PRECISION FARMING:
THE USE OF TECHNOLOGY FOR MORE EFFICIENT PRODUCTION

Peter C Rüsch*, PrEng, MSAIAE, MWISA

VKE Engineers, PO Box 72927
Lynnwood Ridge, 0040

ABSTRACT

Precision Farming is by far the most exciting new agricultural technology developed during the past decade, and although technology transfer is especially difficult in agriculture for a number of reasons, this technology has survived its initial stages of implementation. Historically field boundaries were often along natural soil boundaries, leading to small fields, which were treated homogenously. As agricultural machinery was developed and grew ever larger, fields were often combined to allow for more efficient cultivation. As result, fields with varying properties were created resulting in inefficiencies. Precision Farming was developed to overcome this problem. In this paper some results of initial research undertaken in South Africa under a variety of circumstances will be shown.

Key words: Precision Farming, varying yields, efficient production.

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1. INTRODUCTION

Technology, defined by Galbraith (Walker, 1987) as ***the systematic application of scientific or other organised knowledge to practical tasks*** was instrumental in the making of precision farming.

Over the past 30 or so years farm machinery was perfected. Tractors were developed where the operator could work for hours on end in the comfort of a modern, noise dampened cabin, soil engaging implements were developed to cultivate the ground to a predefined depth, fertiliser spreaders and sprayers can deposit chemicals were they were needed most. Combine harvesters were developed which could harvest these crops at sub 1% losses in almost any terrain, or circumstances.

Somehow market forces, and technical innovation led to machinery sizes growing (as any sales statistic will demonstrate), and with the consolidation of farms leading to larger and larger farms and thus fields, this advance in technology created a new set of problems and challenges. This was because field boundaries which were drawn naturally along different soil types, disappeared (Moore, 1998)

In the early 1980's (Moore, 1998a) research undertaken by Massey Ferguson UK, in collaboration with Dronningborg (the manufacturers of Massey Ferguson combines in Denmark) tried to proof differences in the yield across a field, and if, how large these differences were. This research directly led to precision farming as it is known today.

2. PRINCIPLES OF PRECISION FARMING

Precision Farming is a process where a large field is divided into a finite number of sub-fields, allowing variation of inputs in accordance with the data gathered. Ideally this will allow maximisation of return on investment, whilst minimising the associated risks and environmental damage. The German (Profi, 1998) term for precision farming, 'Teilflächenwirtschaft' is far more descriptive of this process.

Figure 1 illustrates the processes involved in the precision farming system (Massey Ferguson, 1996). From this diagram it is evident that a number of processes are needed to have a complete Precision Farming system.

2.1 Factors affecting yield

There are a number of factors, which determine the yield of a particular crop on a particular field, these are:

2.1.1 Weather (no control)

With a climate as variable as the South African one, and little predictability as to how the season will turn out, the weather may have a profound impact on both the quantity and quality of the yield. However, as input into the precision farming system, the climate can be analysed, and can be grouped into a number of possible typical seasons, for use in precision farming systems.

2.1.2 Soil (little or no control)

The farmer has only limited control over the soil, for example, he cannot change the inherent fertility of his soil such as the soil structure, likelihood of water logging, but he has some control over the fertility status he can achieve. For example, the farmer, for a particular field cannot choose if the soil is a Hutton or a Katspruit, but within limits, he can achieve a higher fertility status by conserving humus and correcting nutrient status.

