Easton&OtleyCollege

A Study Tour to Iowa, USA

FINAL REPORT TO THE FARMERS CLUB

Purpose of tour:
To up-skill and update knowledge on agricultural precision management systems in Iowa, USA and how they are taught.

By Dr Tony Wilson

Acknowledgements

I would like to extend my thanks to Dennis Friest, David Hansaker and David Granzow for allowing me to visit their farms and for answering my questions with patience and grace. Moreover, I would like to express my gratitude to Luke James of Ag Leader, Dustin Hahn of Kinze Manufacturing, Christopher Murphy of Iowa State University as well as the kindness shown by employees of Pinnacle, Monsanto and the USDA, for taking the time to explain what they do and why it is important.

The author would especially like to thank Dave Nelson for his kind invitation, enthusiasm for the tour and for putting me in touch with Kelvin Leibold and Kevin Butt. Both Kelvin and Kevin made the trip of phenomenal value to me professionally and I will always have a debt of gratitude to them both that I fear I can never repay. Built up over three decades, Kelvin's knowledge of Iowa farming and its rural community is extensive and he used that knowledge to put me in touch with a number of significant and important people in the precision agriculture. Moreover, Kelvin accompanied me on many visits, introducing me to three of the four farms I visited and provided valuable insight as to the motivation behind the adoption of the new precision technologies in Iowa.

I would also like to especially thank my colleague in agricultural education, Professor Kevin Butt, whose kindness and willingness to ensure that I was well looked after during my stay is highly appreciated by both me and my family! I gained invaluable insight not only into agricultural education in community colleges in the USA, but in how the young farmers groups operate, the importance of county and state fairs and just how good mid-west food is! Thanks buddy.

Contents

1. **Introduction**

In July 2015, with monies from the Farmers Club Educator's Bursary fund, I undertook a study tour of Iowa State with the express intent to research the use of precision agricultural technologies and the role of companies, extension services and educational establishments in the precision agriculture business. The companies visited are involved in data application, machinery manufacturing, biotechnology and environmental service. The range and depth of precision technologies being developed was impressive and in particular, the software platforms intended to collate and connect different data sets. These data sets include yield, soil, nutrient and topographical data. Having collected data for many years now, Iowan farmers have embarked upon a programme of normalising the data, connecting it together and developing management zones. Great work has been done in the development of these in-field management zones to inform management decisions or prescriptions for seeding rates, agrochemical inputs and even varieties. These prescriptions are fully automated with the use of planters and spreaders capable of responding to satellite signals indicating position and relating them to the prescribed management zones. There is debate about the return on investment, the role of research and education in precision technologies and there is both opportunity and uncertainty in this sector.

This report describes the tour and the various organisations visited, as well as conferences attended. It explores the precision agriculture landscape in the mid-West USA and reviews the implications of the findings for agricultural education in the UK.

2. **Farmers**

The use of precision technologies and big data in farming is the focus of this report and to that end it seems sensible to start this report with the farmers I visited and their farms.

2.1. Dave Nelson, Nelson Family Farms

Dave farms near Fort Dodge in Iowa and the Nelson have farmed land in the locality since 1886, making Dave and his family sixth generation farmers. The Nelsons farm a two course maize (corn) and soybean rotation and have diversified their business to include a fertiliser, sprayer and farming equipment dealership called Brokaw Supply. It is clear that there are three broad foci of the farming operation: a sustainable business, good stewardship of the land and the use of new technologies to enhance productivity.

Nelson Family Farms consists of Gary and Karma Nelson with their son Dave and his wife Fonda. It is very much a family operation, which is nonetheless forward thinking, embracing of both innovative farming and business practices to enhance productivity and the farmed environment. The farm size has increased rapidly since 2008 when Dave returned to the business, from 323ha to 1620ha today. 70% of this land is put down to maize (corn) with the remaining 30% planted with soybean.

The soil type is rich black loamy Wisconsin glacial till (NRCS, 2016) otherwise termed 'Black Gold'. It has a pH6.7, phosphorus levels of 25ppm, potassium levels of 170ppm and organic matter at 3.5%. The land is very flat and as a consequence water has a tendency to pool in certain areas of the field. Therefore, much of the land is drained with tiled drainage to remove excess water that enables the crop to take up nutrients and water to the levels it needs (see Figure 2.1.1 for a satellite image of Dave Nelson's Farm).

Figure 2.1.1 The Nelson Family Farm near Fort Dodge, Webster County, Iowa (Google Earth).

The farm is proactive in pursuing sustainable practices to improve and enhance environmental conditions, particularly soil condition and structure (commonly referred to as soil health). The issue of soil loss and degradation has been of great concern in Iowa and it has been highlighted that full-inversion or heavy tillage approaches in the Autumn (Fall) combined with heavier rainfall patterns has led to top soil run-off and a reduction of top soil levels from 30 – 50cm in 1850 to 15 – 25cm in 2014. This alarming rate of degradation needs to be arrested so that future generations can continue to farm and produce food. Although there are no legal limits to fertiliser applications, the Mississippi River Basin authorities have developed a water quality strategy that encourages farmers to apply less nitrogen and phosphate. This is based on the three principles indicated in Figure 2.1.2: right source, right place, right rate and right time for the crop plant. The outcome of this approach is that more of the available nutrient will be taken up by the plant and not leached or form particulates with the soil that can run-off during heavy rain. This approach has led to more and more farmers adopting sustainable tillage approaches and precision management systems, which when combined provide a powerful array of tools that reduces soil degradation, reduces inputs, boosts yields and consequentially improves profitability.

Figure 2.1.2 Nutrient application taking place on the Nelson Family Farm. The image shows the application of anhydrous ammonia (NH_3) and phosphate.

(Dave Nelson)

On some fields, a strip tillage approach is adopted Strip tillage has been defined by the Conservation Technology Information Centre (CTIC) as a modification to a direct drilling system where disturbance of less than one third of the total field area is cultivated (Morris, 2016). This, as the name suggests, is done in strips and these cultivated strips need to be both straight and an exact distance apart. GPS-based guidance systems are used for this operation involving the most precise method, real time kinematics (RTK). Strip tillage, referred to as conservation tillage in the USA, combined with variable rate nutrient application technologies, can reduce soil disturbance encouraging increases in soil biota activity, improve soil organic matter content, reduce water loss and improve soil water holding capacity, and reduce fuel, machinery and labour costs. The overall benefits of this tillage approach on the environment are highly positive, reducing both run-off and leaching of nutrients leading to an improvement in water quality.

Figure 2.1.3 Conventional or reduced tillage system used in Iowan cropping systems during the Autumn. This is a combination cultivator using discs and aggressive tines.

(Dave Nelson)

The farm uses a more conventional non-inversion tillage approach where a disc/aggressive tine system is pulled through the ground in the Autumn and this is allowed to lie over the winter. The crop residue including the previous crop's roots keeps the soil on the field during rain, but the soil is exposed to the hard frost and extreme cold of the mid-west winter. This freeze-thaw effect helps break up the soil making it more friable and amenable to further cultivation in the spring resulting in a good fine seed bed for planting (see Figure 2.1.4).

Figure 2.1.4 Conventional or reduced tillage system used in Iowan cropping systems during the Spring. This is a combination cultivator using tines, spring tines and packers/rollers.

Dave Nelson

A cover crop of ryegrass is employed in this system to further decrease run-off, maintain soil structure, increase the organic matter content of the soil on inclusion and capture nutrients within the cover crop as the nutrients move through the soil profile thus preventing leaching. The cover crop is then killed using an application of glyphosate and strip tillage or reduced tillage approaches are then sued in order to establish the next marketable crop. It is worth noting at this point that the main markets for maize and soybean are ethanol production, livestock feed and export markets (particularly China). The farm has produced 4.826 tonnes per acre (11.57t/ha) of maize on a 10 year rolling average, and 1.33 tonnes per acre of soybean (3.19t/ha) on a 10 year rolling average (Nelson, 2015).

