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IMPLICATIONS OF PRECISION FARMING FOR AGRICULTURE AND THE FERTILIZER INDUSTRY

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RESUME

Dans cette présentation, les différents constituants de l'agriculture de précision seront décrits et illustrés. Leurs implications pour la communauté agricole et l'industrie des engrais seront examinées. Les constituants comprennent la cartographie des rendements, l'étude des parcelles et les prélèvements d'échantillon de sols, l'emploi des Systèmes d'Information Géographique (GIS) pour traiter des données de nature spatiale, les Systèmes d'Experts dans le cadre de l'agronomie et enfin une application d'engrais cousue main. D'autres services et applications potentielles de ces technologies seront également abordés.

Chacun de ces constituants sera considéré en terme de bénéfice qu'il offre à l'agriculture et à l'industrie des engrais et les limites de chacun seront également décrites.

Pendant la présentation, des images de la mise en oeuvre pratique de certains de ces constituants seront projetées avec une brève description de certaines des technologies utilisées (Système de Positionnement Global Différentiel par exemple). Quelques résultats de cartes de rendement en couleurs produites par les bases de données GIS seront présentés pour la Région Cap Ouest d'Afrique du Sud.

L'objectif de la présentation est de permettre à l'industrie des engrais d'avoir un meilleur aperçu du potentiel de l'agriculture de précision comme outil de marketing et service à la communauté agricole, ainsi que pour illustrer certaines des tendances technologiques à l'intérieur de l'agriculture et la nécessité économique et d'environnement pour ces développements.

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INTRODUCTION

In the beginning, a field was treated as a homogeneous unit ... and so it has been to our present time. But over the past fifteen years or so, precision farming has been emerging as the « new way ». Precision farming is the process in which fields are managed as if comprised of a number of sub-fields (or units). Each 'sub-field' area is treated according to the specific needs of the soils within it. This new trend in agriculture has been motivated by dreams of improved profits (Fixen and Reetz, 1995) and by concerns for the environment (Ogg, 1995). The environmental drive has come from legislation instituted in the USA and in some parts of Europe (including Germany). This legislation has resulted from the excessive leaching of nitrogen, pesticides and other harmful chemicals into the groundwater.

The components needed for precision farming will be described and illustrated in this paper, together with their limitations. The implications of each component for both the farmer and the fertiliser retailer will also be considered, especially since the fertiliser industry might wish to use the potential of precision farming as a marketing tool and service to the farming community.

THE COMPONENTS OF PRECISION FARMING

The essential components required to manage the spatial variability within a field are:

- yield mapping
- field surveying and soil sampling
- agronomic evaluation and
- spatially variable treatment.

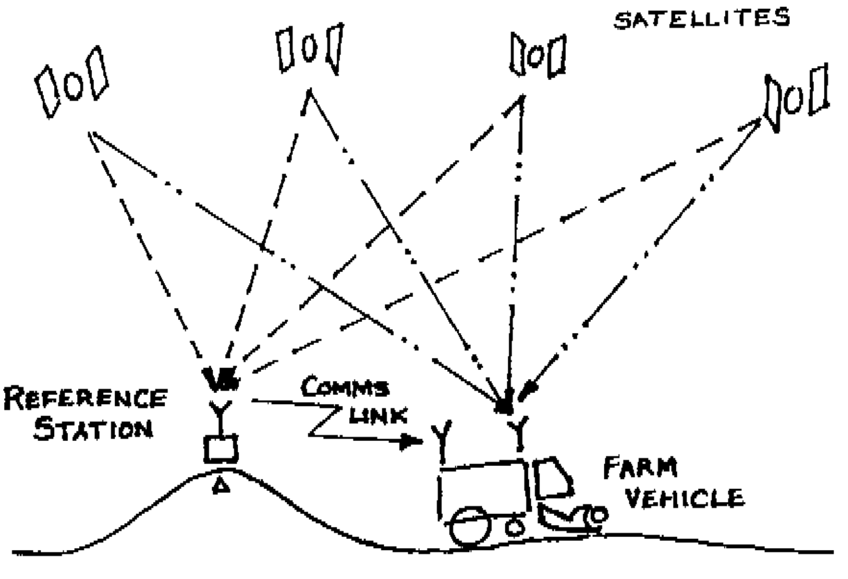
These components are carried out within each phase of the farming cycle.