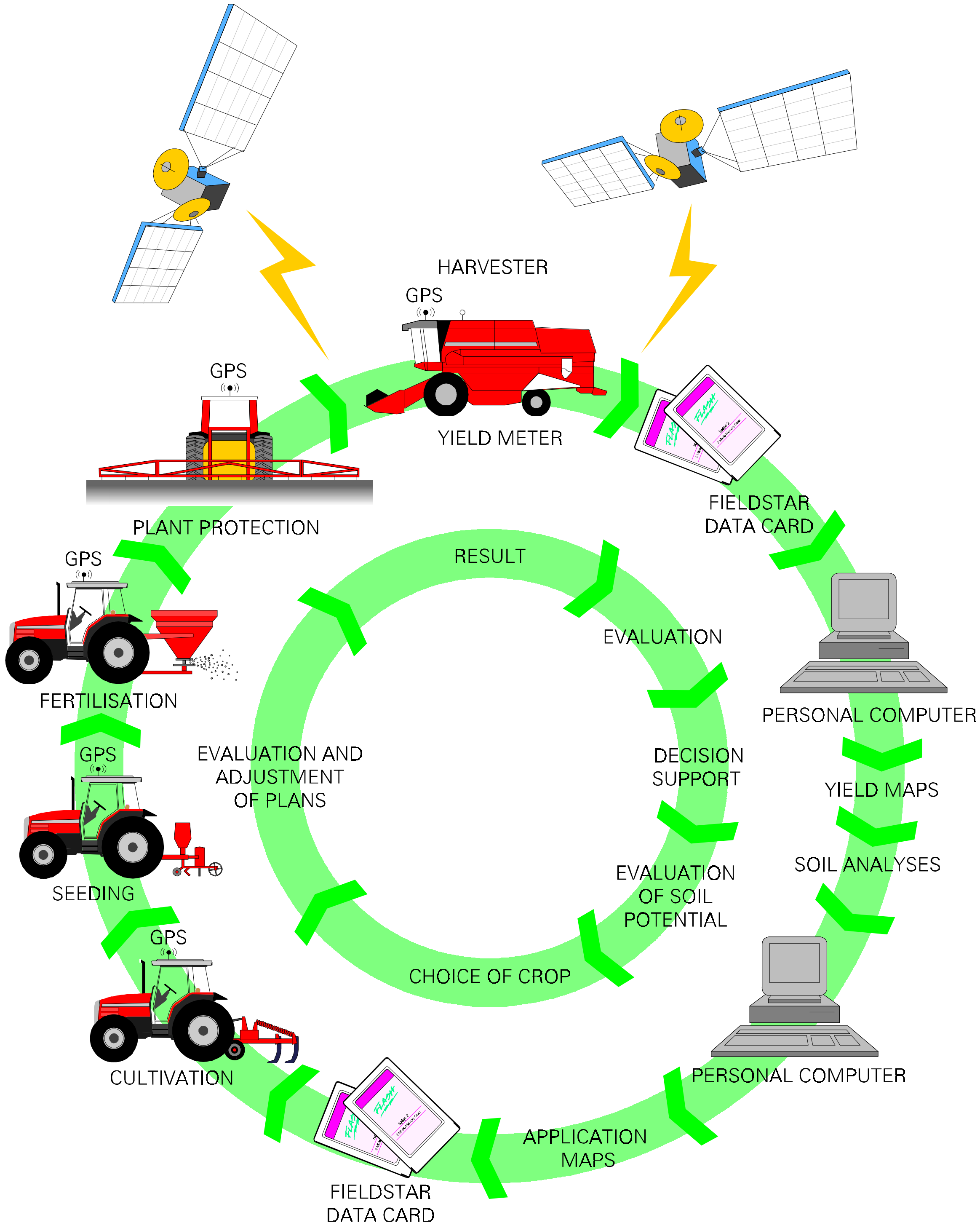


fig. 1: Precision Farming Circle

2.1.3 Husbandry (full control)

The farmer has full control over the husbandry of his crops. He can choose whatever he prefers to plant on his fields, and how he prefers to treat the individual crops for the conditions he may encounter. Although he is bound by inter-dependencies as to how he can treat the crops, these are known prior to committing a field to a particular crop. He has furthermore full control over the methods used, the timing and efficiencies of application.

2.1.4 Plant (full control)

The farmer has full control over his crop choices. He can choose between crop such as sunflower and maize, and for a particular crop he can also choose a particular variety suited to his particular circumstances. For a particular crop he can also choose row spacing, and intra-row spacing. He can also plan crop rotation to suit his overall farm management, and circumstances.

The interrelationship between these factors may be depicted as in figure 2, adapted from Moore, 1998:

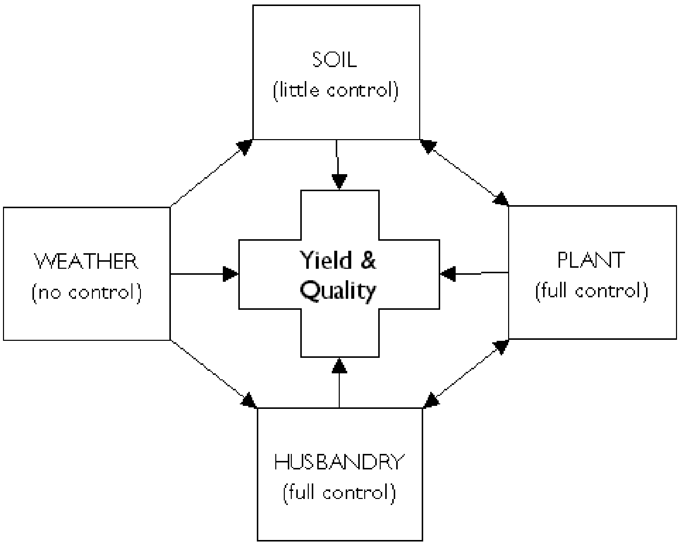


fig. 2: Factors affecting yield and quality

These interrelationships depict the influence these various factors have upon each other, e.g.:

- The plant chosen the previous season may have an influence on the fertility status of the soil, for follow on crops
- The weather of a particular season will have an influence on both the soil and the husbandry
- The husbandry may have an influence on the soil and plant for the next season

2.2 Factors affecting farming strategies

The farmer, when making decisions in his day to day running of the farm takes the above factors into account, as well as other influences on these decisions, such as:

- Personal Strategies (such maximum profit vs. maximum yield…)
- External influences (such political, estimated crops elsewhere, environmental, stocks, futures etc…)
- Local knowledge

A farmer who gathered information from his operation, related these to the weather patterns for a particular season, and taking pests and diseases into account, has been able to make fair predictions of the yield potential for a particular field in his given climatic conditions. He then utilised this predicted potential in combination with all of the above factors to work his fields. After another harvest the farmer readjusted the potential of a field.

