PRECISION FARMING - THE MANAGEMENT IMPLICATIONS

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Abstract

Precision Farming with it's use of satellite technologies in arable farming is now with us and will have a dramatic effect on large scale farm management in the next decade and beyond. It is a fast moving and dynamic development, with much of the agricultural supply industry becoming involved. Like Integrated Crop Management, Precision Farming will become an increasingly pervasive management concept.

This paper reviews some of the wide range of uses, possibilities and hoped for benefits of Precision Farming, and sets out to identify those aspects that are likely to make a major contribution to the management of growing arable crops and their profitability.

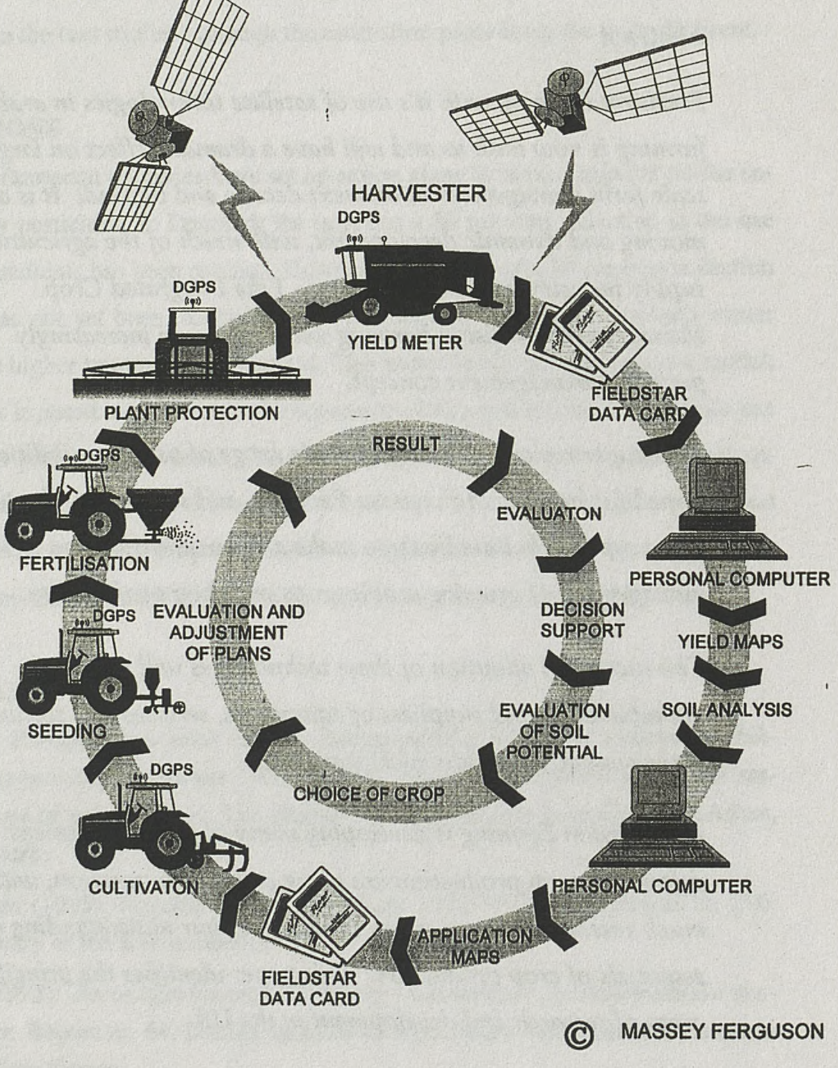
The successful adoption of these technologies will require manufacturers and suppliers of equipment, services and software to agree common (world-wide?) standards.

As Precision Farming is developing many of the management systems of crop production are being called into question, with much research now necessary to underpin our understanding of the essentials of crop production. This paper identifies the principal areas of research and development in the UK.

Introduction

Precision Farming (or Precision Agriculture as it is also commonly known) is one of those titles that does not mean very much on first reading. As with Integrated Crop Management (ICM), nothing immediately comes to mind to

PRECISION FARMING MODEL



the uninitiated, although many farmers would associate precision with the accurate application of inputs in the context of arable crops - something many would consider they are already very adept at doing.

Precision Farming is not a product or range of products - it is a concept, much in the way that ICM (into which Precision Farming fits so well) is a concept. It has numerous parts and facets, many of which are still being developed. It is technology led, it is with us and over the next 20 years it will make a major impact on arable and possibly grassland farming.

My definition of Precision Farming, and I am sure there are many, runs something like this:-

> **The collection of a range of relevant information regarding the variability within a field from which management decisions can be made (and action taken) on the variable application of inputs, both cultural and physical, for growing a crop.**

This collection of data and fixing it to a relatively exact position in a field is core to the whole process of Precision Farming. If there is variability, and results regularly show this to be considerable for a wide range of criteria, then we as farmers (or business men) ignore the variability at our cost. Having identified the variables we can decide not to do anything about them if it is not worthwhile, but given that the information can be economically collected then we need to have that information for our decision making.

The fixing of data to a position is normally done using a global position system - by satellite signals. The data coupled with the position is stored and / or relayed to a computer where the information can be assembled and interpreted into 'maps' for visual inspection. However this need not be the only method; sensors can be used to detect variation in real time, and a pre-defined action taken by a machine (e.g. in seed bed preparation).