Nelson Family Farms uses a sophisticated planter to plant maize and soybean (see Figure 2.1.5). This planter is able to control the rate of planting on each individual row and apply fertiliser appropriate to the rows needs. It is also able to plant different varieties in the same field in accordance with a prescription. Essentially, it is possible, with this planter to plant a 'defensive' variety of maize that is able to cope with conditions in poorer sections of the field and plant an 'offensive' variety in better sections of the field more able to provide that variety with what it needs to succeed. This is made possible by employing a two hopper system combined with individually computer controlled rows. As shown in Figure 2.1.5 the decision to plant which variety where in the field is provided by a prescription map. This map is constructed using both pH and soil texture/soil type data combined.

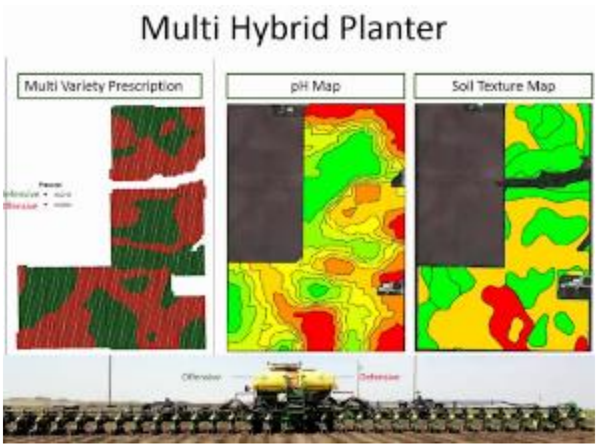

Figure 2.1.5 A figure showing a multi-hybrid planter that is able to plant two different varieties in the same field according to a prescription map.

The following technologies are standard in Iowa: yield monitors, auto-steer, grid sampling for pH, soil type and nutrients, planter row shut-off and sprayer section controls. Nelson Family Farms, however, also uses the following technology: variable rate application, individual row planter controls, electric drive seed meters, multi-variety planters, normalised yield data, management zones, normalised differential visual inference, electro-conductivity mapping, plant tissue sampling and nitrogen modelling. This heightened level of data generation enables the Nelson Family to make decisions that are better informed and have the potential to generate better financial returns on their investment.

It is worth spending some time reflecting on the use of management zones in this system. Management zones are a collection of data sets, yield, pH, soil type etc. collected over a period of time (11 years in the case of Nelson Family Farms), normalised (averaged and 'flatenned out') to provide an overall prescription to inform a management decision, particularly as it relates to variety choice and seed rates. The Thomas Doerge (2016) of the International Plant Nutrition Institute offers this definition of a management zone:

> *A "management zone" is a sub-region of a field that expresses a relatively homogeneous combination of yield limiting factors for which a single rate of a specific crop input is appropriate.*

It is this concept of a homogenous zone offering a straight forward management solution that would seem to provide a user-friendly use of the often complex data sets that can feed into a farm. It is the themes of machine, data and management revealed by my visit to Nelson Family Farms that will run through this report as they relate to precision agricultural tools.

2.2. Dennis Friest

Dennis Friest is President of Friest Farms Ltd and is a very successful pig, maize and soybean farmer (see Figure 2.2.1). The reason for the visit was to see how Dennis has used precision agricultural technologies to both enhance his business and the conservation of the farmed environment.

Dennis's Farm is in Radcliffe in Hardin County and, like many farms in the region has prime soil and is outstanding agricultural land. Precision management systems have been adopted by Dennis and this has been helped by his involvement in agricultural associations and levy boards.

Figure 2.2.1 Pictured from left to right, Dennis Friest with Kelvin Leibold, Iowa State University Extension Service.

Dennis is on the Board of Directors of the Iowa Corn Growers Association (ICGA) which is active in the areas of education, research, details regarding the ethanol market for maize in Iowa, information about livestock as it connects with maize growing and policy. Like our own levy boards, the ICGA lobbies government on both state and federal issues that protect the rights of maize growers in Iowa (ICGA, 2016).

An area of major concern to Dennis over the years has been the practice of conservation tillage (reduced tillage approaches) and nutrient management. As discussed in the previous section, this is of particular importance in regard to water quality and reducing inputs to improve gross margins. With the use of side by side tests and soil sampling, Dennis has built up a large body of knowledge on not only how his fields perform, but the impacts of variable rate nutrient application practices (Pocock, 2005). This is highlighted by Figures 2.2.2, 2.2.3 and 2.2.4.

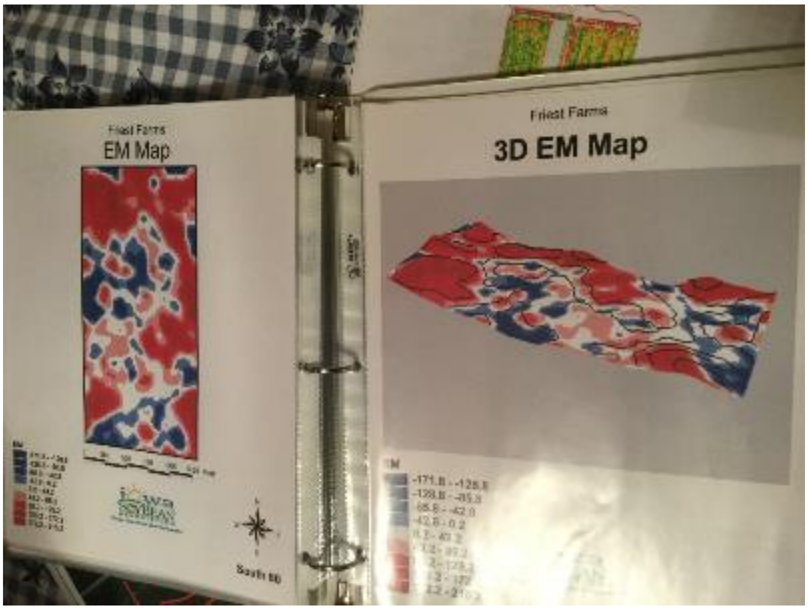

Figure 2.2.2 An electromagnetic (EM) conductivity map used on Dennis's farm.

The EM map shown in Figure 2.2.2 gives a strong indication of soil characteristics at 0 to 60cm depths or 0 to 1.35m depths and, as can be seen, is able to describe elevation, slope and general topography. The soil characteristics that are inferred through the measurement of electro-conductivity include soil component ratios (sand, silt, clay) and stone. This ratio is related to the cation exchange capacity of the soil, water holding capacity, bulk density and salinity. From this data it is possible to determine the more productive areas of the field and describe management zones or prescriptions for variable rate approaches (seeding or nutrient application).

A Hagie sprayer (see Figure 2.2.3) is owned by the farm, GPS enabled with auto-shut off, this sprayer is used for most of the agrochemical applications on the farm, the height of the

Figure 2.2.3 A Hagie sprayer for use with the tall crop, maize. As with much of the farm machinery seen on my visit, it is immaculately presented (also pictured is Kelvin Leibold, Iowa state University Extension Service).

wheels enables the spraying of tall crops such as maize. When the maize is tall, however, crop spraying is often carried out often using aircraft (see Figure 2.2.4) late in the season targeting end of season fungal pathogens, such as *Fusarium spp.* in particular.

Figure 2.2.4 Crop spraying using aircraft.

The crop grown on Dennis's farm is genetically modified for resistance to glyphosate (roundup). This has enabled Dennis to keep a very clean crop free from weeds and means that much of the technical agronomic thinking can be focussed on the major pests and diseases of maize and soybean (see Figure 2.2.5).

Figure 2.2.5 Farmer, Dennis Friest, walking (scouting) his soybean crop.

It is clear that Dennis has profited from the use of precision systems and in particular, takes great care to use this technology to enhance both his business and the farmed environment. Being extremely active on levy boards, Dennis has first-hand access to new knowledge and technology specific information that has been invaluable. Moreover, he has also been fortunate enough to have been involved in trials and side-by-side tests that has enabled him to see how well the new precision technologies work and adopt where he thinks it would be of long-term benefit to his business.

2.3. David Hansaker

Soil in Iowa is of extremely high quality and can be classified using the UK terminology as silty clay loam. Much of the soil in Iowa is dominated by silt sized particles with some 20 to 40% clay content depending on the soil type. A typical soil profile can be seen in Figure 2.3.1. As is apparent on immediate inspection of the soil profile, the soil is rich and has a highly friable texture, this lends itself to being worked by machinery and the production of a fine seed bed.

