Is precision agriculture irrelevant to developing countries?

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Abstract

A commonly stated reason for low adoption rates of precision agriculture (PA) is that its benefits are insufficient to justify the costs. Ostensibly, this seems to preclude any possibility of PA in developing countries, where profitability is much lower than in developed economies, and where there is only localised prospect of supporting high technology. We question this assertion, and postulate that the basic purpose of PA - to provide spatial information to reduce the uncertainty - far from being a luxury, could be viewed as essential to accelerate change in the developing world, even if it is used in a different form to that offered in Europe or North America.

Using examples from Latin America and elsewhere, we examine this question in relation to three key topics: The value of information, or conversely, the cost of ignorance; the reality of providing information to decision-makers and the comparison between PA in the developed and developing world.

From the description of site-specific activities it is obvious that although PA - *as seen* in Europe and North America - is largely irrelevant in developing countries, the need for spatial information is actually greater, principally because of stronger imperative for change and lack of conventional support. The acquisition and interpretation of spatial information in developing countries is a major impediment to progress, and here, we suggest alternatives to expensive data-gathering technology which build on available information at regional and local scale. Such methods would eliminate the opportunities for technology suppliers, who have been key to much of the progress of PA in the developed world, so we propose an organizational structure which could implement change without these actors.

Keywords: Developing agriculture, poverty alleviation, decision-support.

Introduction

A commonly stated reason for low adoption of precision agriculture is that its cost outweighs its perceived benefit. The typical image of precision agriculture is of an intensive crop management system, served by high technology. This contrasts strongly with the image of developing agriculture as a low- or no-technology activity, undertaken by subsistence farmers with minimal resources. The two images appear to be diametrically opposed. While there are a few known cases of precision agriculture (e.g. bananas in Costa Rica, oil palm in Malaysia, rice in the Philippines) ostensibly, precision agriculture seems irrelevant to people in the developing world, who rely on subsistence and cash cropping.

We question the assertion that PA has nothing to offer the developing world. While the information technology that lies at the heart of PA is clearly unattainable and inappropriate to all but a few farmers in the developing world, the principles of using spatial information to reduce uncertainty in a rapidly changing world has much to offer. Indeed some of the principles within PA may prove essential to the sustainability of agriculture in the face of increasing pressures from agriculture in developed countries.

We examine this argument in two parts: First, we identify the potential value of spatial information to developing agriculture, through the cost of errors which arise through decision-making in ignorance. Second, we assess the reality of providing spatial information in developing countries.

The value of spatial information in developing agriculture

The value of information is in the improved decisions it enables. Such decisions avoid two sorts of mistakes, which we call here type I and type II errors (Figure 1). A type I error occurs when a farmer fails to act in a way which is of potential benefit, for example, by failing to change when she or he should have. A type II error occurs when a farmer does something that is harmful, or at least non-beneficial; for example, planting a crop which proves to be unprofitable; cultivating in a way which results in erosion; or cutting down trees which provide long-term value. Many examples exist of type II errors which occur because actions which provide short term or local gains create long term or broader range problems. All farmers wish to avoid these errors, yet errors persist because farmers are unaware or uncertain that they will occur. In some cases, they may be forced to detrimental action through economic constraints.

Quantifying the value of information is difficult. It requires an assessment of the 'ideal' decision which can be made, given perfect insight of the outcome, and its difference between the decision which is made without this information. A pragmatic alternative to actual measurement is to realize that a uniform decision which fails to recognise actual variation introduces error.

Farmers have the reputation for making type I errors due to risk aversion (Antle, 1987, Kingwell, 1994), a characteristic that is associated with low real growth rates as the world around them changes faster than they do. While it is logical to assume that farmers with virtually no financial assets have to be extremely careful to avoid 'taking the wrong step' (most farmers in the developing world exist on less than $2 /day), there is increasing evidence to question this generalization of risk aversion (Henrich and McElreath, 2002). Information that identifies areas of certain opportunity reduces type I errors. Further, anecdotal experience from the thousands of agricultural micro-credit schemes suggests that poor farmers can be surprisingly quick to change, once they are presented with the opportunity.