There is a saying "there is nothing new under the sun" and one could say that Precision Farming by the use of new technology is bringing back the management style of the days when farming was done in small strips and

Datavision
Yieldmapping
System

Yieldmap [T/ha]

19960017

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Farm               : King's
Field              : Parkwood
Field area [ha]    : 7.22
Date               : 23/08/96
Total exp./ha [£]  : 280
Crop               : Winter Wheat
Variety            : Brigadier
Crop weight(DV) [T]: 62.59
Avg. yield [T/ha]  : 8.67
Min. yield [T/ha]  : 7.1
Max. yield [T/ha]  : 12.8
Price/tonne  [£/T] : 98
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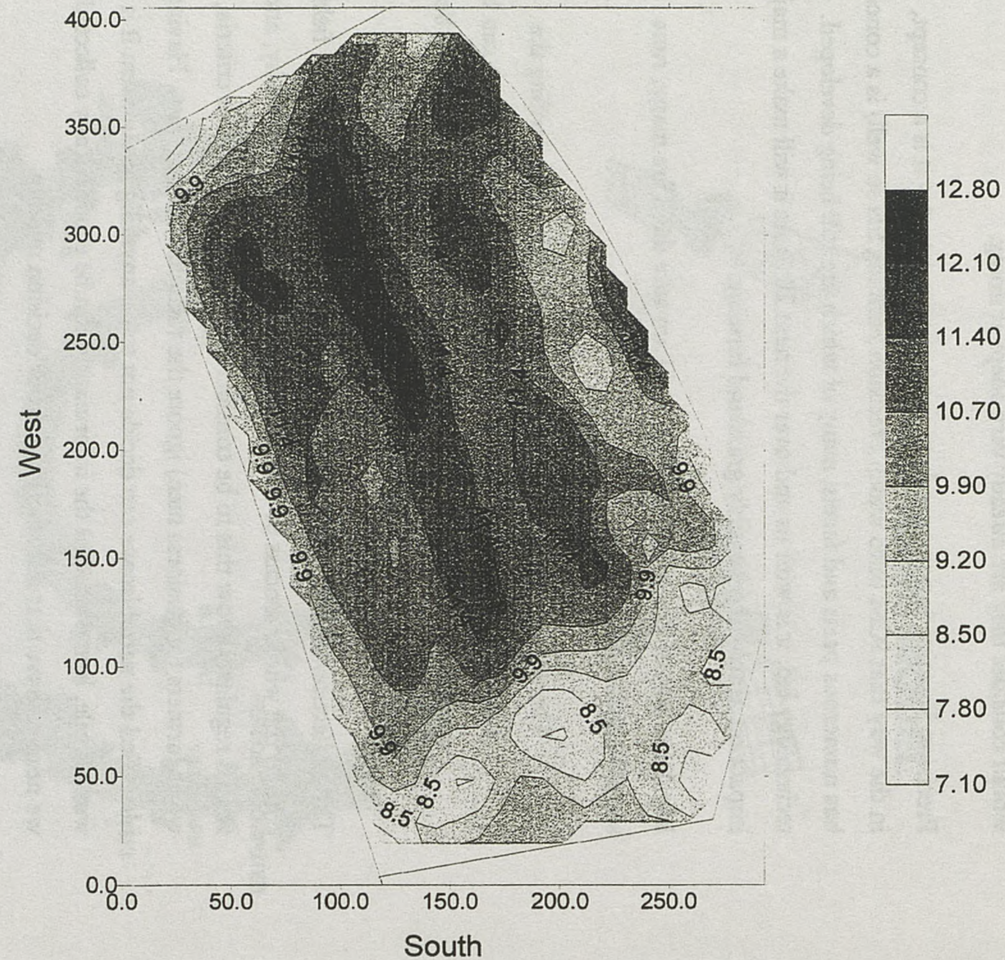
Low yielding area at south end
followed 2yr grass set-aside



where the farmer had an intimate knowledge of each strip or piece of ground, and managed it accordingly. As economic pressures rose and farm machinery required larger fields, such detailed management was sacrificed on the alter of efficiency. Another more up-to-date analogy is that of the modern dairy herd where technology has allowed the herdsman to feed each cow automatically according to its needs depending on where it is in it's lactation and how much milk it is producing. Precision Farming allows similar individual management of each part of a field. At present we tend to treat our fields as uniform platforms of production, applying our inputs uniformly over the whole field as if it was producing the field average yield. In reality there is considerable in-field variability of a whole range of production related factors.

Precision Farming essentially sets out to identify and, where it is possible and cost effective, to rectify yield limiting factors in every part of a field - and to optimise the use of inputs and thereby the whole field profit.

Current Mainline Uses of Precision Farming Technologies and Developments in the UK

There are a number of Precision Farming activities that are well developed and are being used by a growing number of interested farmers, although these are still being checked by researchers for accuracy, and there are still arguments about the best way of obtaining the information, and how it should be interpreted. The two most developed are Yield Mapping and Soil Nutrient Mapping.

Yield Mapping - Combinable Crops

Yield mapping has been developed over the last 10 years. It is estimated that there will be some 200 combines in the UK, and 500 in Europe, capable of yield mapping during the 1997 harvest. Currently these are fitted with either Massey Ferguson or RDS Technology systems. Within the next year or two it is expected that most of the large combine manufactures will offer yield mapping on their machines, and all their combines will be built "yield mapping ready".

