DEVELOPING THE PRINCIPLES OF PRECISION FARMING

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ABSTRACT

Precision farming is now having an impact on agriculture throughout the world. It is clear that the underlying principles remain the same but the implementation changes between crops and countries. This paper sets out to identify the underlying principles of Precision Farming to enable researchers and practitioners to adapt them for their own conditions.

Keywords: Precision Farming, Precision Agriculture.

1. INTRODUCTION

Precision Farming is defined by the author as the management of arable variability to improve the economic benefit and reduce environmental impact. This definition serves a two-fold purpose. Firstly, it identifies management of variability as the essential factor and not technology as many people seem to believe. Secondly, it identifies the drivers for changing the existing systems, improving the economic returns while reducing the impact of management practices on the environment. Both of these drivers work in the same way to improve the efficiency of the agricultural process. The way in which these drivers are implemented changes between different crops and different countries. Underlying these different implementations are the principles that apply universally.

2. A SYSTEMS APPROACH

Precision Farming (PF) is a systems approach to managing crops and land selectively, according to their needs. It utilizes expertise from many disciplines and integrates the latest information technology tools and techniques to enable farm managers to get a better understanding and control of their fields. Management is the essential factor to achieve a stated outcome for the farm. Managers should identify their own strategies and practices that allow them to deal effectively with the variability found on their farm.
Three types of variability have been identified. The first type is spatial variability, which can be seen as changes across the field. An example would be where one side of the field yields higher than the other side. Temporal variability is identified when parameters change over time. This can be seen when a crop starts by growing well but results in a poor yield.
Predictive variability, is the difference between what the manager predicted would happen and what actually happened. The classical example of predictive variability is where the manager predicts that a certain yield will be achieved if a certain amount of fertilizer is applied, but the crop does not achieve it because the weather changes. Each type of variability must be measured, assessed and possibly influenced, according to how significant it is.

3. MEASURING VARIABILITY

The first stage in the process is to measure important factors that indicate or affect the efficiency of the growing crop. The two main approaches are to create yield maps through instrumenting the harvesting system or assessing soil parameters by sampling. Both techniques give information about different parts of the cropping system. Yield maps are historic and cannot be used while the crop is growing, but record the actual yield during harvest. Soil sampling can be expensive but many soil parameters such as texture and horizon depths do not change over time, so are a good investment. Measuring soil nutrient status must be treated with care as repeatability, let alone accuracy, is difficult to achieve. Sampling strategies based on a simple grid tend to be expensive and better-targeted sampling techniques are being developed [1]. Asset surveys can also be carried out to record physical features, such as field and crop boundaries, high trees that may cause shading, compaction in gateways, etc. Other high-density measurement techniques are rapidly becoming more important such as Remote Sensing and ADP (Aerial Digital Photography) or non-contact sensing (e.g. Electro-magnetic induction). ADP can give real-time information of the crop canopy and allow management to be modified while the crop is growing.

4. Assessing the Significance of Variability

Once the variability has been measured, it must be assessed to see how significant it is to the manager. Normally this is done by looking at the spread of the histogram or seeing if the extreme values lie outside acceptable thresholds, such as indices for soil nutrients. One technique is to reclassify yield data into 'gross margin' maps [2]. See Fig. 1. This technique deducts the variable costs from the income, which varies spatially with the yield, resulting in a gross margin map that shows which areas generated more income than others. Some gross margin maps have shown areas that actually loose money. Given enough detail, a similar map based on inputs could be produced to show environmental impact such as nitrogen fertilizers in a nitrate sensitive area.

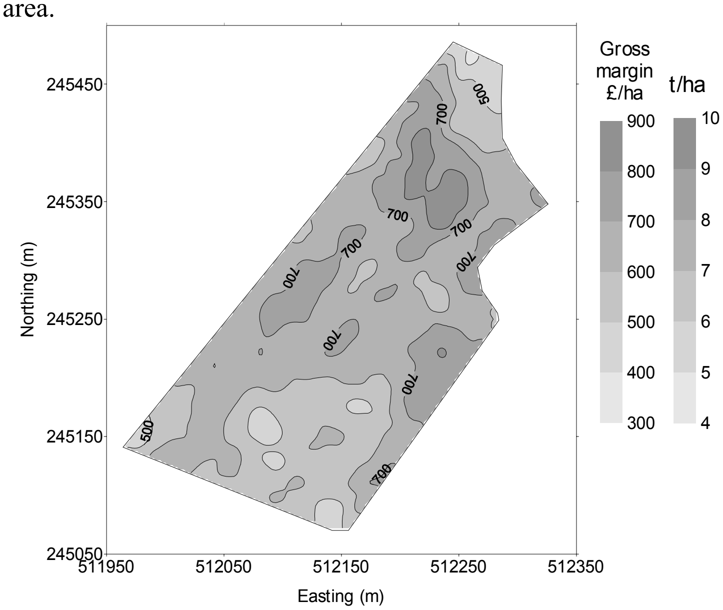

Fig. 1. Gross margin map with yield scale (1GBP=1.6USD)

5. Management of Inputs

Most traditional systems over-apply inputs such as seed, spray and fertilizer to reduce the risk of crop failure. With better assessment techniques, the inputs can be reduced or redistributed to optimal levels and the risk of failure can be managed. This will result in making the system more efficient.