Yield mapping entails instrumenting a harvester with a means of obtaining ton per hectare information. A positioning technique is required to enable the yield information to be tagged with position information for the generation of a yield map. Additional field data is collected during the surveying and soil sampling component. For this purpose, navigation to specific areas indicated on the yield map will often be required. The data obtained from these first two components is then collated and evaluated by the agronomists. The result is 'site-specific' recommendations that need to be implemented by the farmer in his management of a particular field. This spatially variable treatment of the field could include site-specific fertiliser or trace element application. In this case, the recommendations need to be encoded into a computerised map which will be used to control application rates based on the applicator's position within the field.

A POSITIONING TECHNIQUE

Common to most of the precision farming activities, is the use of a positioning technique of suitable accuracy. In a typical agricultural environment, the differential Global Positioning System (dGPS) has been found to be most suitable (Eatock and Inggs, 1993) and is no longer questioned as the positioning technique for precision farming. Positions with a 30 to 100 metre accuracy can be achieved by placing a GPS receiver on a farm vehicle and tapping into any 3 or 4 of the 24 GPS satellites orbiting the earth. A differential GPS configuration is required to improve that accuracy to 3 to 5 metres for precision farming. Differential GPS requires setting up a « reference station » by placing one GPS receiver at a surveyed position. The reference station will then be able to calculate the positioning corrections to be applied to the information received by the GPS receiver on the farm vehicle. In the case of yield mapping, these corrections can be made after the data is collected at both sites, in other words, using a post-processing mode. Site-specific application however, requires that corrections are made during field operation by means of a communications link, so a real-time mode is needed. Real-time corrections are necessary for controlling the application rates at the correct positions in the field. Figure 1 represents the concept of dGPS.

Figure 1 - The principle of dGPS



YIELD MAPPING

A yield map provides the farmer with an excellent view of his harvest. With his intimate knowledge of his field, a farmer can quickly assess the causes for some of the yield variations, the extent of which may cause him to make macro changes to his farm management practices. On a ridged field, for example, one farmer noticed the drop in yields due to wilpier (weed) infestations on the gently sloping edges of his ridges. Immediately after the harvest, he flattened out his ridges and cut the troughs at sharper angles.

Yield mapping could be a service provided by an independent business established for the purpose, or for example by a fertiliser retailer. The latter could integrate yield mapping into its business as a marketing service to complement its product range.

If you were to set up your own yield mapping service, your choice of GPS, yield measuring and data logging equipment would depend on the nature of your business. There are a number of commercial yield monitoring devices available (Haneklaus et al., 1995; Ag Retailer, 1995) each with their own unique advantages and disadvantages. If, for example, you were to operate your business through a fleet of your own harvesters, you could use a yield meter dedicated to that particular model of harvester. If you were to install the equipment on a range of different farmers' harvesters, then you would need a yield meter that could be adaptable to different machines. If buying commercially available and fully integrated yield mapping systems, they may be tailor-made for the supplier's local market and not meet all of your particular needs. The medium over which dGPS corrections are conveyed, for example, may not be feasible in your specific circumstances.

The yield mapping and site specific application components can share much of the same technology. Nevertheless, even if it is possible to use the equipment in real time mode, it is preferable in practice to use dGPS in post-processing mode for the yield mapping component. This is due to the difficulty in setting up and maintaining the reference stations required for dGPS, keeping within range of the reference station and the cost involved in supplying each yield mapping location with a separate reference station. There are other options for accessing differential corrections, but these may be country or location specific. For example, in some countries a reference signal for differential may be broadcast on FM sub-carrier transmissions as a regional or national service, or a geo-stationary satellite reference station may be available. These options may provide dGPS corrections in real time or after the fact for post-processing solutions.

As with all new technologies, a yield mapping service needs to be flexible as technology changes take place. A commercially available, fully integrated yield mapping system may be less flexible for your particular needs, will probably be costly and may require you to purchase a different system for each component of precision farming. The alternative however, is to have 'in-house' or affiliated expertise to do some of the development and to cope with technology changes.