In doing so the farmer treated every part of a particular field evenly, usually taking one or two soil samples per field per season to assist him in his decisions. Some farmers even treated whole farms (Free State Farmer, 1999) as one unit, even when fields were as far as 20 km apart, and most of the yield affecting factors differed widely.

He effectively ignored the in-field differences, even when he knew about them, because ***no technology existed to geo reference or to quantify these.*** This has, with the development of precision farming changed.

3. COMPONENTS OF A PRECISION FARMING SYSTEM

A precision farming systems has two types of components, the technical system needed to collect data and to apply inputs at a variable rate across a field. Typical technical parts are data loggers, a real time differentially corrected positioning system, measuring sensors, various job computers, as well as a user interface.

On European systems all these technical components work to a practical implementation of DIN 9684 (Marquering, 1997). This Code of Practice ensures compatibility of systems from various manufacturers. These systems are so-called open systems, as one is supposed to mix and match as required.

Some American systems were closed systems; these were therefore only compatible with machinery from the same manufacturer. This is however changing due to market forces (Stiegeman, 1998).

In a precision farming system, fields are divided into a large number sub-fields and it is now technically possible to take all the yield affecting as well as strategy affecting factors into account for each individual sub-field. Decision support systems were developed to address this part of the system, given a sub-field size of around 400 to 500 m^2.

These systems can be fairly simple (such as software usually supplied with the hardware) or can be fairly complex, GIS based support systems, such as one developed by a fertiliser company in South Africa (Lourens, 1999)

All decision support systems, simple or complex, have the same aim, that is to facilitate the 'what – iffing' by the farmer to find the optimal solution for his given set of strategic and yield affecting factors. This process can best be summarised in figure 3.