Regardless of the country and crop, management of an agricultural system is complex. To improve the efficiency, computer based Management Information Systems (MIS) must be sophisticated enough to deal with this complexity and the manager's strategies and practices [3]. The management input and computing support is the same in each country and each crop. Some crops may well have special considerations that should be taken into account when designing the MIS, such as planning the harvesting logistics when supplying crop to a processing factory.

The size of the management unit in the treatment map depends on the ability to measure and manage it. Although a DGPS may be accurate to within one metre, a combine header may be ten meters wide, and the spreader width may be 24 meters. The management unit will be limited by the spreader but the area of understanding what is causing the variability is likely to be even larger.

A draft methodology for dealing with in-field variability has been proposed [4].

6. EXAMPLES OF PRECISION FARMING

Cereals in Northern Europe and North America and Australia

The crops tend to be cereals grown in rotation with break crops and are in relatively large unstructured fields. In the UK, inputs are very intensive with the expectation of high yielding crops (7-8 t/ha.). North America tends to be less intensive and Australia has extensive areas with little input and smaller yields (2-3 t/ha.). Harvesting is carried out by large combine harvesters and yield maps are produced by fitting the combine with a DGPS and yield monitor. Field inputs are applied by large applicators with various levels of automatic control. A number of commercially available systems can now accept digital application maps in conjunction with a DGPS and change their rates in real time.
The main driver for Precision Farming in this system seems to be economic pressure although there are mounting environmental concerns that may force the development.

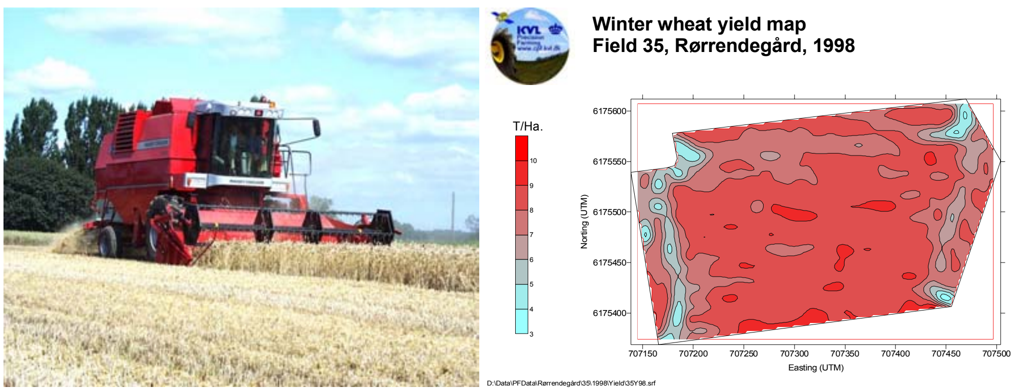

Figure 1. Yield mapping combine and resulting yield map

Tea in Tanzania and Sri Lanka

Tea is a highly structured crop grown in blocks in seven-year cycles [5]. Once each block has been properly surveyed and uniquely identified, positioning systems (such as DGPS) are not required. Yield maps are produced by recording the weight of tea plucked, (and by whom, for payment purposes) as well as which block it came from. Inputs are also applied by hand, and the treatment map is implemented by dividing the workforce into different teams that apply the desired amount in each area. There are special logistical considerations to be taken into account with tea, such as balancing the quality and quantity of the leaves entering the factory.
The cost of implementation in this system is very low because of the highly structured fields and much of the recording system was already in place. The highly flexible workforce allowed quick and simple implementation. This is one of the best examples of Precision Farming.