Datavision
Yieldmapping
System

Gross margin map [£]

19960017

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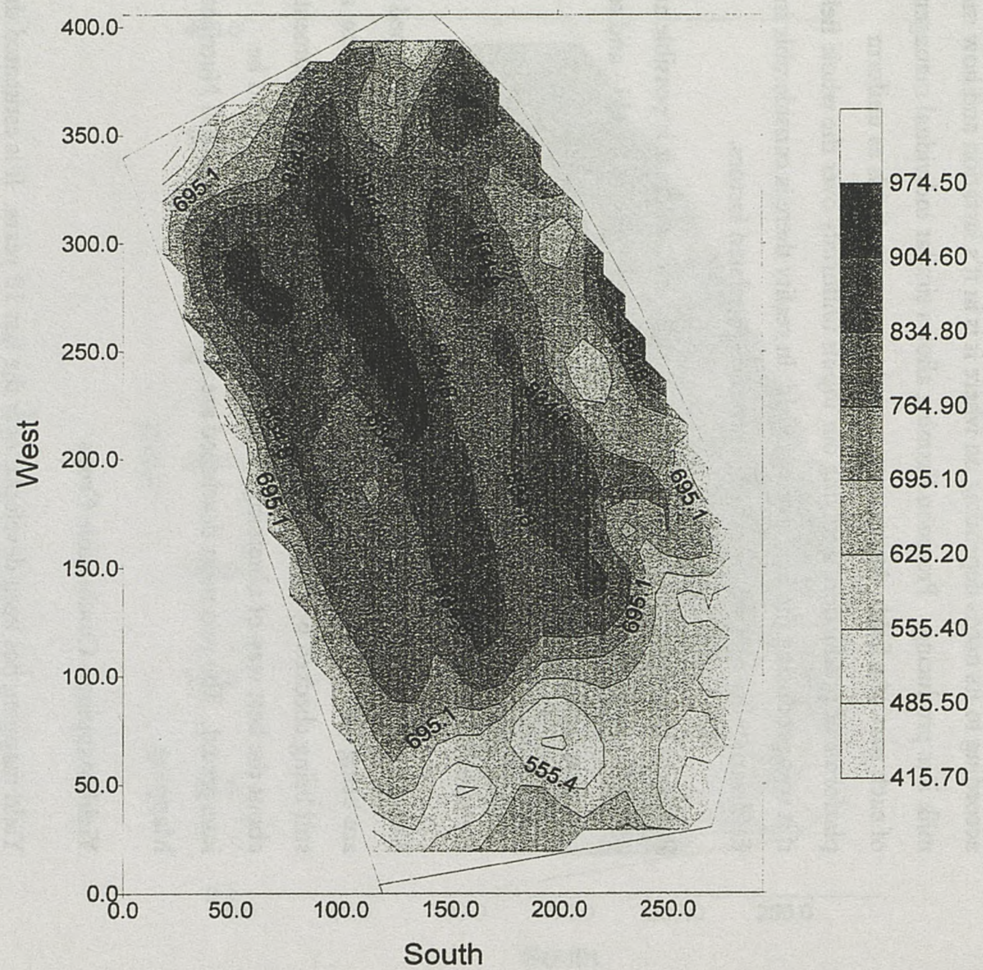


Yield mapping is achieved by recording weights of grain passing into the grain tank together with the position in the field of the combine usually by DGPS (Differential Global Positioning System). The information is transferred on disc to a computer where a software package transforms the information into contour or coloured maps with yield bands selected by the user.

From this information coupled to financial information provided by the user it is also possible to produce Gross Margin maps. To most farmers the first yield and gross margin maps on his farm are a revelation, and whilst many farmers may know where the low yielding parts of their fields are, they are not aware of how low, or the cost of the poorer parts of their fields. Also most farmers are not good at identifying the highest yielding areas (as opposed to the medium) of their fields. Mostly differences of between 50% and 300% are found between the lowest yielding parts and the highest yield, with around 100% differences most common.

Yield mapping needs to be carried out on successive crops (3 years preferably) to begin to build up a confident picture of those areas that regularly produce high, medium and low yield. Not surprisingly some parts, possibly the majority, of a field will not be consistent from year to year due to different growing conditions. Moisture availability will be a major factor perhaps giving opposite yield effects between wet and dry years.

Yield maps are purely an indication of the variation in yield, and should not necessarily be read as indicating problems in the low yielding areas. Yield limitation may actually be worse in the high yielding areas (see nutrient mapping), but the tendency will be to investigate the lowest yielding parts of the field to see if a problem exists. Problems such as rabbit damage (a rapidly developing problem once again in the UK) or a blocked drainage system can be assessed immediately and a decision taken as to whether action will be cost effective. Soil compaction is frequently the cause of loss of yield, and following investigation, remedial deep cultivation can be used to that part of a field that is affected.

Yield mapping is an obvious tool for deciding which areas to *set-a-side*.

Nutrient Mapping

Nutrient mapping has been developed as a commercial service to farmers in the UK, usually linked to a fertiliser supply and / or application service. Most of the present systems are American in origin, often sold as a service to the farmer with the implication that yield mapping is not necessary - just the variable application of nutrients to even out the field, or at least to ensure that individual nutrients are not limiting yield. However unless the expected yield is known one cannot make accurate nutrient replacement plans. The two need to be done together and the yield map will give a measurement of the benefits of varying the inputs.

Commonly nutrient samples for analysis are taken on a 100 metre grid system with the positions in the field located by DGPS, giving one sample per hectare. Many would argue that this is nowhere near enough, especially in the smaller fields of Europe and with varying soil types, and that a 50 metre grid (4 samples per hectare) is the minimum necessary. Recent research work (Dawson et al) on phosphates suggest that it is necessary to take 16 samples on a 1m grid and amalgamated to give an accurate sample for each point.

