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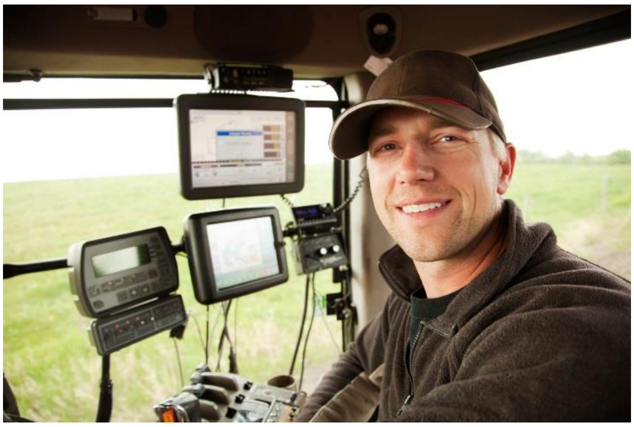
Precision Farming



Precision farming uses technology to improve efficiency. It offers benefits for yields, profits and the environment. However, uptake by farmers has been slow. This POSTnote describes precision farming methods, adoption and factors influencing it, and future practices.

Overview

- Precision farming combines technology with livestock and crop science to improve agricultural practice.
- Benefits include improved animal health, greater crop yields and reduced environmental impacts.
- Many UK farmers feel the costs of the technology are a barrier to uptake. The use of some techniques is more prevalent in northern Europe, Australia and the US.
- Automation of repetitive tasks reduces the need for some jobs, but precision farming does not replace humans fully, and creates demand for high skilled work.
- Data collected in precision farming has great value and potential, but it is not always clear who owns and has rights to use it.

What is Precision Farming?

Precision farming techniques help farmers to select and apply the right inputs at the right time and at the right scale.[1] For example, farmers can target fertiliser where it is most needed, rather than apply it uniformly across the whole field, reducing costs and overall use. More efficient use of inputs can sustainably intensify food production: optimising yields while reducing environmental impact. 'Precision farming' and 'precision agriculture' are terms often associated with crop production techniques developed since the 1980s.[2] The principles are also applied to animal rearing, known as 'precision livestock farming'.[3]

Interest in precision farming has slowly grown in the last two decades as it becomes easier to use and to access advice and services.[4] Farmers' motivations to adopt the techniques include saving costs, increasing production and improving quality.[5] Crop producers save costs by more efficient use of inputs like pesticides and fertilisers. Dairy farmers save around 20% on labour using robotic milking systems.[6] However, substantial investments are required, particularly in technology, and returns are hard to predict because the cost of inputs and the price of produce are volatile.

The UK Agri-Tech Strategy (Box 1) was launched in 2013 to encourage innovation in agriculture. Combining UK research strengths in areas such as soil and crop science, robotics and ICT could lead to products and services for export.[7] Some precision farming products developed under the strategy have been commercialised, such as Silent Herdsman, a cow health monitoring system.[8] However, researchers at Harper Adams University, Shropshire, are concerned that partners in the UK have not been found to develop and build autonomous farming robots based on research funded by the strategy.[9] This POSTnote covers precision farming in crop and livestock production, the benefits and challenges of these approaches and possible future techniques.

Box 1. UK Strategy for Agricultural Technologies

In 2013, the Coalition Government launched the Agri-Tech Strategy, aiming to make the UK a global leader in agricultural technology, innovation and sustainability.[10] It recognises that work to translate research into practice has been underfunded in the UK, which has harmed competitiveness in agriculture. The strategy includes:

- An Agri-Tech Catalyst fund, with Government investment of £70 million. The Catalyst supports innovative projects that lead to new products with co-investment from the private sector.
- Creation of a small number of new Centres for Agricultural Innovation, with £90 million of Government money. These aim to bring together business and academics to help industry exploit new technologies. The first, opening in Autumn 2015 at Rothamsted Research, Hertfordshire, will study data from across the food chain to seek insights into best practice and measure sustainability. Details of the remaining centres are yet to be announced.

Precision Farming Techniques

Crop Production

Precision farming methods in crop production use satellite positioning to locate vehicles within fields. Global positioning signals are adequate for some techniques, but advanced practices need accuracy to within 2 cm, requiring installation of a local base station. Satellite positioning enables:

- automatic control of agricultural vehicle steering to reduce overlaps in field operations (Box 2)
- site-specific crop management: measuring how conditions vary within a field and adjusting treatments for contrasting areas (Box 3)
- controlled traffic farming, which reduces damaging soil compaction by ensuring machinery drives only on specified wheel tracks (Box 4).