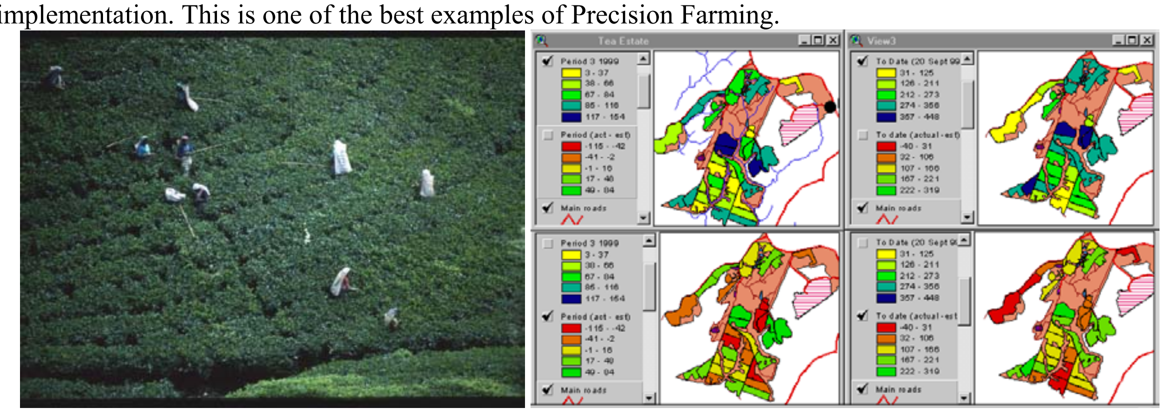

Figure 2. Tea harvesting by hand and estate yield maps

Paddy rice in Japan and Korea

Paddy rice is a very intensive crop, in terms of both inputs and labour [6]. The fields are relatively small (less than 1ha.), flood irrigated and highly productive (6-7 t/ha). Most managers are also owners and know their fields intimately. Asian culture has a high regard for technology and most farms are already highly mechanized. Yield maps can be produced by fitting DGPS and yield monitors to the small efficient, head feeding combines. The optimum size for the treatment unit may be the current field or it may prove to be something smaller. Treatment maps can be implemented by applying spatially variable controllers to existing equipment.
As the Japanese farmer operates within a protected market (getting five times the world price for the rice), the main driver for PF is environmental protection.

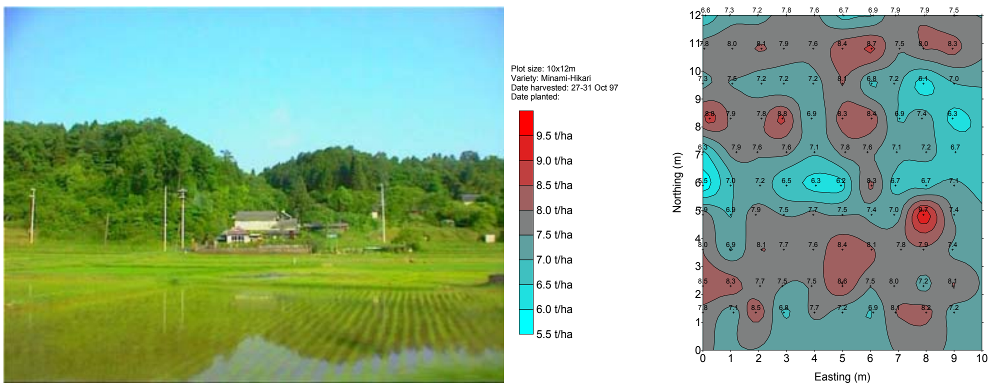

Figure 3. Japanese paddy field and yield map from Kyoto University

Dates in Iran and Saudi Arabia

Dates are a high value, culturally important crop in many Arab countries [7], [8]. Many date groves are well established and, like tea, are highly structured. Once the trees have been surveyed and uniquely labeled, yield maps could be produced by recording the amount and quality of dates from each tree. Again, no extra cost is incurred apart from recording this information at the time of harvest. Treatment areas could well be blocks and performance of individual trees could be monitored. Traditionally, fertilizer is applied by hand and can therefor be easily adapted to being varied spatially.
A special consideration is that there are consistent labour shortages due to the dangers involved in climbing the trees and the cultural importance of the dates may outweigh the economics.

Figure 4. Date palm being harvested by hand

7. CONCLUSIONS

This paper set out to investigate the similarities between different farming systems and identify the common underlying principles involved with Precision Farming. In all systems the following points were considered:

1. Precision Farming is a management process, not a technology.
2. Measure the spatial and temporal variability
3. Assess the significance of the variability in both economic and environmental terms
4. State the required outcome for the crop and the farm.
5. Consider the special requirements of the crop and the country
6. Establish ways to manage the variability to achieve the stated outcome
7. Consider methods to reduce or redistribute the inputs and assess the risk of failure
8. Treat crops and soil selectively according to their needs

Once these factors have been considered, researchers and farmers must adapt them to suit their own conditions

8. REFERENCES

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