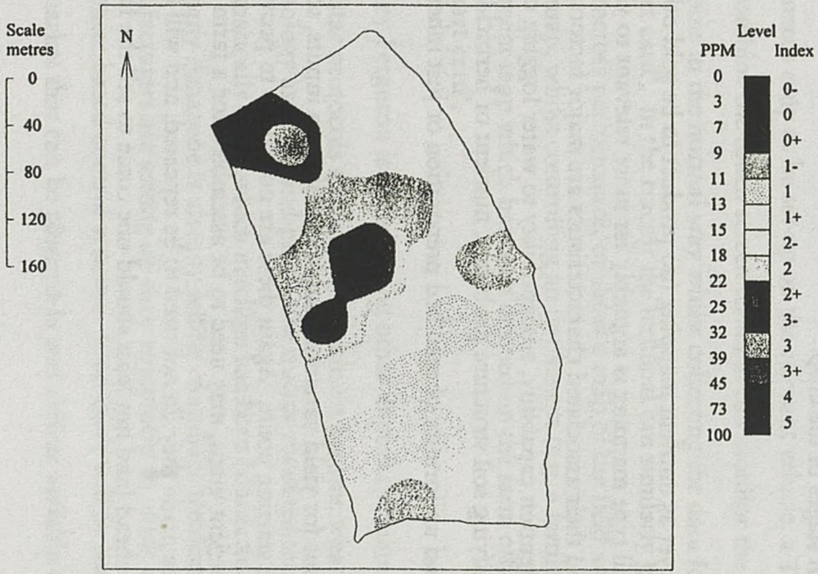
Clearly this can be an expensive exercise, with many arguing that it is only necessary to collect samples from the low yield areas of a field. However it is often found that the highest yielding areas have the lowest levels of P & K since the fertiliser applied is not sufficient to maintain the level of output, whilst the poorest yielding areas have high nutrient levels as the crop has not been able to utilise the fertiliser applied. So both high and low yielding areas need to be checked. This sampling and analysis would not have to be done very often - perhaps only once in 10 years once the base levels have been addressed, with random spot checks in between to see that nutrient levels are not limiting yield. With the base nutrient levels correct it will only be necessary to replenish that removed by the crop (measured from the yield map) to keep the nutrients in balance.

With nitrogen different approaches need to be taken, partly because of N leaching from soils, and partly because of the variation caused by the

SOYL LTD

SOIL FOR OPTIMUM YIELD LEVELS

Field Name: **Parkwood** **Area:** **7.69 Ha**



Soil Nutrient Level Map

Phosphorus

Client:	**Mr John Van de Peer**	Agent:	**Banks Agriculture**
Farm:	**Ciba Agriculture**	Ref. No.:	**BS271**
Short Code:	**CIBAAG.-PKWOOD**		
Eastings:	**545515**	Sampled By:	**SOYL**
Northings:	**239076**	Date Sampled:	**02/09/1996**

Created by SOYL-EQUI

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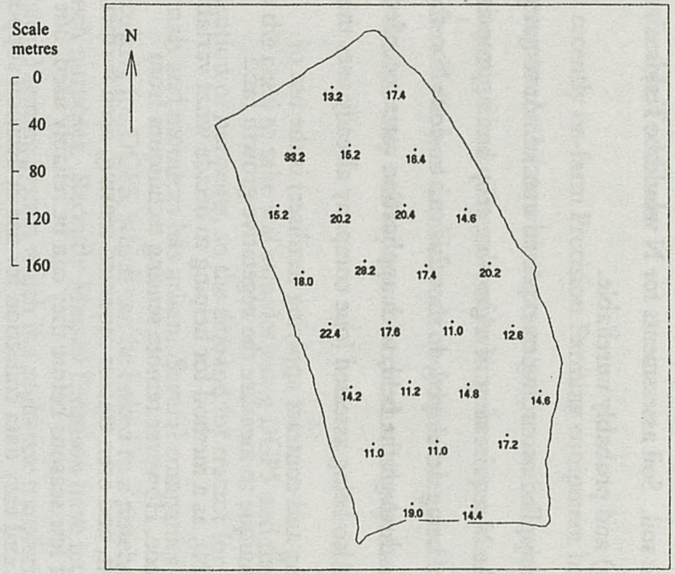

Sample Map

Phosphorus

Client:	**Mr John Van de Peer**	Agent:	**Banks Agriculture**
Farm:	**Ciba Agriculture**	Ref. No.:	**BS271**
Short Code:	**CIBAAG.-PKWOOD**		
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Created by SOYL-EQUI

mineralisation of N in the soil. Soil assessments for N would be very expensive (deep sampling) and probably unreliable.

Nitrogen fertiliser can be applied according to expected uptake. Automated real time assessment of the N requirement of a growing crop and appropriate N application systems are being developed, so that this can be done "on-the-run" as the tractor passes through the field, with application rates recorded as the machine progresses. Also being assessed (one company already uses this method for recommending and contract applying fertiliser) is the use of satellite imagery as a technique to measure the vegetative growth (and therefore likely need for N), as a method for helping to decide what variable N application should be made. However remote sensing techniques from satellites and light aircraft, and even tractor mounted sensing, need further verification over the next few seasons before they can be reliably used, but they should then provide fast and easy data collection for use in decision support systems at critical growth stages of the crop.

Soil Type Mapping

Whilst not as developed yet as nutrient mapping (no product to be sold other than the service itself) soil type mapping is arguably far more relevant to yield limitation. Soil types and their associated characteristics are major factors in yield - be it moisture retention capability, susceptibility to water logging or compaction, ease of rectifying soil structure problems, nutrient or herbicide holding capacity, ease and uniformity of seed bed preparation or just inherent production capability.