As can be seen in Figure 2.3.1 the maize roots are able to penetrate the soil profile for water and nutrients. This indicates a well-structured soil with fissures running vertically complete with a crumbly, small granular ped structure. The pores enable the roots to penetrate, aeration of the soil and water to infiltrate and pass through the profile. The hard winters experienced in the mid-West freeze the ground for three to four months and this creates a freeze-thaw action that separates the soil, making a fine tilth.

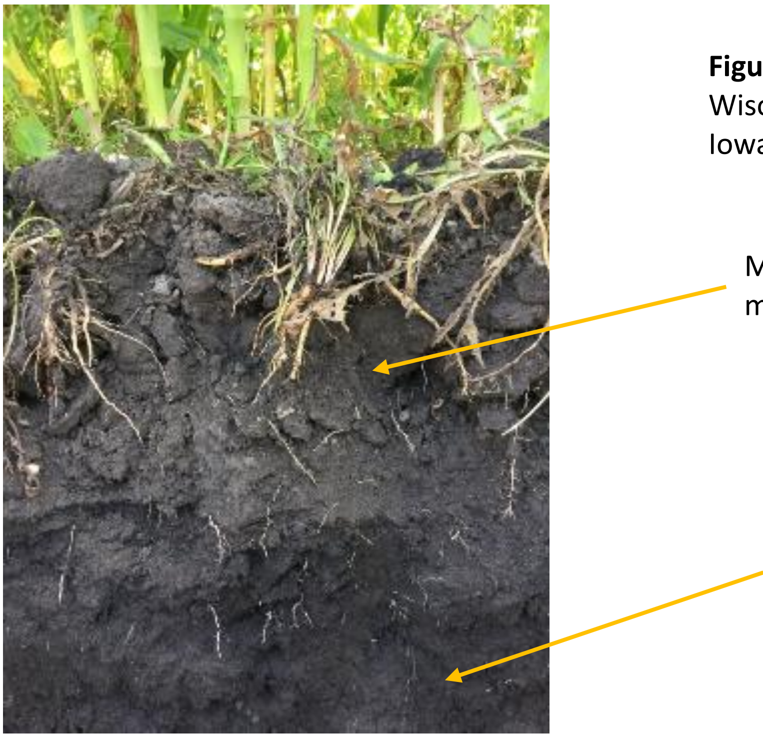

Figure 2.3.1 A typical soil profile of Wisonsin Glacial Till in Hardin County, Iowa.

Medium silt surface material

Fine glacial subsurface material

Wilson, Radcliffe, Iowa

Nevertheless, water logging and compaction are still issues with this soil type and in this environment (see Figure 2.3.2) and it is interesting to note that there are certain soil types that are more prone to water logging than other (eg Okoboji soil). There is also a propensity for certain soil types to leach iron, thereby causing iron deficiency chlorosis (IDC) in soybeans. The most dominant factors causing this problem are carbonate levels, salts and depression all field areas that have a tendency to water log. High pH (>7.8) can also cause IDC. Because the topography in Iowa is so flat, it is difficult to get the kinds of falls required in the drainage systems to move the water off the land quickly. Moreover, small depressions in the soil can provide ideal places for water to gather, often resulting in no plant growth whatsoever due to water logging. The total cost of this problem of water logging and associated issues is estimated to be $100M across the Mid-West USA. It is, therefore, necessary for farmers in Iowa to have the capacity to remove the water from the land and this is done using tile drainage.

Figure 2.3.2 A water logged field in North East Iowa.

As in the UK, modern tiled drainage involves the use of perforated plastic pipes placed at depth that feed into a stream or ditch. These tiles are installed using heavy duty chisel ploughs (see Figure 2.3.3). The pattern of installation is extremely important to maximise the effect of the drainage, improve surface and subsurface removal of water and reduce the impact of high levels of water, flash floods and heavy inundations on the environment.

Figure 2.3.3 A trencher used for the installation of perforated pipes.

Wilson, Radcliffe, Iowa

The key to drainage installation is position and this has been calculated using time consuming surveying instrumentation. It is possible to use remote sensing technologies such as satellite imagery and GPS to both position tile drainage correctly and produce a detailed map of the farm's drainage.

Figure 2.3.4 David Hansaker at work in the farm office.

Wilson, Radcliffe, Iowa

David Hansaker (pictured in Figure 2.3.4) in collaboration with the rest of his family which includes four cousins at 30 years of age (David, Brett, Jacob and Brian) has developed a method of using remote sensing technologies to plan the installation of drainage systems on farms and map out drainage networks. This has developed into a successful business whereby the service of drainage installation is provided to other farmers using specialist knowledge and equipment. Figure 2.3.5 shows a drainage network on a field on the Hansaker Farm That has been mapped precisely using new GPS enabled remote sensing - technologies. This field is well drained and it is expected that the productivity of this field will increase, but this will need careful monitoring to determine the success of the drainage system.

It is clear that GPS technologies can help survey the land and plan drainage systems cheaply and effectively. The nature of the soils and topography in Iowa make tiling drainage essential for consistent crop productivity. The use of modern precision technologies in the installation of drainage demonstrates another highly effective use of these innovations. The software used is Farmworks by Trimble can determine the pattern of drainage based on drainage coefficients off the field. The pattern determined by this process is then followed by a small four wheeler to determine topography and drains can be chisel ploughed according to the mapped prescription. Moreover, Farmworks is capable of determining an in-field economic assessment of the impact of the new drainage per hectare.

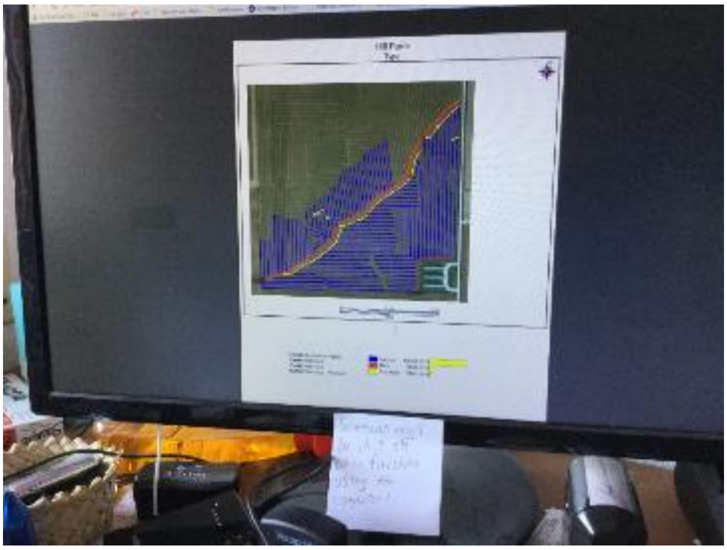

Figure 2.3.5 A field drainage map for a field on Hill Farm. Note the blue feeder drains running into the red and yellow larger drain or ditch. These maps are kept on Dropbox not SMS or equivalent software.

Tony Wilson, Radcliffe, Iowa

Similar to the UK, the identification of existing tiling or drainage can be a headache. New scientific methodology such as monochrome and colour infrared aerial photographs can detect the quicker drying soils under drainage, ground penetrating radar, geomagnetic surveying and electromagnetic induction can also help in detecting existing drains. There are, however, a number of low tech solutions in identifying where existing tiles may be (Ruark *et al.*, 2009):

1. After snow melt existing ponds will disappear more quickly under drainage.
2. In a wet and cool late May or early June, knee high maize will often be a deeper green colour over tiled drainage due to improved nutrient availability.
3. Soybean plants will follower up to a week earlier in tiled zones than in non-tiled zones.
4. The weed foxtail flourishes in compacted and wet zones of the field – non-tiled areas.
5. GPS yield monitoring data can indicate yield increases or decreases that may be attributable to drainage.

2.4. David Granzow

Figure 2.4.1 From left to right: Kelvin Leibold, Extension Officer, and David Granzow, Farmer, in an excellent crop of soybeans.