Figure 2 is an example of a 1993 yield map. It shows the degree of variability that can exist within a field. Our experience has been that yield variation can be surprisingly large; this field looked reasonably uniform before harvesting but yields ranged from less than 0,5 to more than 4,5 tons per hectare (at a resolution of 10 metres by 10 metres).

FIELD SURVEYING AND SOIL SAMPLING

Where yield variations cannot easily be accounted for, further analyses are required. A field needs to be surveyed by a 'trained eye' to account for the yield map variations. Such a survey could identify for example water drainage problems, or signs of pest or weed infestations, etc. GPS guidance may be needed to find certain problem areas indicated on the yield map. At these locations, soil samples can be taken, profiles cut and soil hardness readings made. This exercise could afford the farmers a more scientific explanation for their field's behaviour. Some sectors of the precision farming world (mostly American), consider it necessary to sample soils intensively on a grid pattern. There are differences of opinion as to what size the grid should be. Some believe a sample every couple of acres to be adequate (Keller, 1991), while others believe that sampling needs to be done on a grid size that is within the shortest range of spatial dependence (Mulla, 87) of all the nutrients of interest. Such intensive sampling is required to get an accurate interpolation of the chemical characteristics over the area. Intensive sampling is cumbersome and very expensive to implement practically. Our experience has been that much useful and cost-effective information can be gleaned from selecting some points of high yield and some of low yield from the yield map, and intensively analysing these particular sample points for their chemical and physical characteristics. Typically four points of high yield and four of low yield might be selected on a field of perhaps 30 to 60 hectares in area. In our work, chemical analyses include P, K, S, Ca, Mg, trace elements and pH; physical analyses include soil depth, soil types, hardness using a recording penetrometer, and conductivity. Both the absolute and the comparative analysis results can guide the agronomist or soil scientist to the reasons for yield variations over the field. Of course, analyses carried out after harvesting will lack information about two important factors influencing yield, namely soil nitrogen and moisture status during the growing season.

AGRONOMIC EVALUATION

To facilitate the agronomic evaluation of the collected data and to produce yield maps, software is required. Geographical Information Systems (GIS) are comprehensive software packages that can handle spatial data (i.e. position data with attributes tagged to it). Built into the GIS are graphical features to represent the data, clever algorithms to cross-reference the various 'layers' of data and databases to store the data. As precision farming is an agronomically-intensive procedure, the agronomic evaluations need to be automated as much as possible. Expert systems are well suited to this task (Fisher et al., 1993).