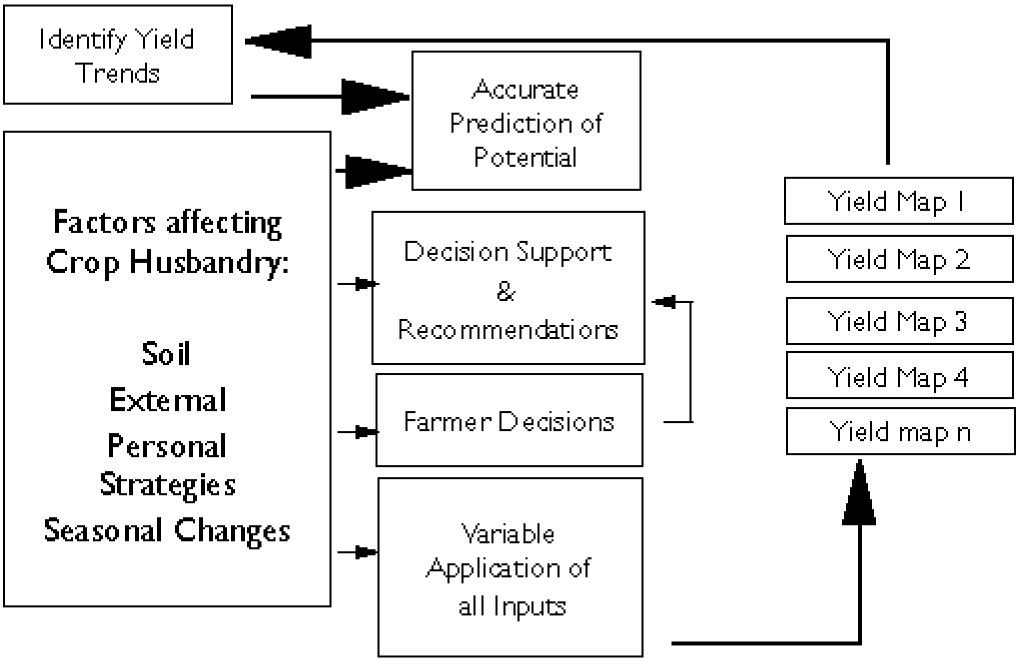


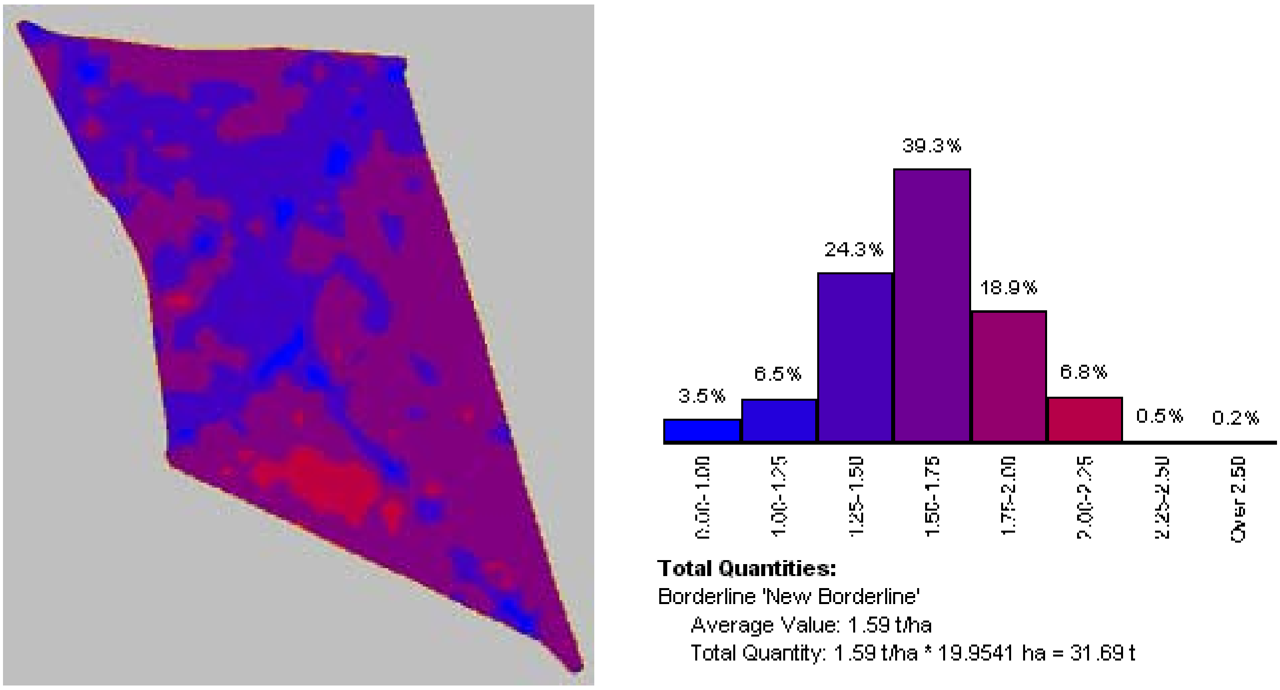
fig 3: Diagram showing decision making process

The important result is that the farmer does not follow a completely new process, but that he follows the principles he has derived over years, but only applies them to smaller sub-fields, instead of the larger, original field, or even the farm. He has now the tools to divide a field into the smaller units they were some time ago (especially in Europe), without introducing the physical boundaries, thus retaining economies of scale.

4. VARIABILITY OF YIELDS IN SOUTH AFRICA

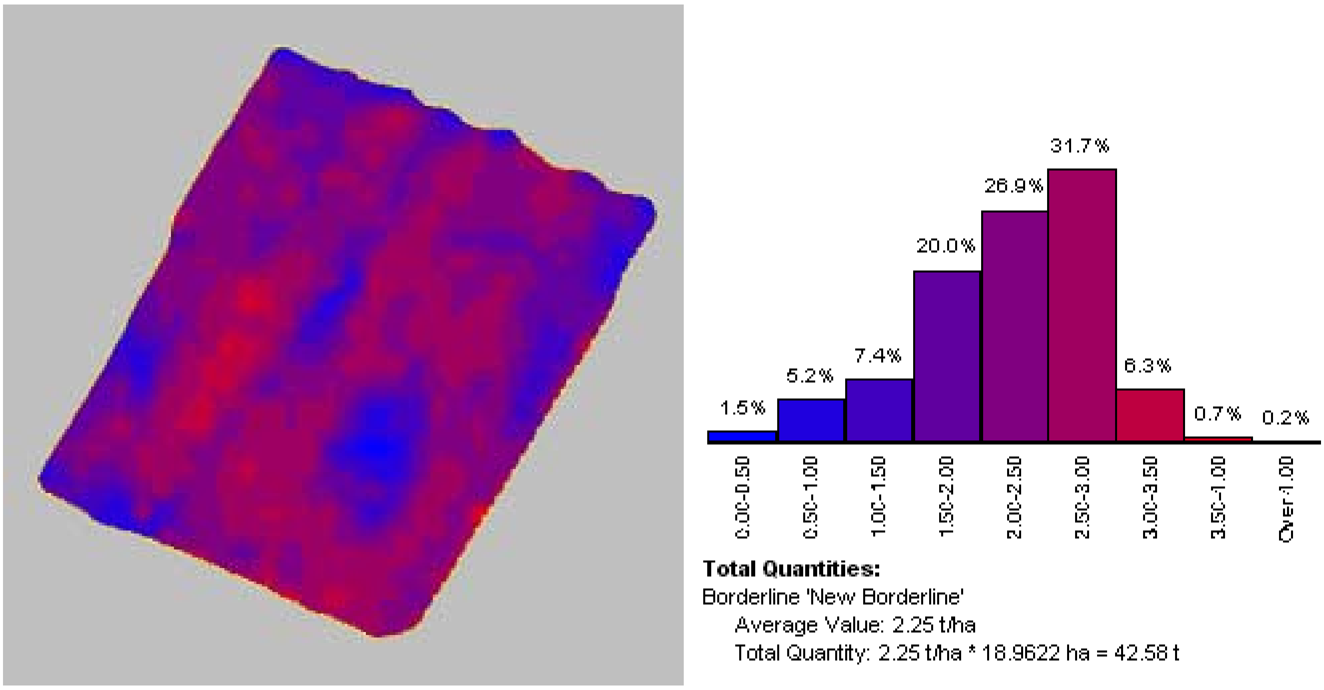
The author has over some 20 months collected data from a number of sites in South Africa. These are highly variable as the yield maps in figures 4-7 show. These yield maps were compiled between October 1997 (Canola, Swellendam, fig 4) and June 1999 (Maize, Reitz, fig 8). It may be noted that figures 6 & 7 are the same field in Reitz, and the differences in yield were 0.75t/ha on 15,2% of the field to over 6t/ha on 9,6% of the field (fig 6). The differences for maize in the same field are not as marked as for wheat. It is noteworthy that there is a correlation between the two maps, an encouraging result. The sunflower field from the Free State has been included to show the yield differences of a crop believed to be relatively resistant to drought.