David (pictured in figure 2.4.1) grows corn and soybean. He also grows corn for seed. The ethos of his operation is one of care for the soil and the environment to maintain productivity and provide a sustainable environment in which to continue farming into the future. The soybean crop shown in Figure 2.4.1 was amongst the best observed during the tour and during discussion David gave some interesting reasons for the success of this crop. Figure 2.4.2 shows a crop of soybeans. The ground between the rows was covered with the trash of the previous crop that acted as a mulch and breaks down to add organic matter to the soil, thereby, improving soil water holding capacity, cation exchange capacity and friability of the soil.

David establishes his crops using a strip tillage approach and as understood by the author, the same strip is used throughout the rotation meaning that only half of the field is cultivated and then only minimally. The thinking behind this is that this practice encourages the flora and fauna of the soil to reproduce and create a subsurface activity that encourages organic matter breakdown, nutrient release and nutrient cycling. It also enables plant roots to more readily establish a symbiotic relationships with mycorrhizal fungi in the soil, aiding nutrient cycling further and improving the efficiency of fertiliser uptake and use by the crop plant.

Figure 2.4.2 This crop of GM soybean is weed free and no disease or pest damage was detected. The stand is even and the strong growth has resulted in plants further forward in their growth stage than any other soybean crop seen on the tour.

Strip tillage approaches on David's farm involve the use of GPS precision technologies. However, David was one of the more unusual farmers on the tour as he talked at length about minimising traffic on his fields and reducing the impact of compaction. Compaction can reduce yields and impact severely on productivity, therefore, there is a reduced traffic system in place. This attention to detail is not always seen throughout the state of Iowa, but it is becoming a more important issue. The effect of the hard winters on the soil often encourages people to think that the main cultivation challenge has been dealt with and there is no need to keep to prescribed routes on the field to reduce the impact of compaction. By keeping to prescribed routes and minimising traffic on the fields of the farm David has reduced the impact of compaction on crop growth and yield.

Figure 2.4.3 A detassler used to remove the male reproductive organs of the maize plant.

Wilson, McCallsburg, Iowa

Another enterprise on this farm is growing maize for seed. This involves the removal of the male reproductive organs or tassels from the maize plant (see Figure 2.4.4). Maize seed is hybrid seed that makes use of the genetic enhancement conferred by hybrid vigour. This means that the seed produced by David is the result of a fertilisation event that took place on the farm. In each stand of maize for seed there are six female rows and two male rows. This means that the plants in the female rows need to have the male reproductive parts removed (Farmwest, 2016). This is done using a GPS controlled detasselling machine (see Figure 2.4.3). This piece of equipment has been engineered to sit on the front of a sprayer and with the use of GPS can locate the exact rows needing to be detasseler. This operation

Figure 2.4.4 A detasseler in operation. The rubber 'wheels' placed either side of the maize plant rotate and sever the tassel from the main stem.

Wilson, McCallsburg, Iowa

ensures that the hybrid cross needed to make the seed is correct and meets the market specifications.

3. **Manufacturers**

3.1 AgLeader

AgLeader is a company that has been working in the field of precision agriculture for some twenty years. In that time, it has become a truly international outfit having developed and brought products to market in North America, Europe, South America and Australia. The company is founded on a basic concept – could a technology be developed that enables farmers to know the yield of a crop within any given field. If a field could be subdivided into different sections and each section be monitored for the yield of crop from that section then this would potentially give the farmer important information useful for making management decisions (AgLeader, 2016). The headquarters of AgLeader is situated in Ames, Iowa just off Interstate 35 on South Riverside Drive.

In 1986, Al Mayer's, the founder of AgLeader, initiated the development of a yield monitor. This process took six years and six generations of prototypes, before the first yield monitor was took to market in 1992. In 1995, Al Mayer's was selling upwards of 1500 yield monitors per year. The modern yield monitor has the capability of measuring both yield and moisture during the combining operation. AgLeader has developed its product range to include data handling software, displays, guidance and steering technologies including real-time kinetic (RTK) correction, hydraulic downforce systems for planters, variable rate fertiliser application technology (AgLeader, 2016).

The moisture sensor

Initially, threshed grain is fed into the harvester's elevator where a sensor measures the moisture content of the grain. The sensor does not measure moisture, but rather electrical properties such as capacitance and the ability of the grain to insulate electrical charge. Capacitance is a measure of the amount of electrical charge that is stored or separated for a given electrical potential and therefore, capacitance exists between two conductors insulated from one another. Another thing to note is that a dielectric constant can be determined by measuring the capacitance of a material.

There is a relationship between the moisture constant of grain and its dielectric constant and it is this relationship that is exploited by moisture sensors in combine harvesters.The dielectric constant can be determined measuring the capacitance (electrical storage capacity) of a capacitor or two conductors or plates (see Figure 3.1.1) with air between the plates and then with a dielectric material between the plates. The ratio between these measurements gives the dielectric constant. As water is a poor conductor of electricity it will, therefore, raise the dielectric constant in relation to the quantity of water in the sample being tested. After the sensor has been calibrated with a series of knowns, the moisture content of the grain can be determined (Lee, 2006).

Figure 3.1.1 – Ag Leader's moisture sensor fitted to the grain elevator in a John Deere combine harvester.

Wilson, Ames, 2015

The ability of the combine to measure grain moisture and relay that to the farm manager in the office and the operator in the field is extremely useful. It enables a better informed decision to be made as to whether to combine or not. Subsequent drying and processing of grain can be expensive and in understanding grain moisture better, the timing of harvesting can be calculated in order to avoid any unnecessary costs.

The yield sensor

Threshed grain is taken up via a power driven conveyor in the combine, the mass flow of which is measured by an impact plate situated at the point where the grain moves into the auger. An electronic control unit converts the voltage generated by the movement of the impact plate through a magnetic field into a numerical value that is relative to the voltage output (see figures 3.1.2 and 3.1.3).

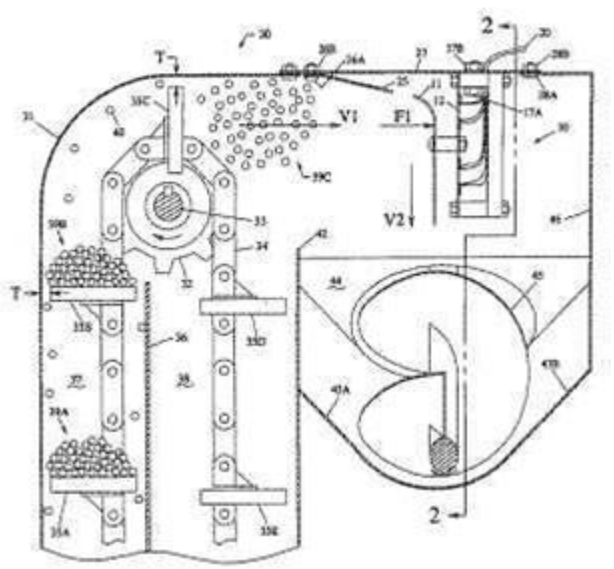

Figure 3.1.2 A diagrammatic representation of the yield monitor initially used by AgLeader (after Risius, 2014).

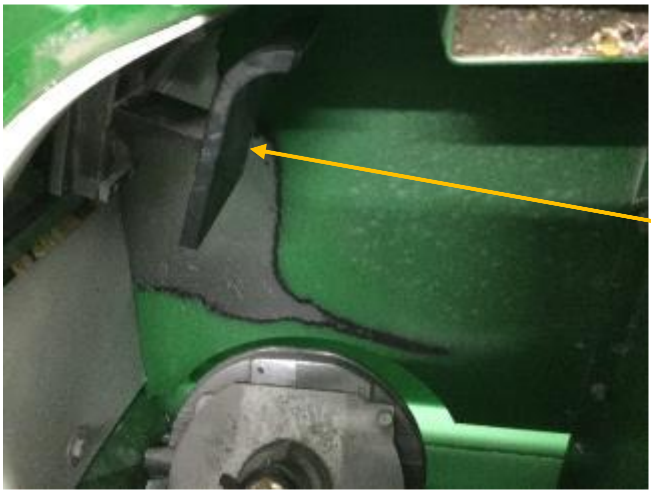

Figure 3.1.3 An image to show an impact plate shown in situ within the conveyor area of the combine. The impact plate is indicated by the arrow.