Type II errors occur on a massive scale in the developing world, as witnessed by the severe environmental effects of land use change in a poorly buffered environment. Many examples exist of the type II error in agricultural development, both of which were based on insufficient information about the likely effects (see, for example Dent and Young, 1981).

	Benefit occurs	No benefit occurs
Act	Correct action	Type II error. Loss caused
Don't act	Type I Error. Lost opportunity.	Correct inaction

Figure 1. Type I and II errors

PA offers benefit to this process through the ability to make site-specific decisions – at a range of scales. While the term 'precision agriculture' seems inappropriate in developing countries, 'site-specific agriculture' does not, and it is this that we use largely here. Site specific information reduces the chance of errors caused by generalization within areas which are significantly variable. For example – the knowledge that fertilizer should be applied to one location but not another; the decision that a cropping system variety is suitable for one area, but not another; or the knowledge that markets can be accessed from one area but not another. Such targeting of change can have a significant impact.

How can spatial information be delivered in developing countries?

Clearly, very few farmers in developing countries can consider the technology used for PA in Europe and North America and alternative pathways are required to influence change. Spatial information technology is being targeted – at a range of scales- to try and counter the so-called digital divide (Analysys, 2000). Agriculture remains the mainstay of livelihoods of people in developing economies, so the emphasis is on more productive, sustainable and equitable land use. However, somewhat parallel developments are being pursued in medicine to provide support to poor regions through the internet (Fraser, 2000).

At a regional and national level, several donor-funded programs aim to improve strategic planning through better provision of spatial information to government departments. The decision-makers at this scale are normally national ministries or equivalent organizations, who require information to maximize the benefit of strategic investments in infrastructure, hazard protection or land reform. Examples include the recent World Bank funded project in Latin America aimed to establish a platform of GIS (WorldBank, 2002). It is easy to underestimate the benefit of information in enabling institutions to operate effectively. The degree of effectiveness of institutions is regarded by some economists as the sole significant factor which determines development in tropical regions (Easterly and Levine, 2002). Improving information and knowledge management systems is the first stated objective of a USAID strategy for improved management of natural resources in Africa (USAID, 2002).

A large body of spatial information exists in the developing world, much of it freely available. The challenge lies in overcoming issues of scale and uncertainty, and finding meaningful ways of delivering this information to farmers. A more accessible approach for farmers is to create their own local spatial data at appropriate scales.

Even without external assistance, commodity groups can organize themselves to use spatial information for site specific management. In Colombia, for example, the value of site-specific agriculture has been recognised for some time by sugar cane growers. Yields and inputs are recorded for individual blocks of sugar cane – still largely harvested by hand – and fertilizer recommendations modified accordingly. All records are geo-referenced and spatial trends analysed to respond to queries from individual growers (CENICANA, 2001). This contrasts, for example, with the non-site specific recommendations still used by sugar cane industries in Australia (Bramley and Quabba, 2002). Oil palm growers in Colombia are considering to geo-reference single trees and monitor oil production. Oil palms often produce for more than 25 years establishing the ideal situation for simple to implement spatio-temporal explicit management schemes.

Site-specific natural resource management at catchment and community scale has seen a substantial increase through the use of participative research methods (Hinchcliffe *et al.*, 1999). These methods aim – somewhat belatedly perhaps – to recognize the wealth of local experience about natural resources and capture it in the process of monitoring and planning natural resources, which are viewed predominantly as a collective resource. The most difficult stage of the process is for farmers' to structure and visualize their own knowledge about the natural resource. Not surprisingly, this is often expressed as maps or other spatially explicit diagrams.