Slightly less differences in yield occurred under irrigation, where Maize in 1998 (fig 8) and Wheat in 1998 (fig 9), both maps are from the same field in Hopetown.



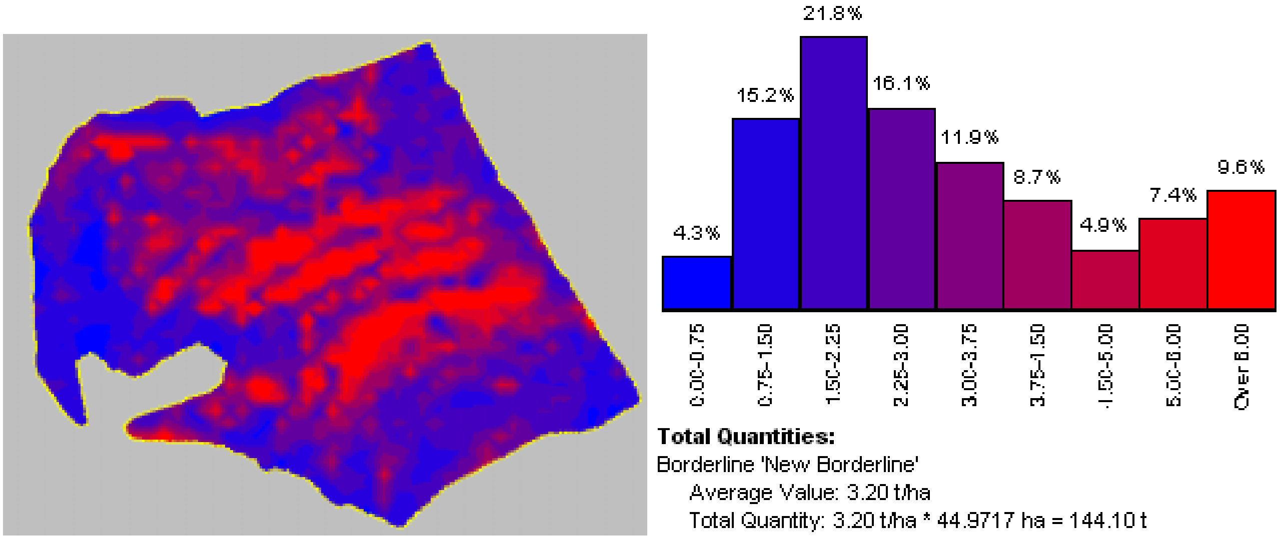
Total Quantities:
Borderline 'New Borderline'
Average Value: 1.59 t/ha
Total Quantity: 1.59 t/ha * 19.9541 ha = 31.69 t

fig 4: Canola (1997)



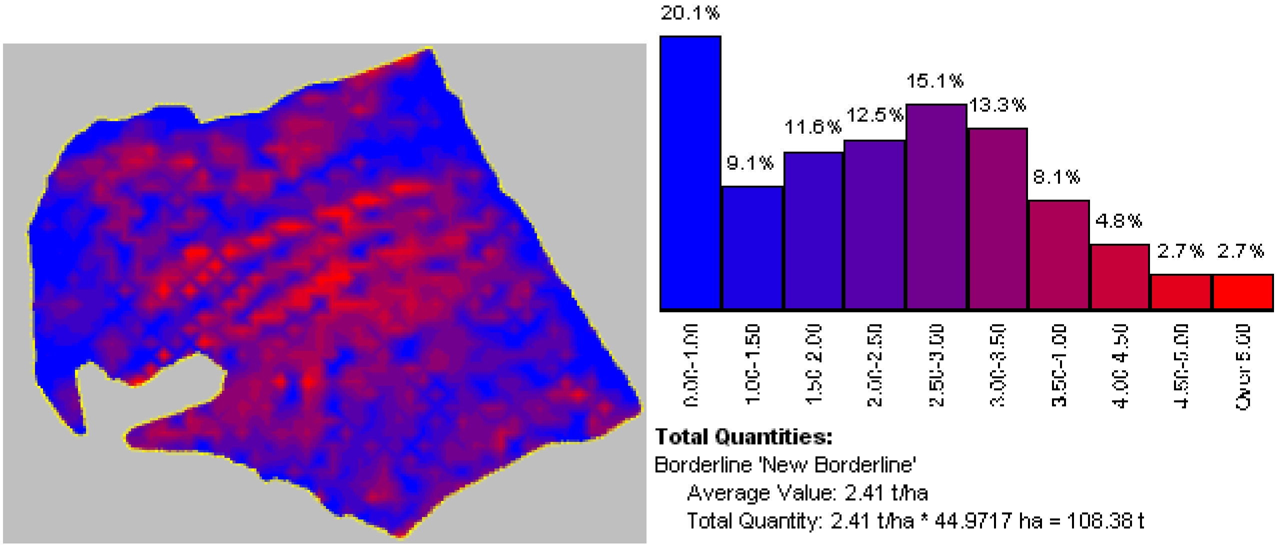
Total Quantities:
Borderline 'New Borderline'
Average Value: 2.25 t/ha
Total Quantity: 2.25 t/ha * 18.9622 ha = 42.58 t