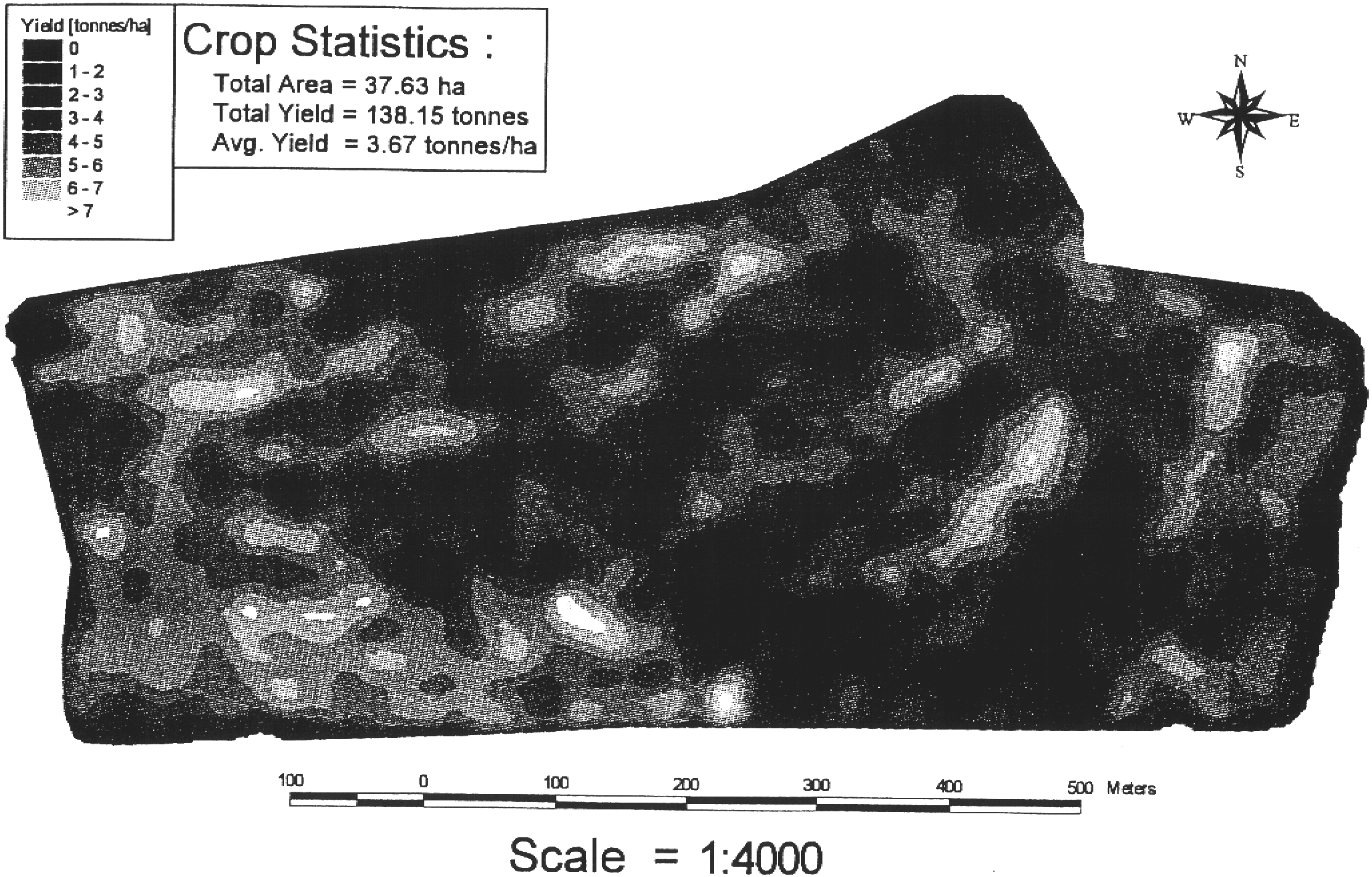


Figure 2 - A 1993 yield map indicating crop yield variations over a 37 hectare field in the Western Cape region of South Africa. Average yield was 3,67 tons per hectare

Specialised expertise is required to customise GIS to your needs. There are various commercial software packages available which employ some features from GIS and expert systems. These packages can be used to produce yield maps or store sampled data in databases or help with the recommendation process. If GIS or expert system development is too daunting, then such packages may be ideal. Again, however, note that these packages may not meet all your needs and it may be necessary to acquire a number of them to fulfil all your precision farming requirements. The compatibility of these modules will need to be investigated.

The fertiliser retailer could use these packages to provide a site specific recommendation service for the farmer. There are, however, additional advantages to setting up a GIS facility. As information is added to the database year after year, detailed customer information will become available which may prove invaluable for market research. The farmer and agronomist will have detailed historical data and layers of yield maps which will help establish trends and models and fine-tune the recommendation process. Area-specific recommendations and statistics can be generated on the GIS. Topographical, meteorological and even remotely sensed images can be added to your system for future research. It seems likely that as farming becomes more hi-tech, suppliers of information services such as these will be in high demand.

SPATIALLY VARIABLE TREATMENT

It may be disappointing to the fertiliser industry that the greatest causes of crop yield variations often do not seem to be the chemical variations in a field. In our experience the factors which influence yields the most are the field's topography especially as it relates to drainage and soil depth, together with the climate (rainfall) experienced during the growing season. Other physical effects, such as poor cultivation practices leading to sub-surface compaction layers (pans), have significant effects on the crop yield. One may also find that soil type and composition show a good correlation with crop yield. Only after all these effects have been eliminated, may one begin to see the spatially variable effects of P, N and K and micro-nutrients. Priorities for spatially variable treatments in farm management practices will also tend to follow the sequence given above. With all these different factors affecting yield, improvements in crop yield brought about by precision farming practices may be hard to quantify or prove in the natural agricultural environment. Some faith in the science of agronomy (i.e. that recommended treatments are beneficial) may be needed!