Livestock

Electronic Identification (EID) facilitates precision farming of livestock.[11] Small devices fitted to animals contain chips read by detectors using radio frequency identification. EID is mandatory for sheep in the UK.[12]

A basic form of EID is an ear tag, which aids record-keeping when moving animals between sites or vaccinating. EID also allows automation; for instance, robotic milking systems (Box 5) use it to monitor animals' milking frequency and yield. Automated gate systems can sort animals into pens by sex, breed or weight using EID, reducing stress and labour.[13] Another element of precision livestock farming is the monitoring of animals (Box 6). A range of sensors are available that incorporate EID and collect data from animals.

Adoption of Precision Farming

Extent of Adoption

Statistics on the use of precision farming in the UK are not generally collected by Defra, but some data are available:

- The use of methods for site-specific crop management (Box 3) in England rose from 2009 to 2012 (Figure 1).[5]
- Controlled traffic farming (Box 4) is used on a small proportion of suitable farms (estimated at less than 5%).[7]
- Robotic milking systems are used for approximately 5% of UK dairy cows, according to industry experts (Box 5).[14]

The use of some precision farming techniques is more common in other countries than in the UK. Robotic milking systems are most common in the Netherlands and Scandinavia.[23,24] A 2014 survey found that 83% of Australian grain growers use GPS steering (Box 2), and 34% operate controlled traffic systems (Box 4).[25] Meanwhile a survey of dealerships across the US estimates that GPS steering is used on 68% of suitable land.[26] Greater UK uptake of precision farming would bring multiple benefits. However, farms that use older methods and those on less viable land may struggle to compete.

Box 2. Automatic Control of Agricultural Vehicles

When applying treatments to a field, satellite positioning can help the driver to steer accurately. This reduces overlap when treating the field in parallel strips, saving 6-10% of inputs, fuel and time, and reducing driver fatigue.[15] Two systems can aid steering: 'lightbar' displays show steering adjustments for the driver to make, whereas 'autosteer' systems steer automatically.[16]

The most hi-tech sprayers have nozzles that automatically switch off to avoid unwanted application when passing over areas previously covered or outside of the cropped area. Known as 'automatic section control', the technology can save around 9% of sprays,[17] and is fitted on about 75% of new machines.[7]

Box 3. Site-Specific Crop Management

Mapping

Conditions often vary between different parts of a field.[18] Measurements taken throughout fields are linked to their satellite-referenced position to make maps showing variation in soil conditions, crop growth or yields. To create these maps, a service sector has developed providing soil analysis and imaging of fields from satellites, aircraft or UAVs (drones). Alternatively, farmers can measure crop growth and yield throughout a field with sensors mounted on agricultural vehicles. Using maps, farmers can divide a field into zones with distinct characteristics and adjust treatments for each zone.

Variable Rate Application

Variable rate application devices enable farmers to adjust the delivery of seeds, fertilisers, herbicides or other inputs in different parts of the field.[19] Software predicts the optimum amount for each part of the field, using either maps of variation in the field or data gathered in real-time from sensors on farm vehicles. By adjusting the delivery of inputs to the requirements of different parts of the field, total inputs are often reduced while maintaining yields.[20] Savings can be around 10% for nitrogen fertiliser,[21] which is the largest input in growing crops.[22]

Factors Limiting Adoption

Financial Investment

Adopting precision farming usually requires significant investment. A survey of 1,454 farms not using it found the most common reason was the high initial costs or low cost-effectiveness (47%).[5] While financial benefits are a key factor in the uptake of innovations by farmers,[27] it is difficult to predict returns on investment, as they may depend on:

- factors that vary from farm to farm, such as field size
- the skill-level and training of the farmer
- profit margins that can fluctuate with market prices for produce and the costs of inputs like fuel, fertilisers and herbicides.[28]

This uncertainty tends to make farmers more cautious about making investments.[29,30] Costs for technology have decreased, and if this continues, adoption will likely rise.[31] Grants for up to 40% of the cost of some equipment were available to crop and livestock farmers in England through a

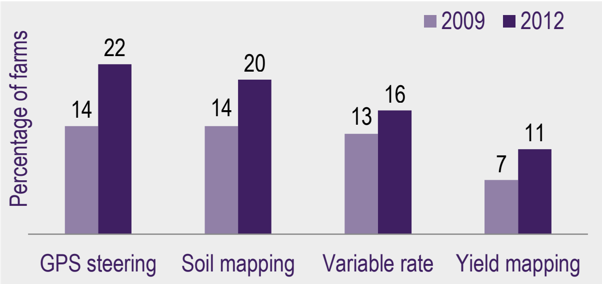


Figure 1. Use of precision farming in England.[5]