fig 5: Sunflowers (1998)



Total Quantities:
Borderline 'New Borderline'
Average Value: 3.20 t/ha
Total Quantity: 3.20 t/ha * 44.9717 ha = 144.10 t

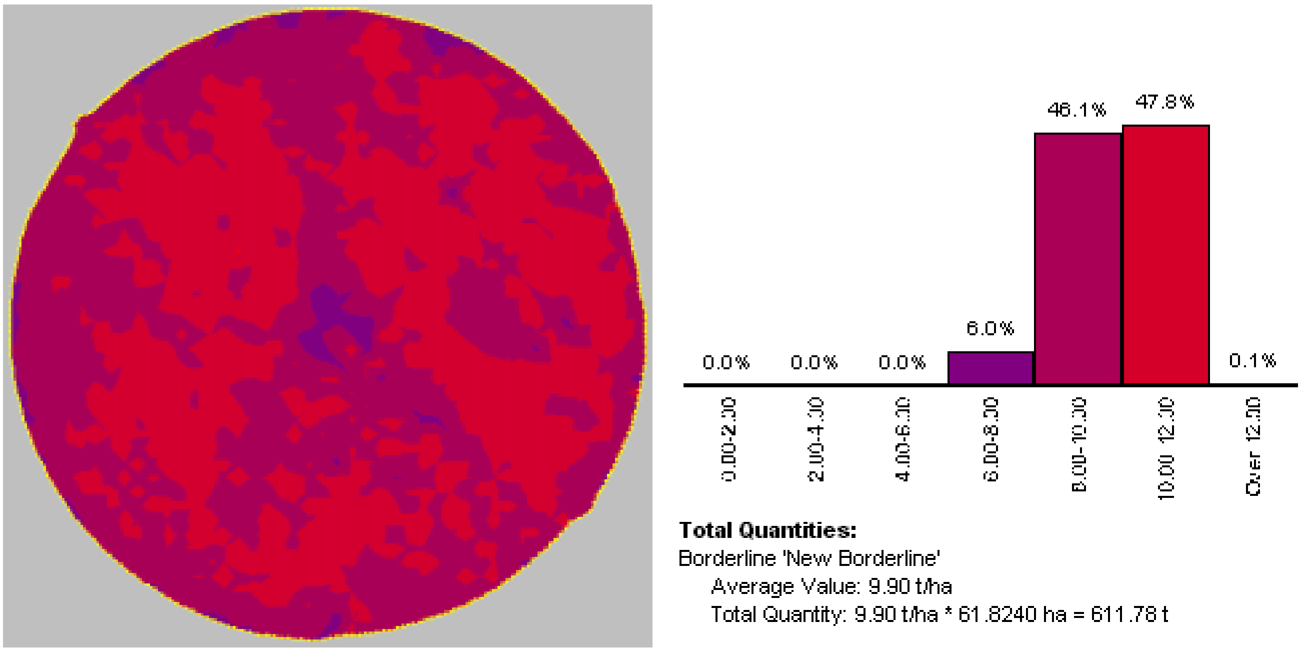
fig 6: Wheat (1998)



Total Quantities:
Borderline 'New Borderline'
Average Value: 2.41 t/ha
Total Quantity: 2.41 t/ha * 44.9717 ha = 108.38 t