Even without physical maps or diagrams, farmers in the developing world can still apply site-specific concepts. Many smallholder farmers often own such a small amount of land that it is possible to have mental maps of for example soil variability, and vary management accordingly.

Two other features of local site-specific development that are gaining usage may be of interest. The first is the use of participatory three-dimensional mapping (P3DM). Instead of yield map, this uses a terrain model as the basic information source, generated by the local community itself. Like yield maps, 3-dimensional terrain models – in both physical and virtual forms- present a framework of spatial information that is intrinsically meaningful to farmers and scientists alike (CIAT, 2002). Both groups find it easy to locate and distribute features on 3-D terrain models, which also provide quantifiable objective measures. Farmers of the Poterillo catchment in Colombia's Cauca Department were for example able to identify and locate in a 1:3000 P3D model, road crossings and their farm houses with relatively small average accuracy errors of 98 m and 46 m, respectively. Work in the Philippines has shown that the vertical accuracy of community generated P3DM often reproduces that of conventional topographic maps (http://www.iapad.org/).

The final detailed example of low-cost site-specific agriculture is kite- and balloon based aerial photography (CIAT, 2002). Priced low enough for extension workers, farmer-research groups or the growers of cash crops such as sugar cane, oil palm and bananas to deliver, this source of information promises rapid, objective spatially explicit data for estimating yields of on-farm crop trials, identify indicator plants in fallow systems, pin-point pest and water stress hot-spots which can be used by farmer groups. The information is delivered directly into the hands of the farmer groups. Additionally, this information can be further analyzed and quantified by scientists to generate answers to specific management questions that are not easily obtainable from the images by the farmers. As topography in P3DM, colour provides a common, spatially explicit language for farmers and scientists to communicate.

Conclusions

Precision agriculture in developed countries is growing out of a need to manage variation of natural resources more effectively to satisfy internal demands to meet economic and environmental standards of production. In developing agriculture, site-specific information is more about supporting livelihood systems against external pressures, and demands information at virtually all scales. Considerable evidence exists that farmers identify and use variation at scales relevant for management. But increasing land degradation suggests that locally devised methods, on their own, are no longer effective enough to cope with rapidly changing pressures on farmers. Farmers possess a vast body of knowledge about environmental resources on their farms but this knowledge is largely based on observable features rather than generalized knowledge. The lack of process-based knowledge concerning agro-ecosystem function creates uncertainty that obstructs sound decision-making under conditions of change. This creates opportunities for successful application of principles of spatial information to manage variation thereby increasing the efficiency of local knowledge.

The means of acquiring and communicating spatial information is different in the two situations. In developing agriculture, there remains a demand for broad scale information for strategic planning at regional or national scale. At local level, severe cost constraints and virtual absence of mechanization prevent the use of in-field monitors but here the emphasis is on capturing and applying local knowledge of the farmers themselves to reduce uncertainty. For example small-scale farmers do not have access to modern monitoring techniques but they do possess long time-series understanding of relations at distinct locations that has been generated through repeated observations. These accumulated observations can be related to relevant scientific information providing opportunities for the development of spatially explicit management.

There are likely to be two thrusts for the application precision agricultural principles in developing countries: On one hand are the traditional small-holder crops exemplified by coffee that in the past have sustained the livelihoods of millions of small-scale farmers, but are currently in crisis. Here the focus is on identifying the best production hot spots and their management. Another option is to complement these with in less suitable spots with other crops, such as forages, that enable farmers to diversify their cropping portfolio. On the other hand there are new (export) crops such as fresh fruits, cotton, oil palm or banana / plantain, the implementation of which is likely to be impacted by growing concern at local and export markets regarding growing practices, product quality and product traceability. Here precision agricultural principles using spatial information will be applied to comply with consumer quality demands.

In both developed and developing countries, the demand is for more informed activities to reduce the uncertainties of decisions. In both situations, information has potential value to reduce the likelihood of decision errors. In both, the information has no value until it reduces errors through better decisions.

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