So in assessing the reasons for yield variation and in deciding on inputs, soil type maps should be the starting point. Again these are not cheap to provide, and, as perhaps with nutrient maps, may need to be assembled for a farm over a number of years. Once made they do not need to be repeated, and will have great value in the years ahead (and not least should one come to sell the farm).

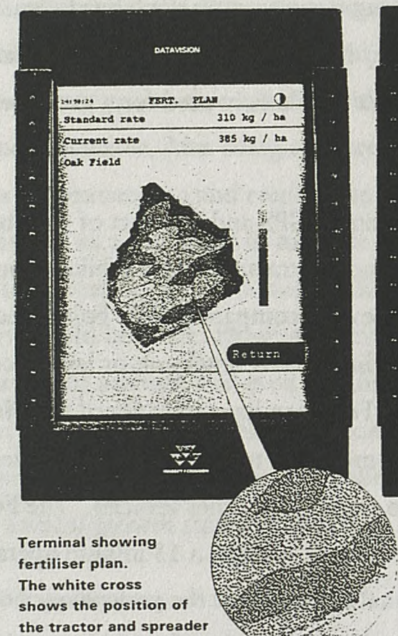
Transferable Terminals

Until recently on-farm Precision Farming equipment has been limited to yield mapping in combines with the terminal, monitor and DGPS receiver all permanently fitted. The cost of having these on a machine has fallen considerably in just the few years they have been available commercially, but never the less they still represent a cost that is only used for a short period each year.

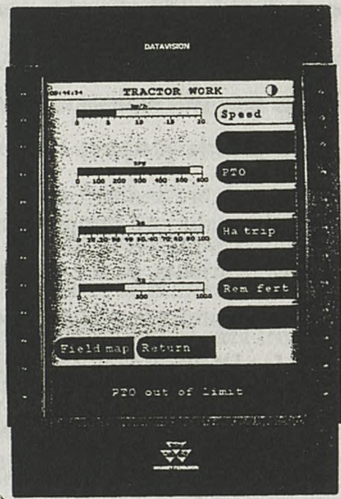
With the need to take soil samples using DGPS and the start of variable application of nutrients, so the demand for tractor (or ATV bike) mounted terminals and monitors has arisen. Several companies offer bolt-on equipment, particularly for DGPS, which can be linked to a notebook or laptop computer for such purposes. Recently Massey Ferguson have introduced the **Fieldstar™** Precision Farming system which is a multi-use transferable monitor/terminal that can be moved from combine to tractor 9or other vehicle). The Fieldstar unit needs only to be set-up on the relevant vehicle, a 15 minute operation. In the combine the touch screen terminal can monitor the performance of the combine in the normal way whilst collecting the data for yield mapping on a 'smart card'. In the tractor the terminal can similarly give information about the tractors performance, or show a map of the field and where the tractor is on that map, whilst controlling an implement (e.g. a fertiliser spreader) using a treatment map which has been devised on the farm office computer and put on a 'smart card'.

Massey Ferguson is encouraging other implement manufactures to adopt the Fieldstar protocols so that their machines become what is known in computer technology as 'plug-and-play' - the tractor mounted terminal will automatically sense which machine has been connected to it. The German company Amazone is already selling compliant fertiliser spreaders, and other manufacturers are setting up their equipment to work with Fieldstar and other computer based control systems. Soon there will be seed drills and sprayers on the market that can be plugged-in and deliver variable rate applications.

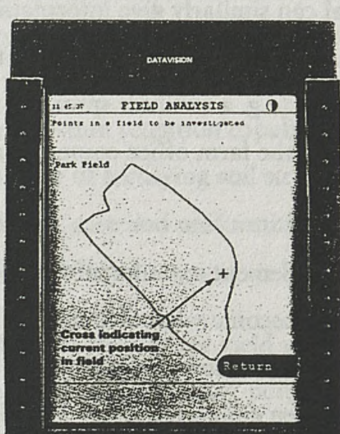
Fieldstar: Monitor Screen and Terminal



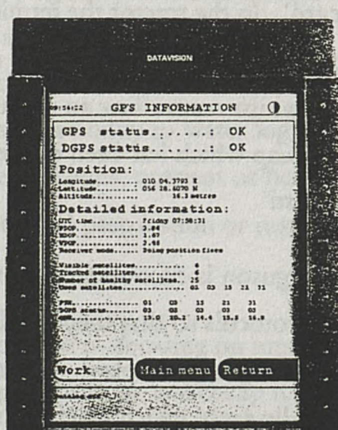
Terminal showing fertiliser plan. The white cross shows the position of the tractor and spreader



'Tractor work' screen screen showing important working information and warning messages



Above: The 'Field analysis' screen gives highly accurate positional information



The GPS information shown here gives a precise location, which can be recorded. This enables you to map features such as pipelines, pylons and trees.

Current Research and Developments for Precision Farming

The next line of Precision Farming technologies is well underway, and in all areas a great deal of research and development work is being carried out both at research institute and manufacturer level.

Over the next 10 to 20 years we can expect far reaching developments in sensor technology and data collection as well as variable application systems. The collection of data has to be as automated as it can be - fast, efficient, accurate and reliable with as little operator time involved as is possible as well as being as cheap as possible. It must come in a form that is compatible with the relevant software.

Cultivations

Fixing soil structure problems using subsoiling, ploughing and other cultivations according to the damaged area(s) in a field as identified by investigation as a follow-up to a yield map is an obvious benefit. A 'treatment' map can be devised, either as a hand-held map that a tractor driver can follow, or more accurately by using an in cab monitor 'treatment map', e.g. Fieldstar.

