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PA—Precision Agriculture

An Economic Analysis of the Potential for Precision Farming in UK Cereal Production

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The results from alternative spatial nitrogen application studies are analysed in economic terms and compared to the costs of precision farming hardware, software and other services for cereal crops in the UK. At current prices, the benefits of variable rate application of nitrogen exceed the returns from a uniform application by an average of £22 ha^{-1} The cost of the precision farming systems range from £5 to £18 ha^{-1} depending upon the system chosen for an area of 250 ha. The benefits outweigh the associated costs for cereal farms in excess of 80 ha for the lowest price system to 200–300 ha for the more sophisticated systems. The scale of benefits obtained depends upon the magnitude of the response to the treatment and the proportion of the field that will respond. To be cost effective, a farmed area of 250 ha of cereals, where 30% of the area will respond to variable treatment, requires an increase in crop yield in the responsive areas of between 0·25 and 1.00 t ha^{-1} (at £65 t^{-1}) for the basic and most expensive precision farming systems, respectively.

Introduction

The potential benefits of managing crops using precision farming techniques include:

(1) the economic benefit of an increase in crop yield, and/or a reduction in inputs, *i.e.* seed, fertiliser and agrochemicals, and
(2) the environmental benefit from a more precise targeting of agricultural chemicals.

Over the past decade, the technology has become commercially available to enable the farmer to both spatially record the yield from a field (Murphy *et al.*, 1995; Birrell *et al.*, 1996; Stafford *et al.*, 1996) and vary both seed and fertiliser rates on a site-specific basis. Significant advances have also been made (Miller & Paice, 1998) to permit the spatial control of weeds on a site-specific basis by varying the dose rate of herbicides depending upon the weed density. However, the benefits of either an increase in yield and/or a reduction in fertilisers and agrochemicals have to be offset against the costs of investing in specialist equipment to enable yield maps to be produced and variable applications to be implemented. The aim of this paper is to address these issues.

A range of potential benefits have been reported, from various combinations of different variable application rate practices. Earl *et al.* (1996) postulated a potential benefit of £33·68 ha^{-1} could be possible combining variable nitrogen application and targeting subsoiling to headlands for a crop of wheat in the UK, when wheat prices were £125 t^{-1}. Increases in returns exceeding £57 ha^{-1}, when maize seed rates were varied according to soil depth, were reported by Barnhisel *et al.* (1996). Measured returns in the range of −£11·14 to £74·09 ha^{-1} were reported by Snyder *et al.* (1998) on irrigated maize in the USA. Schmerler and Basten (1999) measured an average benefit of £38·60 ha^{-1} when growing wheat on a farm scale trial where both seed and agrochemical rates were varied.

Studies conducted by James (2000) investigated the benefits of using historic yield data as a guide to varying nitrogen application, for winter barley on a field with both clay loam and sandy loam soil types. Data from the first years results, *i.e.* 1997 harvest reported by Godwin *et al.* (1999), indicated that an economic benefit of £27·60 ha^{-1} could be possible. This analysis was based

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upon spot measurements of the yield rather than those for the complete zone in either soil type, however, it is generally indicative of the potential benefits. A further part of the experiment applied nitrogen based upon the calculated value of the most economic rate of nitrogen (MERN) and nitrogen rate for maximum yield (NMAX) in the previous year, after the principles developed by Kachanoski *et al.* (1996). The main conclusions of this research were that:

(1) the maximum yield of the response curve for each soil type (NMAX) occurred at the same application rate in each growing season,
(2) the MERN for each soil type were not significantly different, and
(3) based on yield information from previous yield maps, there was no simple variable rate application strategy that provided a yield or economic benefit compared to a uniform application of nitrogen fertiliser.

The work reported in Godwin *et al.* (1999) also demonstrated the effect of the nitrogen/grain price ratio on the economic return to variable application of nitrogen and that at 1999 prices of £80 t^{-1} for grain and £0·30 kg^{-1} for nitrogen the MERN rates were 15 to 30 kg ha^{-1} lower than NMAX.

The costs of implementing precision farming practices have been reported by a number of researchers. Earl *et al.* (1996) estimated the costs of yield map production and the ability to apply fertiliser on a site-specific basis to be £10·46 ha^{-1} for an arable area of 250 ha, at 7% interest rate amortised over a 5-yr period in the UK. A later estimate of £7·81 ha^{-1} was made by James (1998), for a similar system, the difference in cost being the reduction in hardware and software cost over the 2-yr period and the removal of the differential global positioning system (DGPS) costs. In the same year studies, in the USA, Snyder *et al.* (1999) estimated the cost of yield mapping and variable rate equipment, for nitrogen application for two fields of 49 and 64 ha as £8·50 ha^{-1}. Studies by Schmerler and Basten (1999) reported costs of £15·46 ha^{-1} (49DM ha^{-1}) for a 7100 ha German farm, of which 3900 ha was suitable for site-specific management. The major reason for the higher figures reported by Schmerler and Basten (1999) was the cost of the equipment variably applying herbicides in addition to variably applying seed rate and fertiliser.

This paper

(1) examines the increase in revenues that have been achieved through the use of precision farming practices during a 3-yr study of five fields in cereal production in Southern England, where
    (a) the effect of variable nitrogen application to both barley (Welsh *et al.*, 2003a) and wheat (Welsh *et al.*, 2003b) using historic yield map and real-time shoot density data have been investigated,
    (b) significant yield improvements have been made using 'real time' nitrogen management in the wheat crop based upon variations in crop canopy (Wood *et al.*, 2003a), and
    (c) improvements to common crop management problems [e.g. waterlogging, rabbit damage and fertiliser application error, Wood *et al.* (2000)] can be identified and corrected;
(2) estimates the costs of upgrading farm equipment, at the time of purchase, to a level that enables precision farming techniques to be practised; and
(3) compares the costs/benefits and analyses the potential returns from adopting precision farming technology for given farm sizes and levels of variability.

2. Potential benefits from adopting precision farming

The potential benefits considered in this paper arise from:

(1) studies to determine the spatially optimum nitrogen application rate using
    (a) historic yield, and shoot density (Welsh *et al.*, 2003a and 2003b for barley and wheat, respectively), and
    (b) canopy structure (Wood *et al.*, 2003a for the wheat crop); and
(2) identifying and correcting common site-specific problems associated with crop management.

2.1. *Historic yield*

Variation of nitrogen according to historic yield trials were conducted over a period of 3 yr in three fields, Trent Field, Twelve Acres and Far Sweetbrier, using both variable and uniform application rate strategies (Welsh *et al.*, 2003a and 2003b). The variable rate strategies were divided up to give the following treatments.

2.1.1. *Historic yield 1*

The historic yield (HY1) strategy was where the high yield zone received 25–30% more nitrogen, the average yield zone received the standard nitrogen rate, and the low yield zone received 25–30% less nitrogen.