving interactions of many individuals and organizations possessing different types of knowledge in an innovation system, of which the linear model is a part. The innovation system brings together a wide range of actors and their knowledge in varied contexts and provides a framework for adapting to the rapidly changing conditions of contemporary agriculture (World Bank, 2006; Hall, 2005; Hall and Dijkman, 2006).

In the linear model technology was largely derived from a large number of controlled experiments (Pretty, 1991) with each experiment observing the response to variation in a small number of factors with all others being controlled. Researchers identified homogeneous areas or recommendation domains where standard recommendations suitable for mega environments could be used for large relatively uniform areas (see for example Cock, 1985; Gauch and Zobel, 1997; Braun et al., 1996). This model led to the development of genetically improved varieties and improved crop management that in turn contributed to the substantial increase in the productivity of almost all the crops of major importance in the world (see for example Evans and Fischer, 1999; Hall, 2005).The major gains have been made in those crops which are sufficiently important to be the subject of heavy investment in research in the linear model. Furthermore, it appears that whilst initial gains can be made by using broadly adapted technologies and blanket recommendations developed within the framework of the linear model, later improvements depend on site specific technology or precision management (Evenson, 1981; Cassman, 1999; Cock, 2000; Isaacs et al., 2007).

Within the innovation systems concept, there are immense opportunities to apply operational research principles coupled with techniques from precision agriculture, to complement the linear model, with particular reference to adapting technologies to the idiosyncrasies of specific sites and conditions and in those crops which are neither grown in relatively homogeneous conditions nor subject to intense research. Operational research looks at an organization's operations and uses mathematical or computer models, or other analytical approaches, to find better ways of doing them (Operational Research Society, 2006). The operational research approach is similar to that of precision agriculture, defined by the National Research Council of the United States of America (NRC, 1997) as a management strategy that uses information technologies to bring data from multiple sources to bear on decisions associated with crop production.

Farmers face a plethora of changing conditions to which they continually react making adjustments in their practices (Thompson and Scoones, 1994). Every time a farmer prepares a field, plants and manages a crop, he observes and experiments a unique set of conditions. However, the limited range of variation that each individual farmer, or researcher, observes coupled with random effects make it difficult for them to make sense of their observations. Our hypothesis is that an operational research approach coupled with modern information technology now makes it possible to record and characterize a sufficiently large number of these unique events, or experiments, and to use that information to describe and predict the crop responses to variations in the environment and management.

Variation in growing conditions due to natural variation, variation in commercial management practices or carefully designed trials of innovative management practices can be exploited in an operational research approach to provide insights into crop response to varying conditions. Information collected by producers themselves, or researchers, on crop performance under a large number of specific, but well characterized, circumstances coupled with modern information technology can be used to relate crop performance and quality to specific growing conditions and management practices. This information can then provide farmers with information that assists them in decision making.

Operational research and precision agriculture are attractive as they avoid the need to establish and manage the large number of costly experiments that would be required to evaluate multiple factors under highly heterogeneous growing conditions using the linear research model. Furthermore, as the results are based on commercial production there is no need to validate the results commercially: there is no problem of scaling up from small, researcher managed plots. However, it is not possible to directly apply operational research approaches, developed for well controlled industrial processes, to agriculture: the basic principles are maintained but the process has to be adapted to the idiosyncrasies of agriculture.

In order to apply operational research methods to agriculture it is necessary to take into account the variation in both space and time of the production conditions as well as the variation in management practices. The approach described here builds on the experiences in precision agriculture, or site specific management, which is largely based on the principles of observation of the crop response to spatial and temporal variation. Precision agriculture can be applied to a whole field or lot, or to particular spots within a field (NRC, 1997), however, recently it has largely been applied at the within field level (see for example Basso et al., 2001). Plant (2001) categorically states that "Site-specific management (also called, precision agriculture) is the management of agricultural crops at a spatial scale smaller than that of the whole field." However, there is a need for technology which is adapted to the field or relatively homogeneous management units before moving to more precise precision agriculture (Cassman, 1999; Spaans and Estrada, 2004). In the tropical developing world most crops are still at a stage of development where it is more important to define the management at the field level than to refine the management at the within field level.

In precision agriculture at the within field level, the spatial variation is normally related to one single factor such as soil characteristics or localized outbreaks of pests: management and weather conditions are assumed to be constant over the whole field or management unit. They vary on a larger scale than the field or management unit and are not taken into account when analyzing within field variations in crop response. The natural conditions of management units are typically homogeneous in terms of, soil, topography, and weather. Depending on the technical infrastructure, a management unit can be part of a field, a single individual field, a group of fields, or a complete small farm (Morlat and Bodin, 2006).

When variation is observed for management units dispersed over larger distances, and over time differences, as opposed to within field variation, many more variables enter into the equation with climate and weather variation becoming of paramount importance. Furthermore there are numerous different ways of analyzing the information in terms of crop response to the multiple variables associated with each management unit.

For each management unit we have adopted what we denominate as a cropping event as the unit of analysis. A cropping event occurs in a particular site within a given period of time. It is normally taken as the period between planting and harvest, or as the period between one harvest and the next in crops which are not replanted after each harvest. In order to rigorously analyze