The field shown in Figure 2 for 1993 and achieving 3,67 tons per hectare then was again yield-mapped in 1995 (Figure 3). This was a good rainfall year for wheat and moreover this field had been planted to medics (a leguminous fodder) for the 1994 season. Improved yields were to be expected. Neighbouring farmers however, still only achieved a fairly usual 3.5 tons/hectare or so compared with this field's 5.31 tons/hectare average. As a result of studies prompted by the 1993 yield map, the eastern side of the field was found to have a severe sub-compaction layer due to inadequate cultivation. Zinc was also found to be deficient in three quarters of the field covering the entire poorer yielding eastern half of the field. Three alternate contours were deep cultivated on the eastern side of the field to break up the compaction layer, and extra zinc was applied to the field. The result was a higher yielding eastern half of the field with much less variation over the extent of it. At $220 per ton of wheat, the yield improvement over the 37,4 hectares was worth $13 494. Even if only half of this improvement was contributed by yield mapping and the ensuing recommendations, the benefit to the farmer far outweighed the cost ($8 per hectare for the yield mapping service plus the cost of deep cultivation and zinc).

Precision farming has great potential as a service that can assist the marketing of fertilisers. Spatially variable treatments in the form of site-specific fertiliser applications will still be beneficial, even if strong yield-nutrient correlations are not forthcoming. Apart from replenishing areas where essential nutrients are deficient, fertilisers could be applied in accordance with the potential of the soil. A major benefit of these spatially variable treatments to the farmer is more cost-effective operation - using for example less fertilizer where soils are shallow or prone to waterlogging.

Another benefit is improved ground water quality, especially if pesticides, herbicides and nitrogen (Talma et al., 1995) can be variably applied where they are most needed so that they can be properly absorbed or utilised. Spatially variable fertiliser application may not result in larger fertiliser orders for any particular field, but it may help to secure the order. The products will be more efficiently distributed in accordance with the site-specific yield potential.

The implementation of a commercial spatially variable fertiliser application service requires a positioning accuracy that only differential GPS can provide, as well as real-time differential corrections. Before setting up a network of reference stations, it is advisable to find out if your country has or is planning a subscription service for the real time broadcasting of dGPS corrections.