Wilson, Ames, 2015

The yield monitoring system must be calibrated and ground-truthed against actual values recorded in field. This makes the yield values valid and reflective of actual yield quantities as the combine is working. Once this yield value system is working in conjunction with GPS, the geographical position of each yield data point is known and a map can be generated indicating the value of that yield data point and where in the field it was recorded. This provides growers with a powerful data set that can used in the process of decision making for a variety of management options (Khosler, 2015).

Global positioning systems

Ag Leader is a major manufacturer of GPS for agriculture in the US. The various GPS packages on offer include options for auto-steering, field preparation/cultivation, variable rate seeding and fertiliser application, guidance systems, field mapping (soil, pH, nutrient and yield). These systems include a rage of differential GPS capabilities giving accuracies up to 3cm in terms of exact geographical position (RTK ref). Ag Leader technologies use satellite-based augmentation systems or differential GPS, including the Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay System (EGNOS) – both of which give accuracy of geographical position from between 145 to 200mm (see figure 3.1.4)

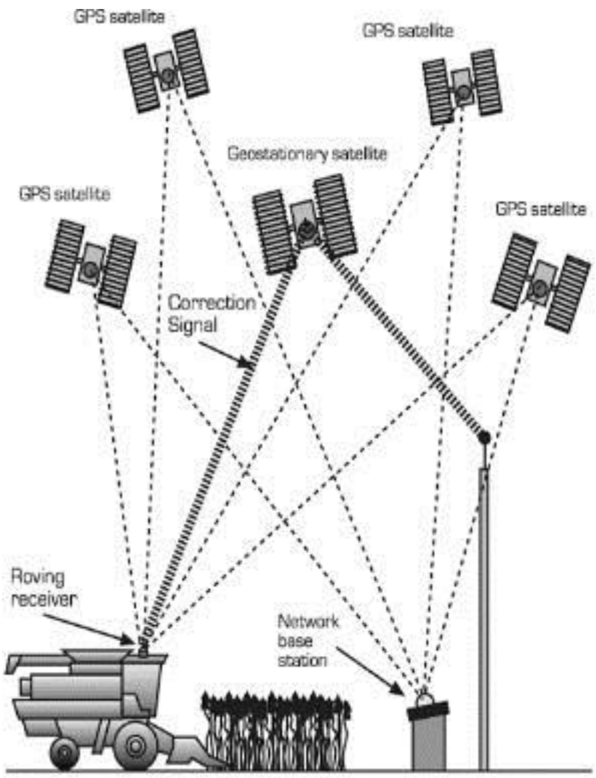

Figure 3.1.4 A diagram showing how satellite-based augmentation systems work. Note, a geostationary satellite is able to provide a secondary signal, initially transmitted from a base station from a known fixed position, that enables a more precise correction to be made on the position of the combine (Virginia Cooperative Extension Service, 2016).

Terra star – D is also used and this system is a capable of greater accuracy from between 70 to 120mm. The reasons for this are that the Terrastar – D system uses two satellite systems, Global Navigation Satellite System (GLONASS), another GPS satellite constellation and two base or reference stations to correct the distances and therefore provide greater accuracy of position (see figure 3.1.5). Moreover, Real Time Kinematic (RTK) systems, with a signal producing base station placed on the farm, offer even greater levels of geopositioning accuracy of up to 20mm. The accuracy of these RTK systems is dependent on the energy or frequency of transmitted signal – a 20Hz signal can transmit further and offers more accuracy than a 10Hz signal for example.

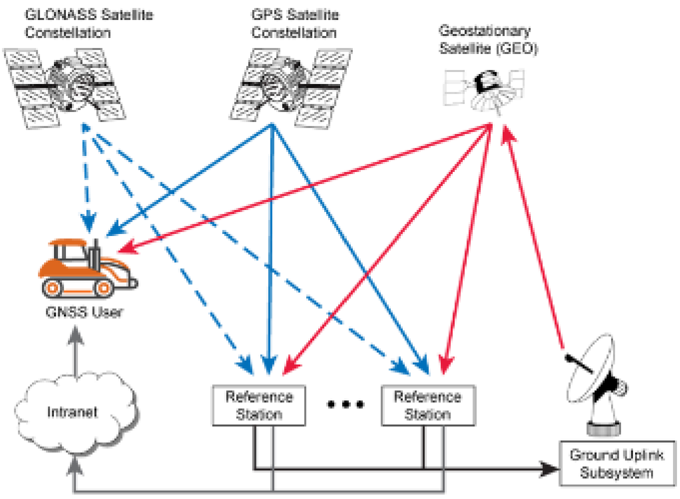

Figure 3.1.5 A diagram explaining the Terrastar – D GPS system (after www.novotel.com)

However, the GPS and data generation facet of Ag Leader's business is partnered by some precision data software packages and data viewing/manipulation tools. Included in these are SMS software packages that enable the amalgamation of data from a variety of sources. It is claimed by Ag Leader that SMS is capable of supporting the following data systems:

AGCO, Autofarm, Case IH, CLAAS, Flexi-coil, HARDI, Hemisphere GPS (Outback), ISO 11783, John Deere, KINZE, Mid-Tech, New Holland, Precision Planting, Raven, RDS, Trimble, Gradient, Shape, Image, Text Files, LIDAR files.

This potentially gives the farmer the ability to overlay and compare data sets from different sources in the one unifying software package. Basic, mobile and advanced systems are available to buy offering an increasing level of sophistication.

Agleader's suite of products and services is an attempt to provide a holistic and integrated precision farm management package. There are other companies that have set off on this route with mixed results and as you will see later in this report, the majority of US start up companies in precision agriculture are targeting the data interpretation market. SMS software is reasonably unique in its capacity to support a variety of software/data systems developed by other companies. This kind of attempt to build 'cross-talk' between systems is much needed as this 'business space' continues to develop. Farmers need packages that are multi-variate, user friendly and intuitive, as well as being powerful and capable of providing reliable evidence that enables good decisions to be made.

3.2 Kinze Manufacturing

Kinze Manufacturing is a family owned business that can boast to be one of the largest speciality manufacturers in North America. Specifically, Kinze specialises in the manufacturing and production of planters and corn carts. Established by Jon Kinzebaw in 1965, the first product taken to market was a 13 knife 30 foot anhydrous ammonia applicator toolbar. From then products have become increasingly sophisticated and include a multi-variety (maize hybrid) planter (Kinze, 2016).

From a precision agriculture perspective, this multi-hybrid planter presents the greatest interest as it combines cutting edge mechanical engineering with motorised computer-control mechanisms and GPS enabled data handling systems. It is by combining these technologies that an innovative product has been developed to promote productivity and potentially increase yields. What this means is that this planter is able to plant different varieties in a single field according to soil-type and field conditions. The evidence used in selecting which section of the field is most suited to which variety is provided by normalised yield data in the creation of management zones (Scheiderer, 2015). These zones indicate whether a robust variety is needed to cope in those areas of the field that present less than ideal conditions or a high yielding, but more environmentally sensitive variety would be a better choice in areas of the field more able to promote growth and therefore, yield.

Figure 3.2.1 A Kinze multi-hybrid planter in operation at Kinze's head quarters in Williamsburg, Iowa.

Wilson, Williamsburg, 2016

A number of key technologies have come together on the machine shown in Figure 3.2.1 to enable accurate and precise planting of both maize and soybean in three dimensions according to a computer generated prescription based on previous year's data. This data will include yield, soil organic matter, topography and soil texture (cation exchange capacity). The key mechanical and electrical technologies include:

Singulation

This is the ability of the machine to present a single seed/grain for each planting event. Duplications, where more than one seed is planted in an event, or skips, where no seed is planted at all can occur and effect the efficiency of the operation, reducing productivity and yield potential. Singulation is achieved with the use of a vacuum applied across a seed separating system or disc (see figure 3.2.2).

Figure 3.2.2 A vacuum disc used to ensure that a single seed is planted during any one given plating event. The arrow indicates where the seed is 'fixed' prior to being dropped onto the coulter during planting.

Wilson, Williamsburg, 2015

With the advent of recent technology (Dick *et al.*, 2012), it is now possible to electronically meter each of these discs and thereby gain control of seeding rates of each row of the planter.