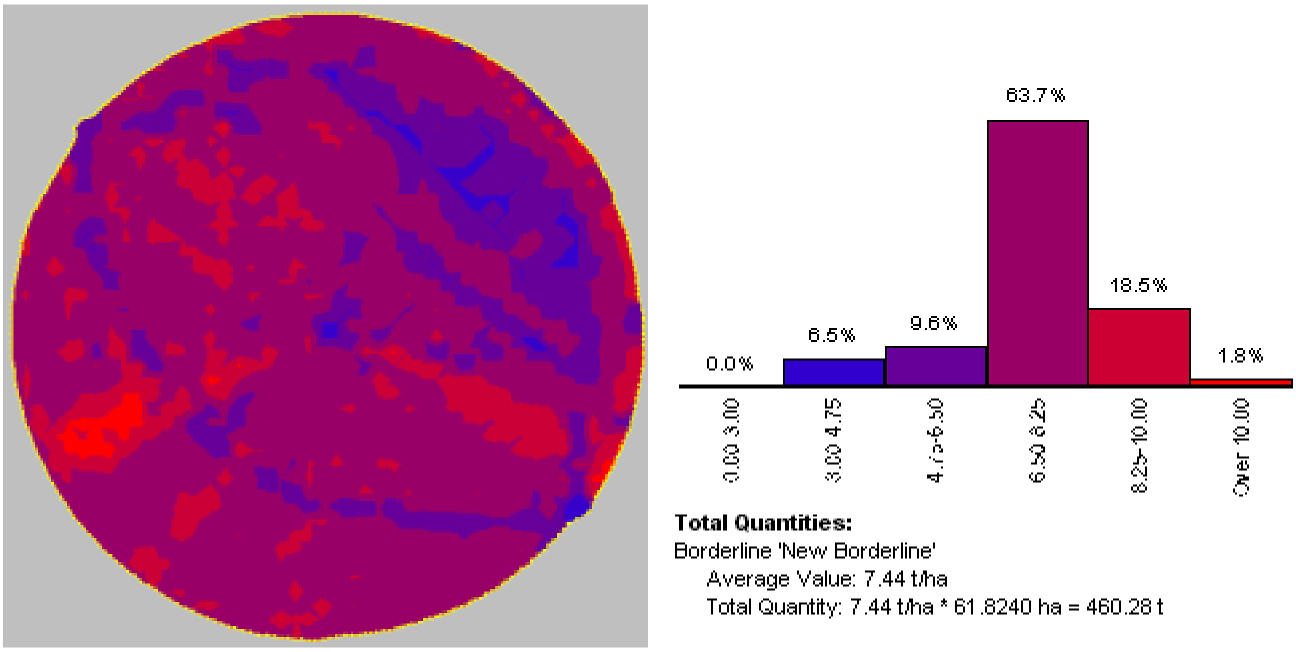
fig 7: Maize (1999)

Moore (1998) reports yield differences between 54% and 104% (based on the lower yield) in the United Kingdom. These results are not directly comparable to the ones obtained in South Africa, as there are other limiting factors applicable. The field mapped in the Reitz area has a highly variable soil depth, and as under the dry land conditions in South Africa moisture is most likely the limiting factor, this will have an influence on the yield. When discussing these maps with the farmer, and an agronomist from his fertiliser company the joint comment was: ‘ We are farming with water in this area.’



Total Quantities:
Borderline 'New Borderline'
Average Value: 9.90 t/ha
Total Quantity: 9.90 t/ha * 61.8240 ha = 611.78 t

fig 8: Maize Irrigation 1998



Total Quantities:
Borderline 'New Borderline'
Average Value: 7.44 t/ha
Total Quantity: 7.44 t/ha * 61.8240 ha = 460.28 t

fig 9: Wheat Irrigation 1998

Note that some low yielding areas in this field are due to a technical shortcoming.

A soil depth map for the field shown in figures 6 & 7 is shown as figure 10, and a typical nutrient map (P) is shown as figure 11