Variable seed bed preparation using a range of sensors on the cultivator (such as a power harrow) which control the forward speed of the tractor, the speed of the rotors, and the depth of cultivation is now being researched (Silsoe Research Institute). The tractor driver could be advised (by the monitor) to repeat the cultivation on those parts of the field needing additional preparation. Information on the state of the seed bed could be collected and mapped for decisions on the rates of seed at sowing.

We can expect to see the development of new sensors for attachment to cultivation equipment that will either inform the tractor driver or control the operation of that equipment to improve performance in relation to soil condition.

Seeding

Varying seed rates according to the quality of the seed bed, the farmer's experience or on the basis of actual data of the germination rates on certain parts of the field, or on economic / performance data (i.e. the inherent production capability of parts of a field) is currently being assessed, and the benefits quantified. However seed rate, crop establishment and final crop performance is known to be highly variable in many crops (for instance the ability of winter wheat to compensate for poor establishment) and are often related to weather and other conditions through out the growing season which are likely to have more influence than seed rate.

New forms of seed breeding (hybrid and genetically modified) are leading to high value, high performance seed that may well need to be sown at lower rates to be viable - optimising the use of such seed may well prove necessary for their commercial success.

Spray Chemical Application

The variable application of spray chemicals is less developed than that for crop nutrients. Work is being carried out to assess the possibilities, and there are already some recommendations. However the large range of products, their formulation, and their differing efficacy against the range of problems they deal with adds complication.

Commercial sprayers adapted for Precision Farming style applications are not yet available in the UK. The reason for this relates to the question of what sort of sprayer is wanted. Is it a machine that can patch spray; perhaps applying an overall spray to the whole field, whilst adding another chemical in for parts of the field, or is it a machine that can simply vary the rate? Or are both techniques required? What functionality and at what price? In recent years new spray delivery systems have come and gone leaving the basic hydraulic sprayer little changed in 40 years of spray application (at least in principle design) although recent designs using compressed air have achieved some success. The principle problem for these developments is that they have not been capable of universal application of all products. The wide range of

different formulations and rates of application have been their undoing. For a chemical company, the formulation of a new product to meet the needs of production, of storage and then for use on the farm is often the major development problem once a new molecule has been discovered and found to have activity, and this leads to the wide range of formulations and rates that farmers face on the farm.

In addition the techniques for collecting information on the variability of weed, pest and disease problems in the field are not well developed or tested, and much work still needs to be done to improve and verify these.

Weed Control

Controlling patches of weeds is an obvious Precision Farming objective. Patches of weeds are moderately easy to identify by eye, but developing weed maps by field walking is slow and laborious. Collection of different weed data by the tractor driver whilst passing through a field during applications of fertiliser and spraying or even at harvest and building it up into a comprehensive weed map can be easily achieved.

Unfortunately not all weeds grow in patches, some such as wild-oats, black-grass and cleavers generally do, but many others tend to be well dispersed throughout the field. Any spray application strategy is therefore likely to need a mixture of products with one or more (often the cheaper products) needing to be sprayed over the whole field, and other chemicals (often the more expensive) wanting to be applied only to those areas with a particular weed problem. The Silsoe Research Institute developed and demonstrated a “patch sprayer” that had two spray lines and control on every 2 metres of the spray pattern controlled by computer and DGPS. It could, by using injection pumps, spray a range of products switching them on and off as required as it progressed through a field following a treatment map. Injection is the obvious system for patch spraying where a number of products need to be applied, but unfortunately not all products (and in particular some of the newer very low active ingredient formulations) can be easily used through an injection sprayer,

and they are also very expensive. Twin tank, twin pump and twin spray line sprayers could, and may well turn out to be the compromise answer.

Weed control chemicals tend to have fairly tight application rate bands in which they can be relied upon to kill 95-98% of a weed species in a range of conditions. There is not often much room for reduced rates where good control is required, although given the right conditions lower rates can be effective, at least in reducing seed generation. Patch style weeds, whilst growing predominantly in patches, tend to have rogue plants spread about the field. These individual plants may not be of much economic consequence in the current crop, but will if left to seed for future years. In this scenario a farmer could apply the full rate to the patches and a reduced rate to the rest of the field where previously he would have sprayed the whole field.

Pest Control - Nematodes, molluscs and insects.

There are considerable opportunities for improving the use of chemicals in relation to those pests that develop in patches. The use of DGPS to map pest problems, such as nematodes by sampling, and devise patch type treatment maps is straight forward- with particular benefits where the cost of treatment is expensive and perhaps previously would not be viable on a field scale.

Plant Growth Regulators

Where PGRs are used to reduce the risk of a crop lodging there are considerable opportunities to make savings in fields where only certain parts of a field are known to be liable to lodging. Such areas may be ascertained from yield maps where reductions in yield have been linked to lodging, or simply from previous experience.

However where PGRs are used to achieve other benefits, then variable rates or patch application to optimise the return for parts of the field should be the approach.

Disease Control

Patch treatments for certain diseases that tend to develop in specific parts of a field (spreading out from an initial foci) is one type of use, but these situations are not so common as those that require the development of protection strategies for a field. Opportunities to use variable rate applications according to the density of the crop and / or the level of protection that the value of the prospective crop warrants are more likely.

Logically the more dense a crop the greater the amount of fungicide it needs to protect it. Given that a devise can be found to measure crop density, and several techniques including satellite, aerial photography and real-time on-the-tractor systems are being assessed, applications could be varied according to the plant density as the sprayer passes through the field. The whole field might well receive the same quantity of product(s), but it would be more efficiently distributed according to each part of the field's needs.