<u>Down force</u>

Down force is applied pneumatically (see figure 3.2.3), although hydraulic versions are also available (see figure 2.2.4) for each row. This enables pressure to be applied when required according to the topography of the field so that a consistent planting depth can be achieved. This has a positive impact on establishment rates post germination.

Figure 3.3.3 A pneumatic down force unit (shown by arrow) enabling an 'on the go' variation in the force applied to the coulter to control the depth of seed as it is planted.

Wilson, Williamsburg, 2015

John Deere use a similar hydraulic down force system as is shown in figure 3.3.4.

Figure 3.3.4 A hydraulic ram used to apply down force to a row in a John Deere planter.

Wilson, Fort Dodge, 2015

Multi-hybrid planting

This system enables the farmer to plant different varieties in a predetermined format according to data that relates to soil organic matter, previous yield, cation exchange capacity and topography. Due to the planters ability to control the rate of planting for each row and access two different hoppers containing the different hybrid seed, this planter has the capability of varying the seed rate per row and the variety type per row. Figure 3.2.5 shows a motor that controls the rate of planting for a single row. Each row is equipped with such a motor enabling the row specific independent control of seed rates.
The electric motor depicted in figure 3.2.5 to drive the speed meters that controls the seed rate replaces conventional ground or hydraulic systems (Dick *et al.*, 2012; Wehrspan, 2016). The measure of control gained through the use of this meter goes from being multi-row to single row in respect to seed rates. Moreover, when this technology is combined with increasing down-force pressure, improving singulation and automated variety selection it results in an extremely powerful machine capable of controlling many of the factors that directly influence establishment rates in field.

It is also important to note that the Multi-Hybrid capability of the planter must respect the target market. That is to say, that maize or soybean varieties planted within a single field will be combined together by the same combine and will, therefore, be mixed in the same tank, achieve similar quality standards and be destined for the same market. Given the yield measuring capability of many modern combines (see Section 2.1), it will be possible to determine the performance of each variety and assess the success of the decision making process in selecting those varieties.

3.3 Precision Planting

On 15th July 2015, I attended a one-day conference at the Huxley Learning Center convened by the precision agriculture company Precision Planting. The Huxley Learning Center (see Figure 3.3.1) has been especially built by Monsanto in order to deliver specialist messages relating to the products and services owned by Monsanto and Monsanto-owned companies/subsidiaries such as Precision Planting and the Climate Corporation.. Emphasis is placed on agronomic education and precision agriculture (Monsanto, 2016). Alongside a state of the art conference centre equipped with a 150 seat auditorium and specialist computer-based teaching room, there are 50 acres of demonstration plots and trials

Figure 2.3.1 The Huxley Learning Centre.

Wilson, Huxley, Ames, 2015

showing the impacts of new precision planting systems, new maize and soybean germ plasm and other new biotechnologies and agronomic trials. Moreover, the centre is used by other organisations to deliver much-needed general information about modern agriculture in the mid-West United States and beyond.

Figure 3.3.2 The down force for each row can be independently adjusted according to need using Delta Force. This is similar to products made by Kinze and John Deere.

The products offered by Precision Planting include:

- 20/20 Seed Sense – this enables the grower to monitor downforce (planting depth), spacing and singulation whilst planting. Any errors can be identified quickly and rectified.
- FieldView – an information mapping system. It maps out spacing, singulation, variety performance, yield data, photographs and crop walking (scouting) notes can be added at a later date.

Figure 3.3.3 The use of Fieldview 'on the go' information system that is able to relay on tractor and implement performance during operations.

- Delta force – a hydraulic down force system to regulate planting depth.
- Air Force – a pneumatic down force system to regulate planting depth

- RowFlow and vDrive – controls the rate of seeding. vDrive consists of an array of independently-controlled electric motors situated on each row giving seed rate control on each row (see Figure 3.3.2).
- Wave vision – consists of high frequency sensors (not optical sensors) that are capable of differentiating seeds from dust/debris to a high level of accuracy. This means that seed counts when plating are accurate and can be checked against expected seed rates giving instant feedback and verification of seed rates. These sensors are situated on the seed tubes.
- Clean sweep – this is a row cleaner that removes/moves residue, but not the soil and adjusts as the field conditions change. Moreover, this technology can the air pressure from the AirForce system.
- eSet and vSet – these are singulation meters and as with other meters have a flat disc and a vacuum to fix seeds onto positions of a defined spacing (see section 2.2). The shape of the 'singulator' is different to others on the market and it seems to give a greater level of assurance that one seed is planted at any single planting event.
- Yield sense – a yield data system that compares yield with planting data.

Figure 3.3.4 A demonstration trial at the Huxley Education Center. This particular trial indicates the flexibility of Precision Planting's equipment in showing how planting speed can be controlled row-by-row to produce curved rows.

Wilson, Huxley, Ames, 2015

Precision Planting, although offering an integrated system, also is able to provide the above products independently. These products are compatible with many of the planters currently on the market in the USA including John Deere, Kinze, Case, White, Great Plains and Monosem. However, the products seem predominantly compatible with John Deere equipment. This could be that John Deere are extremely popular planters amongst US farmers, but also because the other manufacturers are developing precision planting systems of their own and want to maintain a market share by selling ‘packages’ of technology.

The ‘mix and match’ approach offered by precision planting – each product can be sold to growers separately – enables farmers to develop their own bespoke systems unique to their needs. They are also able to slowly build up their technology bundles and spread the cost of adoption. This allied to the different manufacturer compatibility of Precision Planting’s hardware provides a powerful series of technologies that is sensitive to technology adoption theory (Straub, 2009).

3.4 Monsanto

On 27th July 2016 I visited Monsanto’s Head Quarters at Chesterfield, Missouri. This centre for crop biotechnology was built in the 1980s. It represented both a departure from the agrochemical-based research that had been going on up to that time and a huge financial risk, the benefits of which may not be seen for decades. The investments made into bio-technological improvement of crops such as marker-assisted selection technology to help plant breeders, genetic modification and multi-genic trait hybrids started to pay off in the mid-1990s. Now, it is clear, that these investments have proved both visionary and ground breaking with Monsanto having a huge share of the biological solutions to crop problems based markets.

Chesterfield has recently undergone a huge expansion costing the company $400M. Commencing in 2013, this expansion involved the construction of new laboratories, glasshouses, state-of-the-art analytical equipment and even a new multi-storey car park for staff parking. Hugh Grant, CEO Monsanto said:

> "*Our Chesterfield expansion is focused on strengthening our world-class capabilities in the discovery and development of innovations for farmers around the world. Meeting growing demand will require new ways of thinking and new technologies that today we can only imagine. As we look to the future, and work begins to expand this research facility, I'm reminded how important our mission to work together to help farmers produce more nutritious food in a sustainable way will continue to be*."

This quote, represents a very optimistic and positive view of the future that has clearly been, at least, partially responsible for the commitment to invest in expanding the Chesterfield site. The other thing to note is Mr Grant's focus on new technologies and given the investment made in the biological sciences and supporting platform technologies at Chesterfield observed during my visit, it is also clear that Monsanto believe the future of resolving the problems associated with crop improvement, protection and management is biological.

Please see appendices for tour itinerary.

3.5 Pinnacle

Pinnacle, a comprehensive agronomic and environmental consulting firm, offers years of experience in environmental and regulatory compliance for livestock producers. Our mission is to offer our knowledge and experience in environmental and regulatory compliance and develop ag-input synergies that result in lower input costs and higher net revenues for our clients (Pinnacle, 2016). Being a locally owned and operated business, Pinnacle strives to offer our fellow neighbours a solid and profitable partnership.