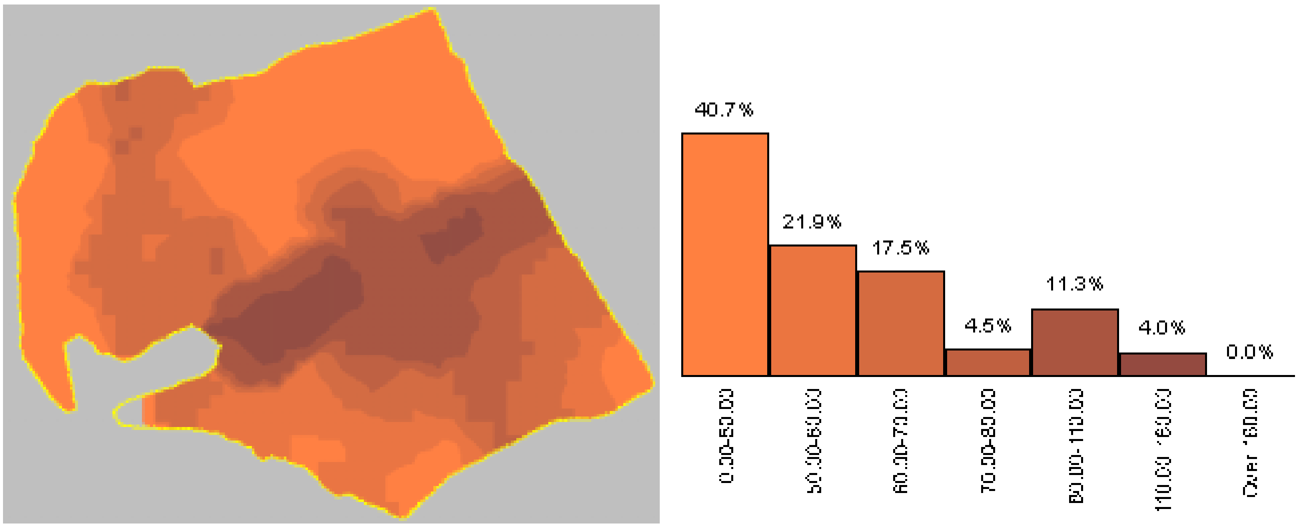


fig 10: Soil Depth

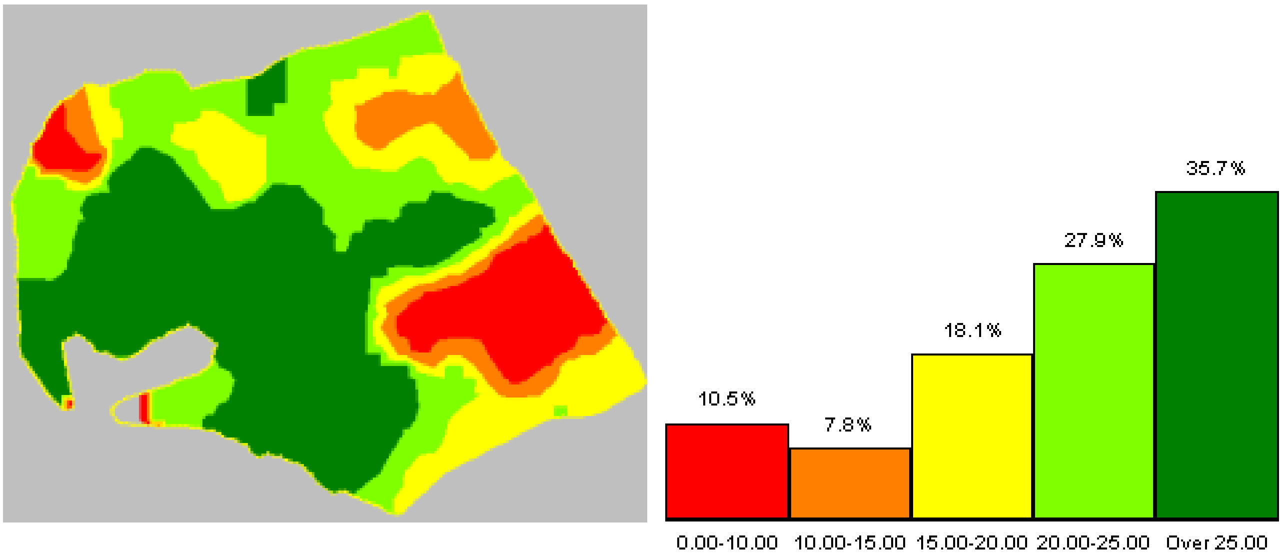


fig 11: P (1999)

The software on which this work was done, does not allow overlaying value maps for advanced queries, which can be typically done with a GIS system. A professional version is in the making.

As can be seen from the above examples, the yields on typical South African fields are highly variable, and that some nutrients vary as result quite dramatically over those fields.

5. FUTURE OF PRECISION FARMING

Agriculture has, in many parts of the world been under pressure from environmental groups to clean up its act. Part of this pressure is due to the fact that up to 30% of the applied Nitrogen (Tom Bourke, 1999) finds its way into our underground water. This percentage will depend largely on the soil conditions and the climatic conditions.

Precision Farming provides farmers with a tool to apply fertiliser according to the need of a particular sub-field, and no longer based on the average of the field. The savings made with this variable application can be fairly large. John Fenton (1995), a pioneer of this technology reports that his average Nitrogen application has been reduced from an average of 220kg/ha to an average of 160kg/ha, without affecting yield. As a result the amount N lost through leaching has been reduced by 60%. When reporting these savings, he was still treating his fields with the traditional blanket treatment method.

A farmer wishing to implement this technology will need to develop an implementation strategy to avoid disaster. Moore (1998) shows, that although there are fairly high yield variations in the UK, most parts of these fields still make a positive contribution to the income of the farm. This is in stark contrast to the conditions encountered in the variability of the wheat field in Reitz. On the field shown in figure 6 it was calculated that with input costs at 80% of the average yield, 55% of the field do not contribute, or even erode farm income. Even a minor reduction in input costs can increase profitability dramatically.

6. CONCLUSION: TECHNOLOGY ON THE HORIZON

This technology is certainly exciting, and is bound to change the face of agriculture in the long term. It will therefore either be implemented voluntary, or as it is happening in some European countries, by law.

The author is well aware of the hurdles presented by new technology, and especially in the case of precision farming the technology at its present stage is not for the faint hearted. Many a farmer has neither the interest nor the time to (Lourens, 1999; Osborne 1999) sit and study long manuals and do extensive analysis as to the best scenario.

It seems that some of the processes will move away from the farmer, to a service provider. This may be along the following lines:

- The farmer will collect the data, not limited to yield maps, but value maps, and forward these to his service provider.
- The service provider will in turn process these maps, and gather other relevant data for the area (such as remote sensing maps showing vigorousness of growth, or water stress), soil data, as well as results from soil sampling done.
- This data will be corrected and presented on a highly specialised GIS system, with simplified user interfaces. This GIS system will be at the service provider.
- The user can then interrogate his value maps, together with other ‘public’ information from his own computer, using the internet and an appropriate frontend such as ArcExplorer. He can then query a number of maps for a common purpose.

This will enable the farmer to use the technology without getting deeply involved in highly specialised GIS applications.

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