Box 4. Controlled Traffic Farming
The wheels of farm vehicles typically cover 55-85% of a field's surface each year.[32] They compress soils, reducing crop yields and causing environmental problems (POSTnote 502).[33] Tilling to break up compacted soils mechanically uses large amounts of fuel.[34] Controlled traffic farming restricts machinery to driving only on fixed routes, covering 15-20% of the surface.[35] It requires accurate satellite positioning. As well as avoiding the environmental problems of soil compaction and considerably reducing energy for cultivation, yields can be 5% higher.[36] Controlled traffic systems need careful planning to position vehicle routes. All vehicles used on the field must have a standard width between wheels. Sprayers cover multiple rows, so they need to have the appropriate width to avoid overlapping or missing parts of the field when driven along every second or third row.

scheme funded by the CAP (EU Common Agricultural Policy).[37] Applications closed in June 2015. A new scheme, opened in summer 2015, supports costs for collaboration between farmers and researchers, but does not cover the purchase of equipment.[38]

Technical Challenges
One obstacle to precision farming is a lack of compatibility between software produced by different manufacturers. Combining data collected by different systems can be difficult; for instance, integrating measurements of animal movement and rumination.[39] Data connections between equipment, smart phones and computers are increasingly used to monitor vehicle status and update instructions.[40] Limited mobile data coverage and rural broadband restrict the use of some technologies, and progress in these areas has been slow (POSTnote 494).

Characteristics of Farmers and Farms
Individual characteristics of farmers may influence their decisions about whether to adopt precision farming. For instance, their personal attitude to risk may play a role, as may their familiarity with computers, their level of formal education, or the number of years they have until retirement over which to recoup investments.[27]

Adoption rate is also influenced by characteristics of farms: for example, larger size is associated with faster adoption, as the fixed costs are spread over a larger area.[41] Some sectors are likely to adopt precision farming faster than others. Crop and dairy producers have well-developed technologies available and see quick returns from investment. By comparison, beef and sheep farming generates lower incomes, so there is less incentive to develop farming technologies for these sectors and, as a result, there are fewer technologies available to these farmers.[42]

Box 5. Robotic Milking Systems
Use of robotic milking systems is increasing.[43] These systems have scanning lasers that detect the position of teats, attach gently but firmly, and detach after milking, without human intervention. Cows voluntarily enter milking stalls, where they are milked an average of 2.5-3 times per day.[23] Increases in milk yields of 2-12% have been reported, but other studies have found no effect on yield compared with conventional parlours.[44] Systems can monitor udder health and milk quality, providing detailed information on individual cows.

Box 6. Animal Monitoring
Beyond the basic ear-tag, more complex devices provide electronic identification while collecting data from individual animals. Devices include sensors fitted around a leg, the neck or within the rumen (the first stomach of ruminant animals). Sensors monitor movement, time spent lying and standing, in-ear temperature and acidity within the rumen. Information is transmitted when animals are within range of a detector. As no two animals are the same, software compares data from each animal with values predicted for that individual.[45] Sensor data can indicate disease, injury or dietary imbalance. Sensors also detect when cows come into oestrus, to avoid missing the time window for fertilisation.[46]

Pigs and poultry have a lower financial value per animal than cows, so monitoring of individual animals is less economic in these sectors.[47] Instead, continuous monitoring at the group level can be used to indicate potential problems. Microphones that monitor indoor-housed pigs acoustically can predict the presence of disease by detecting a difference in the sound of the animals' cough.[45] Visual analysis is used to assess the distribution of flocks of chickens. It can also be used to detect when the proportion of lame birds is above acceptable levels, or abnormal behaviour that might indicate problems with the delivery of food or water.[48]

Knowledge Exchange
Access to information is vital if farmers are to make use of innovations. As farmers have diverse needs, attitudes and capabilities, a range of approaches rather than a single method of delivering information is required.[49] Most farms obtain information from agronomists, personal networks and specialist media, such as magazines.[5]

Skills and Complexity
Some precision farming methods such as autosteer (Box 2) and robotic milking systems (Box 5) require little training to use. Conversely, methods like site-specific crop management (Box 3) require knowledge and training to analyse data and determine management practice.[50,51] In a survey of farms that do not use any precision farming methods, 27% stated that they are too complicated.[5] The lack of agronomists trained in interpreting data limits the adoption of precision farming.[4]

Impacts of Adoption
Environmental Benefits
In addition to cutting costs, efficiency reduces some of the environmental impacts of food production. For example, the production of nitrogen fertiliser is energetically intensive, and if over-applied causes harm, either through conversion to the greenhouse gas nitrous oxide, or by polluting watercourses (POSTnote 486 and 478).