Pinnacle has the following business potfolio

- Environmental compliance for agriculture
- Agronomic Services
- Oils and Lubrication

- Insurance

Precision agriculture technologies are used for the development of manure management plans. This includes the measuring of separation distances between application and public buildings, matrices of action or action plans and manure easements (where can more be applied and why). For example, separation distances – SST software to develop plans for distances for application. In developing a master matrix the following need to be considered according to State and Federal law: the site impact to air, water and the local community and this is essential for placing larger facilities over 1000 animal units

Pinnacle also helps in the production of manure plans so that the environmental compliance rules are adhered to. Information required from farms includes:

- How much manure has been produced by the livestock unit?
- How good is the manure (nutrient levels)?
- How much land is needed to spread the manure?
- Where can it be applied?
- General information about the farm is useful for background
- Application rates
- Iowa P Index

The plans developed for customers by Pinnacle also need to take into account the following issues:

1. Erosion potential
2. Use worst case slope value on the field
3. Most erosive soil – dominant critical area
4. Rotation
5. Residue
6. Contours
7. Buffer strips

8. GIS Soil type

The above process is similar to the UK's Soil Protection Review and NVZ rules. It also estimates soil loss in general and then how do we develop an idea of phosphate movement. All of the above issues (1 to 8) can be assessed using precision remote technologies and this is important in understanding the role that precision systems will play in the future when determining whether farms have been environmentally compliant or not. It also gives an opportunity for innovative individuals with an understanding of the environmental issues surrounding manure application and precision technologies to develop businesses to support farmers.

4. **Educators**

4.1 Ellsworth College

Ellsworth Community College (ECC) is part of the Iowa Valley Community College District. Community colleges in the USA are similar to UK colleges of further education (FE) and like many of our FE colleges, Ellsworth College offers a suite of degree programmes in practical, vocational subject areas. One of those areas is an Associate in Applied Sciences degree in Precision Agriculture, a two year programme equivalent to the UK's Foundation Degree (FdSc), and with a mature degree programme in precision agriculture it was a logical place to visit. The campus is tucked away in the charming riverside town of Iowa Falls, the focal point of my visit. The small-town environment offers a quiet place to study whilst being close to the entertainment, recreation, and career opportunities of bigger cities. This combination is very similar to Easton and Otley College (EOC) and although the degree provision is more mature and there is more accommodation on offer, it clearly offers a blueprint for what may be possible at EOC.

Although there are other larger colleges in the Iowa Valley Community College District, with only about 1,000 students, ECC enables lecturers and other staff to develop relationships that enhance learning through small group-based teaching.

The college farm possesses precision agriculture data stretching back to 2005. This mature data set enables students to analyse and assess data as if they are using it as evidence to make real life decisions. This process is reflective of current agricultural practice in the mid-West United States and therefore enables students to be employment ready. Data includes field nutrient data, yield data, soil texture/type data (cation exchange capacity), normalised difference vegetative index (NDVI).

Figure 4.1.1 A classroom in Ellsworth College complete with laptops, projector and interactive capability. There is also room at the side of this main teaching space for group activities.

Wilson, Iowa Falls, 2015

Lecture rooms are well equipped (see figure 4.1.1) and large enough to hold between 20 and 30 students. Laptops and tablets are available for students to use to both acquire and interrogate data in the classroom or in the field. Classes are linked to data that students themselves have collected on the college farm and input prescriptions for variable rate nutrient applications, variable rate seeding and variety (hybrid) choice are offered to academics, who also manage the farm. In this way the student experience is closely linked to the way the farm is managed and the decisions taken on the farm year-to-year. This brings the learning to life and lends a sense of purpose to what is done in terms of precision data use and application.

Figure 4.1.2 Prof. Kevin Butt with a student demonstrating a GPS enabled small Case ATV equipped with auto shut-off sprayer boom and auto-steer.

After www.iowafarmertoday.com

Ellsworth College has invested in a significant amount of hardware and the career and professional development (CPD) training of staff to use the hardware and associated software. This investment is typified by Professor Kevin Butt, the instigator and driving force behind the Precision Agriculture degree programme (see Figure 4.1.2). Kevin has a background in agriculture having grown up on a family farm near Iowa Falls and graduated from Iowa State University with a B.Sc. in Agriculture. Kevin is unusual in that he has combined high level IT skills and know-how with a knowledge of agriculture and agricultural engineering. This combinations has enabled him to establish the degree programmes at ECC and made Kevin one of the most highly regarding agricultural educators in the USA.

There is scope with the degree courses offered at ECC to combine engineering, IT and biotechnology with agriculture (see figure 4.1.3). This flexibility of provision is reinforced by the high level of investment in teaching resources gained through financial support sought from external sources. Students exposed to this level of teaching resource combined with

Figure 4.1.3 A biotechnology teaching laboratory at Ellsworth Community College equipped with PCR machines, pipettes, centrifuges and incubation baths.

Wilson, Iowa Falls, 2015

knowledgeable lecturers ensures that they are fit for the workplace and can progress onto higher degree programmes at Iowa State University should they so wish.

4.2 Iowa State University – remote sensing and the use of unmanned aerial vehicles (UAVs)

On 17th July 2015 I visited the laboratories and field station of Dr Matt Darr's research group of the Department of Agricultural and Biosystems Engineering at Iowa State University. The focus of the visit was the work on unmanned aerial vehicles (UAVs or drones) taking place at Iowa State University's Biocentury Research Farm.

Figure 4.2.1 Experimental field at Iowa State University's Biocentury Research Farm.

Wilson, Ames, 2015

The demonstration site was a field of maize (see figure 4.2.1) in a large rectangular shape of some 15 hectares in size. This field offered a number of unusual features that were possible to detect by UAV using either infra-red (IR) camera or NVDI camera. Two UAVs were used for the demonstration, one quadcopter drone (see figure 4.2.2) and another fixed-wing drone (see 4.2.3).

Figure 4.2.2 A quad outer drone fitted with an IR camera. This type of drone does not have geo-referencing capability.

Wilson, Ames, 2015

Figure 4.2.3 A fixed wing drone made by eBee fitted with a NVDI camera similar to the one used during the demonstration. This type of UAV does have get-referencing capability.
After: www.farmsolutions.com

Figure 4.2.4 The base station capable of receiving images transmitted from the cameras fitted to the UAVs. From left to right: Zachary Vanderleest and Christopher Murphy, remote sensing specialists, ISU.

It was possible, from a base station situated in the field, to stream images to a computer that was able to accept them in sections. These sections were 'stitched' together later using powerful software and considerable computer power (this programme has been known to crash powerful laptop computers). This station can be seen in figure 4.2.4.

The options for remote sensing crop performance during the growing period are satellite imagery that confidently gives a 5m resolution, although improvements have been made to this recently, contracted flight that gives 25 – 100cm resolution and UAVs that gives 3 – 10cm resolution (Murphy and Vanderleest, 2015). Plants display a greater sensitivity to light not in the visual range, therefore high resolution cameras that detect a range of the electromagnetic spectrum that is not in the visible light range. Examples of this are near IR and ultraviolet (UV) light, where reflected light within these ranges are detected by the cameras fitted to the UAVs. The spectral ranges that can be detected depend upon the camera selected (see figures 4.2.5 and 4.2.6).

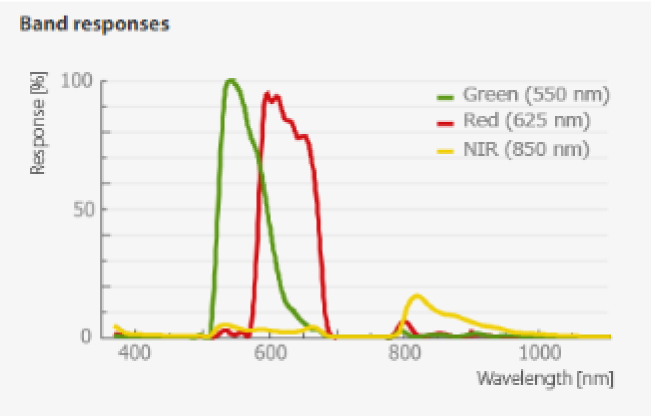

Figure 4.2.5 Band spectral range for the eBee nIR camera.

Courtesy: www.sensefly.com

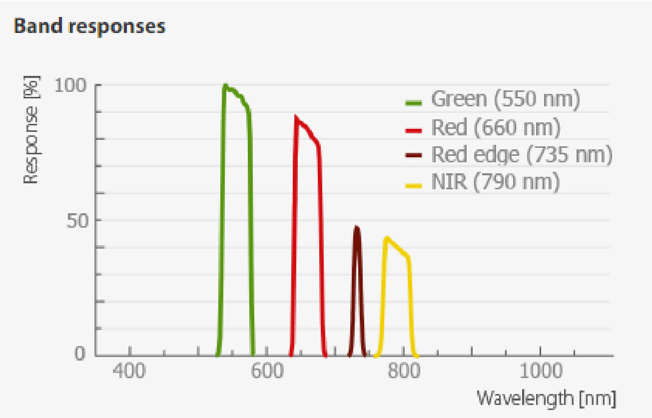

Figure 4.2.5 Band spectral range for the eBee multispectral camera.