Decisions to vary rates of fungicide to different parts of the field could be taken on a financial assessment of a) what individual parts of the crop can afford and b) what the level of financial risk is - lower yielding parts not warranting the level of protection that higher yielding parts do. This could be achieved by varying the rates, or alternatively by adding additional products to specific areas.

The overall cost might be the same, however more appropriate targeting would be expected to bring efficiency savings through reduced waste and improved performance.

Crop Quality Mapping

As an add on to yield mapping, assessments of quality such as specific weight and protein content are being made and recorded to produce quality maps for these criteria. Unfortunately these assessments can not as yet be made automatically, but the results produced so far are extremely interesting - for instance N levels in the high yielding areas tend to be low and vice versa. Not surprising perhaps, but the levels of difference - from 10% to 19% in one field

- does suggest that improvements could be made. It may well be the result of average applications of fertiliser not meeting the full needs and therefore potential of the high yielding areas.

Yield Mapping - Other Crops

Most of the yield mapping work has been done in relation to combinable crops where the measurement of yield has been reasonably easy to develop.

New techniques are being developed for other crops. Root crops (sugar beet and potatoes) are being yield mapped using weigh cells and DGPS on trailers where the crop is collected into a trailer as the harvester progresses across the field. In due course these weigh cells should be able to be incorporated into complete harvesters. Quality 'mapping' may also play an important role.

Potentially the benefits of Precision Farming are much greater in these crops with their higher use of inputs and higher cash values.

Irrigated Water

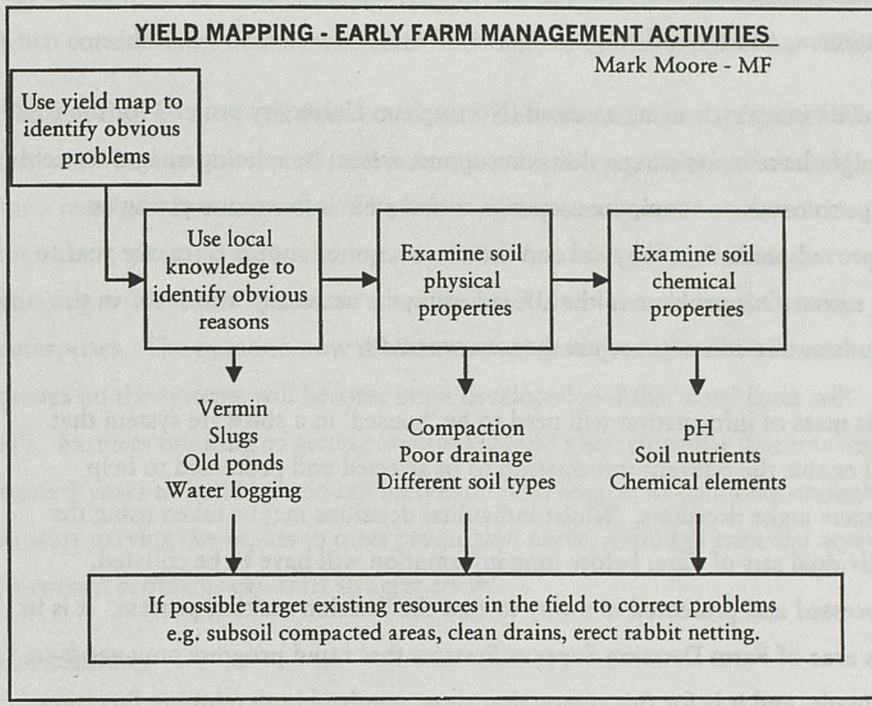
Water for irrigation has become an increasingly important resource to many farmers in the UK, particularly in the eastern counties where the last two years have been the driest since records began.

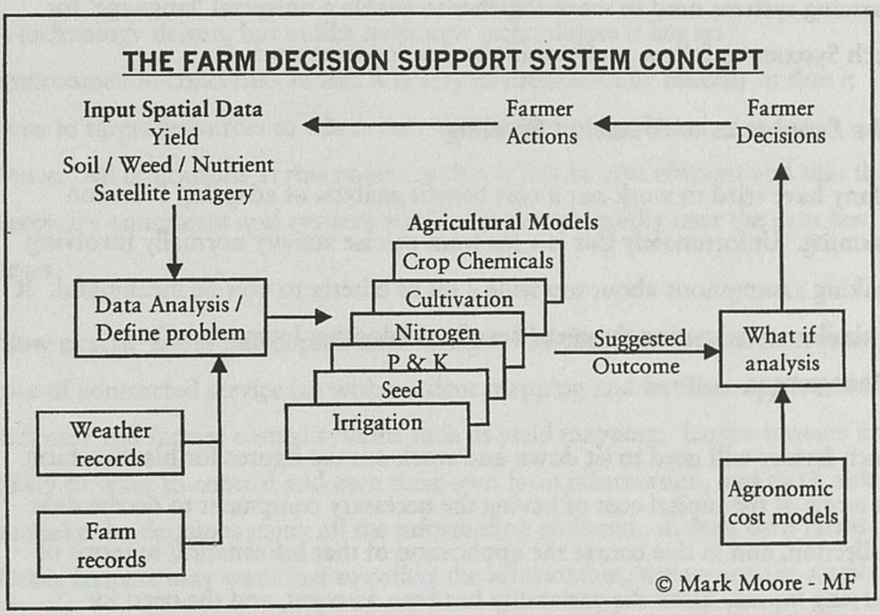
Applying irrigation at varying rates according to soil moisture deficit using installed probes to assess the shortage, or by soil type where the SMD is calculated, would bring both savings and far better utilisation.