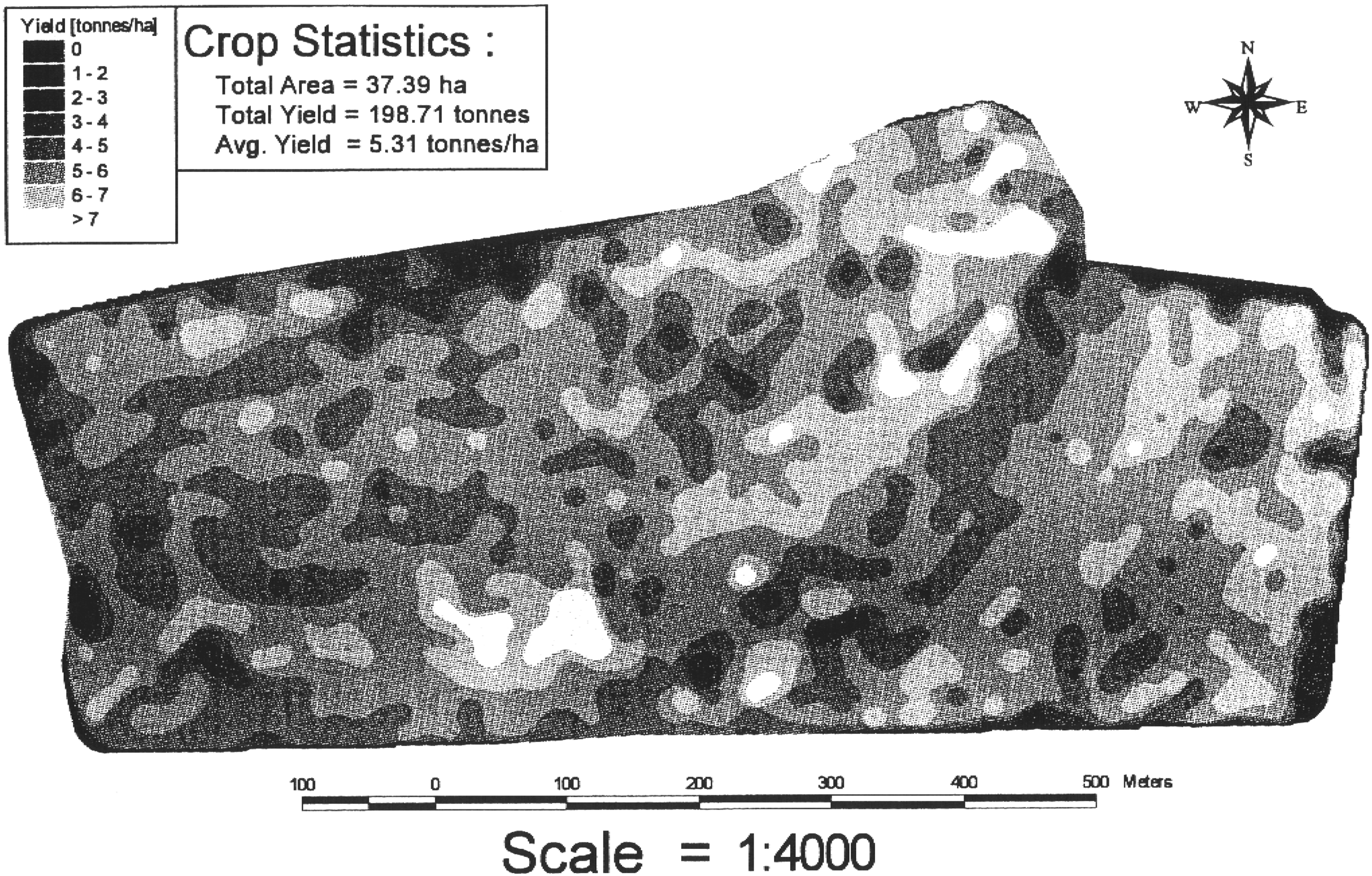


Figure 3 - A 1995 yield map indicating crop yield variations over the same 37 hectare field in the Western Cape region of South Africa. Average yield was 5,31 tons per hectare.

OTHER POTENTIAL SERVICES OR COMPONENTS OF PRECISION FARMING

Precision farming could be very big business in the future. The technologies which could be applied to precision farming are limited only by the imagination. Differential GPS can be used to help navigate over fields to facilitate night time fertiliser applications. The collection of weed infestation data could result in the spatially variable application of herbicides. The farmer could subscribe to information stored in the GIS databases directly through the Internet. Remotely sensed images can be used to provide valuable information on soil types and water drainage patterns and can be integrated into your GIS-expert system recommendation process. Regular updates of biomass estimates from remotely sensed images could be used to help identify and prevent problem areas. These are but a few examples.

SUMMARY AND CONCLUSIONS

The essential components of precision farming have been described. Some opportunities and limitations, for both the farmer and fertiliser retailer, have also been expanded upon. The potential of the various components of precision farming have been expressed with the view to using them as a marketing tool for the sale of fertilisers.

Precision farming technology has so much to offer the agricultural industry. Precision farming in its entirety may initially be suited to a relatively small market of progressive farmers, while more conservative farmers may remain sceptical about hi-tech farming methods or find them fairly intimidating. However the drive to have a competitive edge will surely catalyse their acceptance.

The retail fertiliser industry is ideally positioned to help implement precision farming. It is in regular contact with many farmers and has the products to help improve crop yields. The core requirement determining the success of precision farming is sound agronomic expertise. Should a fertiliser retailer have agronomic services as part of its business, it will be well qualified to venture into the precision farming market. The last ingredient to the mix is obviously the technology. Careful decisions are required and access to technological expertise is essential to provide the flexibility you will require in order to add a precision farming element to your customer service package.

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