Implementing controlled traffic farming (Box 4) improves water infiltration into the soil. This reduces surface run-off that contributes to watercourse pollution, cuts nitrous oxide emissions[52] and lowers flood risk. Lessening soil compaction also reduces the energy needed to cultivate soil, with fuel savings of around 60%.[34]

Livestock production contributes to methane emissions (POSTnote 453). Animal data could be used to tailor diets for individuals, to maximise nutrient use and reduce greenhouse gas emissions.[53]

Animal Welfare

Aspects of precision farming can contribute to animal welfare. Systems identify individual animals suffering from injury or disease to ensure that they receive care quickly (Box 6). This is particularly important as lameness and mastitis are common in European dairy herds.[54] Signs of health problems seen at the abattoir, such as bruising or the presence of parasitic liver-flukes, can be relayed to the farmers more easily through electronic identification. The adoption of robotic milking systems should also allow more time to be spent observing animals.

However, technology is not intended as a replacement for humans with good stockmanship skills, and cannot be relied upon to identify problems. Precision farming could pose risks to animal welfare if farmers increase herd sizes rather than spending more resources on their existing stock, or if they are over-reliant on systems that suffer a failure.[55] Furthermore, precision farming cannot rectify issues arising from the intensive rearing of animals. For example, in chickens the breeding of fast growing animals with low activity levels contributes to lameness and dermatitis, as animals spend long periods in contact with litter.

Jobs

Automation reduces the need for labour in some sectors. Certain technologies, notably autosteer (Box 2) and robotic milking systems (Box 5) can improve working conditions, reduce fatigue and perform repetitive tasks.[56] Robotic milking systems make milking less arduous, particularly for farmers with back, neck or shoulder problems, which could enable older farmers with physical problems to continue farming (POSTnote 391). In addition, the systems offer dairy farmers a more flexible daily schedule, without the need to work at fixed hours every day, though they must be on call to fix technical issues.[57]

Future Precision Farming Methods

The pace of innovations in farming shows no signs of slowing. The future will be influenced by developments in precision farming. In addition, the potential of precision techniques for managing grasslands, which constitute around 60% of UK farmland,[58] is yet to be fully explored.[59]

Record-keeping and Data Collection

Precision farming equipment automatically stores records about fields, animals and treatments applied. In future, farmers who choose to share records could demonstrate regulatory compliance with less paperwork, or allow supermarkets and consumers to view information about the provenance of food.[60] Currently, farmers may choose to share technical data, allowing 'benchmarking': comparison of production and costs with others in the region to identify best practice and improve their performance.[61] Data analytics could identify treatments needed and the best time to apply them on specific farms, incorporating local weather information (Box 7).

The sources of data available to farmers are also likely to increase. For example, sensors placed in fields could transmit constant information on soil moisture and temperature, or the presence of disease spores to help farmers plan when to sow or spray crops.[62] Sensors in smart phones, combined with 'apps' for agriculture offer further opportunities to collect data.

Box 7. Data in Agriculture

Data collected in precision farming, when analysed from many farms, offer opportunities to enhance production. Possibilities include:

- assessing the risks of disease and pest outbreaks in real time
- identifying treatments to maximise crop yields in each area
- assessing the suitability of crops for specific areas under climate change.

The UK Government has funded a new centre to address some of these questions as part of the Agri-Tech Strategy (Box 1). It will enable easier access to data sets from across the agri-food sector and provide modelling and analysis services to industry.

It is not clear who owns data generated through precision farming: farmers, the agronomists or service providers that create data, or machinery and software producers. A key challenge for the new Centre is therefore to build trust among these communities and to demonstrate that the real value in data is in using it to increase profitability. Data collected by providers of farm management software and machinery could be pooled for a range of uses. However, farmers in the US have already voiced concerns about the unregulated use of data from their businesses. In June 2015, Defra announced it would release over 8,000 data sets, including satellite data, aiming to encourage enterprise and increase productivity.

Robotic Farming

The automation of some tasks is possible with robotics. For example, tractor-towed systems are already available that use cameras to detect weeds and remove them mechanically from salad crops when towed by a driver.[63] Autonomous robots are under development that may be used to kill weeds mechanically, with lasers or by placing tiny doses of herbicide on their leaves.[64] This would greatly reduce or eliminate herbicide use and reduce herbicide resistance (POSTnote 501).

Virtual Fencing

Virtual fences allow control over the movement of freely grazing animals.[65] Collars worn by the animal emit a warning tone if a boundary is approached. Boundaries may be a set of coordinates, updated remotely, to which proximity is monitored with satellite positioning. Animals must be trained to avoid crossing the boundary, using either electric shocks from the collar or food rewards. Virtual fencing provides a flexible way to move animals to the best pasture, which could be identified by aerial imaging. The system could also guide animals away from water courses and other environmentally sensitive areas and towards shelter if bad weather is forecast.[66]

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