Where nutrients are applied via the irrigation then these could be varied according to need as the irrigator travels across the field.

Farm Decision Support Systems (FDSS)

With yield, nutrient, soil type, weed, satellite image and many other sets of data being collected there will be a mass of information which will increase as year succeeds year. We will need to be able to compare one year with another,


YIELD MAPPING - EARLY FARM MANAGEMENT ACTIVITIES
Mark Moore - MF
Use yield map to identify obvious problems
Use local knowledge to identify obvious reasons
Examine soil physical properties
Examine soil chemical properties
Vermin
Slugs
Old ponds
Water logging
Compaction
Poor drainage
Different soil types
pH
Soil nutrients
Chemical elements
If possible target existing resources in the field to correct problems
e.g. subsoil compacted areas, clean drains, erect rabbit netting.


THE FARM DECISION SUPPORT SYSTEM CONCEPT
Input Spatial Data
Yield
Soil / Weed / Nutrient
Satellite imagery
Farmer Actions
Farmer Decisions
Agricultural Models
Crop Chemicals
Cultivation
Nitrogen
P & K
Seed
Irrigation
Data Analysis / Define problem
Suggested Outcome
What if analysis
Weather records
Farm records
Agronomic cost models
© Mark Moore - MF

and to combine several years information to show those areas that are consistent, and those that vary.

Satellite imagery is being assessed (Nottingham University project) for the role it might have in assisting a decision support system by relating images to yield maps to combine / compare crop vigour and yield information giving an improved prediction for yield and therefore required inputs from one year to the next. (Our problem in the UK is getting the necessary 'windows' in the clouds to obtain images when they are wanted!)

This mass of information will need to be 'housed' in a software system that will enable the relevant information to be selected and processed to help farmers make decisions. Whilst individual decisions maybe taken using the individual sets of data, before long information will have to be collated, processed and presented in a way to ease the decision making process. It is in this area of Farm Decision Support Systems that rapid progress now needs to be made, and it is for this reason that those involved in developing Precision Farming systems need to work together to enable a universal 'language' for such Systems to follow on from all the development work.

The Economics of Precision Farming

Many have tried to work out a cost benefit analysis of adapting Precision Farming. Unfortunately this is a far from precise activity normally involving making assumptions about too wide a set of criteria to ever be meaningful. It is similar to estimating the cost / benefit of adopting Integrated Crop Management.

Each farmer will need to sit down and work out the figures for his own farm in terms of the capital cost of having the necessary equipment to do the data collection, and in due course the application of that information in terms of varying inputs. Until the variability has been assessed, and the need for remedial action quantified, he will not know the costs, and until action has been taken to optimise the return from every part of the field he will not know the benefits. As more farmers get involved better predictions will be available,

but at this point in time, belief in the basic concept will be the essential decider when considering whether, when and how much to get involved.

The fact that all the work done so far, and there are now several (astute) UK farmers who have been yield, soil nutrient and soil type mapping their fields for a number of years now, and have found consistently large variations in their data, gives me the confidence to predict that before long Precision Farming will become the 'norm' amongst large (and later medium) farming enterprises. The question now is when to start getting involved? As time moves on the systems will become more developed and the 'start' costs will fall. Farmers thinking of getting involved should also remember that it takes some 3 years to build up enough individual field data to be confident enough to start varying the inputs to meet production needs, although remedial actions to correct problems can start straight away.

Conclusions

Precision Farming is now with us and is gaining momentum at a rapid rate. It is technology driven, but unlike most new technologies it has no environmental concerns - in fact it is very environmentally friendly in that it aims to target resources to where they will be best utilised, and to reduce waste. All indications at this point are that it will be cost efficient and that the necessary equipment and systems will be developed rapidly over the next few years.

How exactly it will be adopted onto farms is less clear. At present there is a mix of contracted service (as with nutrient mapping and fertiliser application services) and farmer owned systems such as yield mapping. Larger farmers are likely to want to control and own their own farm information, and to be able to make the decisions using all the information gathered, on their own farms. Other farmers may want just to collect the information, use an outside service to make the decisions, and then implement those decisions with his own or contracted machinery, with the outside service monitoring the performance.

In due course one could see agronomist services providing the decision support system; gathering the data together, such as field yield and weed patches from

the farmer, and other data such as nutrient and soil variation and satellite images from other sources (some of which the agronomist may well supply) and processing that information and linking it with other intelligent information sources (such as variety information, weather and disease forecasting) and providing the farmer with treatment maps that are then used to control the farmer's application equipment. Certainly a great deal of development work (much of it government backed) is going into developing and testing highly sophisticated decision support systems at the present time.

Whilst there is a great deal of information available on every aspect of growing arable crops, the development of Precision Farming and the information it is providing is raising a whole new set of demands for further information on the factors that create 'yield'. We do not as yet understand the impact of many of the interactions that go towards growing crops, and so Precision Farming offers huge scope for developing a better understanding of the processes.

Farmers will need to stay attuned to these new developments, and to assist this process and reduce confusion in the mass of information that is being generated the Shuttleworth Precision Farming Alliance was formed in the UK in 1996 to act as a forum for all involved - researchers, manufacturers, service providers and particularly farmers - with regular meetings and a newsletter.

Arable farmers are at the dawn of a new and very exciting era, and perhaps at long last they will be catching up with their colleagues in the dairy industry.

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