Courtesy: www.sensefly.com

Figures 4.2.4 and 4.2.5 indicate the range of the visual and near visual electromagnetic spectrum detected by the nIR and multispectral cameras for the eBee fixed wing UAV. It indicates that it is possible to detect any differences by the near-visual spectrum wavelengths indicated by these figures (550 – 790nm for the multispectral camera and 550 – 850nm for the nIR camera) reflected from the plant surface. An example of an nIR image of a corn field can be seen in figure 4.2.6. As can be seen from this image, zones of poor and stunted growth due to in-field compaction issues can be detected and if the UAV is equipped with GIS/GPS capability this image can be geographically referenced and management procedures to alleviate the compaction can be precisely prescribed.

Figure 4.2.6 A near IR image of a field of maize taken from a quadcopter UAV. The arrow indicates areas of compaction that are difficult to spot using a camera using the visual spectrum.

Murphy, Ames, 2015

Compaction in the State of Iowa is an issue. Figure 4.2.7 indicates the impact of compaction on maize (corn) growth in field. This poor growth resulting from limited root development and consequent reduced water and nutrient uptake can reduce yield from between 12 to 18% (Murdoch and James, 2008). Compaction zones can also be detected using NDVI imagery (see figure 4.2.7).

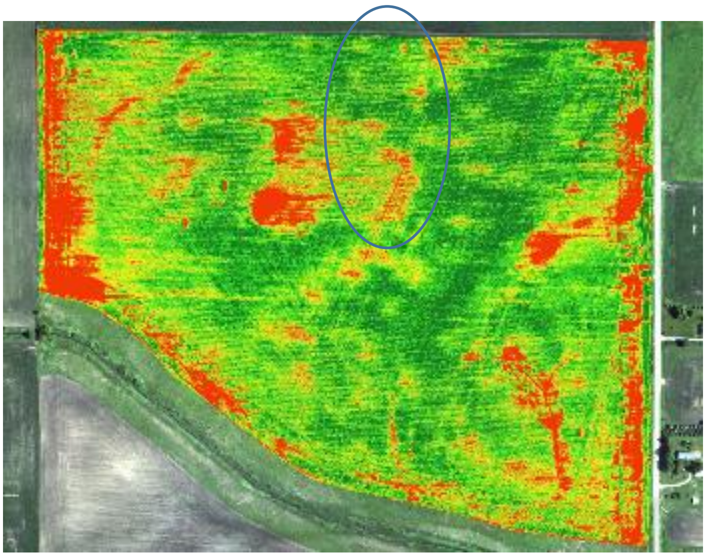

Figure 4.2.7 An NDVI image taken with a high resolution RGB (red green blue) camera on a fixed wing UAV indicating zones of poor yield in red. The circled area indicates a pattern of compaction caused by machinery.

Murphy and Vanderleest, 2015

It is worth noting that the red sections shown in figure 4.2.7 indicate poor performing, the yellow moderate performing and green high performing parts of the field. This NDVI image is in fact an a 'dimensionless, radiometric measure or indices that indicates relative abundance and activity of green vegetation, including leaf-area-index (LAI), percentage green cover, chlorophyll content, green biomass and absorbed photosynthetic-ally active radiation (APAR)' (Jensen, 2007). This measure is 'relative' against other measurements taken within the field or for that species of crop and is often used as an indicator of relative crop health.

Another technical issue that has to be resolved when using this technology is computing power. In particular, the fixed wing UAV because of its ability to take photographs sequentially, of a predetermined size that are geospatially referenced, it is possible to 'stitch' these photographs together. This requires intensive computer storage capabilities:

Fixed wing UAV eBee (based on 180 acre field):

- 600 images pre-processing
- 10 GB depending on file type pre-stitching
- Stitching and secondary data could require an additional 10 GB or more depending on the field size.

In order to stitch the recovered images together, a number of computer programmes can be used:

- Post flight Terra 3D
- Arc GIS or Arc Map
- Reads Imagine
- Global Mapper

Each of these software have advantages and disadvantages in terms of speed of processing, value of image generated to growers, ease of use, cost, ability to 'talk to' other software and use different types of files. The computational requirements recommended by Sensefly eBee are:

- 4–6 core i7 or Xeon processors
- NVIDIA Graphics with 2 GB of RAM
- 32 GB of RAM
- Minimum of 120 GB of HDD Free Space

Reflections

This series of technologies and innovations is of particular value to research and will give growers of added-value crops much needed in season growth data.

There is no doubt that remote sensing in all its forms satellite, airplanes and UAVs will have an increasing role to play in improving on current agricultural productivity, particularly for high value produce. The fixed wing UAV's ability to both produce high resolution imagery that is geospatially referenced and can produce large data files with the aid of post flight software capable of giving 25cm to one pixel resolution; greater than any other platform to date. It is the combination of technologies – UAV, cameras, computing power and software – that has enabled this innovation to develop. This implies a level of cross-talk between people from different epistemological backgrounds and with accompanying different skill sets. The 'silos' of knowledge have been breached in this case and I suspect that it is a number of 'polyglots', able to speak and understand the different languages associated with agronomy, computing, physics and engineering that have enabled these silos to be breached in this case.

5. InfoAg Conference

Session 1 – Paul Fixen: thinking like a futurist

Paul is a soil scientist and plant nutrition expert. He is Vice President of the International Plant Nutrition Institute (IPNI) and Director of Research. The IPNI supports 150 research projects worldwide. This talk mapped out the impact of InfoAg over its 20 year history as a conference focussing on precision technologies for agriculture in the USA.

Paul reflected on the 20 years of the InfoAg Conference, the reasons for its inception and the way the priorities of the conference have changed to reflect the changing nature of precision agriculture. He started with the concept of the Hype Cycle (Sonka, 2014) (see figure 5.1) in relating the nature of new technologies, innovations and the interest shown in them. He also directly compared the Hype Cycle to the numbers of people attending the InfoAg conference over the last 20 years and the first 10 years or so followed a similar pattern. 800 people attending the first conference in 1996, numbers declined to a low point of 380 in 2003 and since then there has been a steady increase to the current levels of just over 1400 people. This is both reflective of the Hype Cycle, often seen when new innovative forms of management are being proposed, and the power of precision technologies in improving husbandry and productivity.

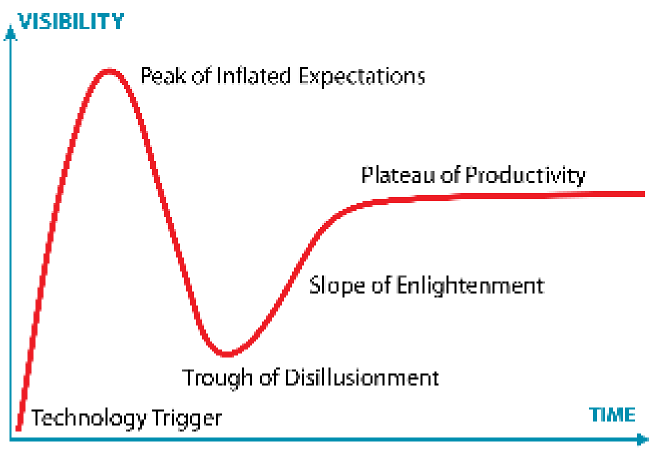

Figure 5.1 The Hype cycle

The InfoAg conference organisers have tracked the changes in trends in the precision agriculture sector, but there have been a number of constants. These constants over the years include plant nutrient management, soil 'health', environmental impacts of farming, crop performance and weed, disease and pest management. Another constant, surprisingly has been data and its use.

In 1996 the key data topics were data analysis, handling data and integrated data management software. The 2015 conference included the following data-oriented subjects: data analysis, weather data, yield data, big data, data issues, data warehouses and using NASA satellite data. It is clear that data has been very much in the minds of precision agriculture pioneers, but it is interesting to see the way that the subject has matured to include wider data uses (eg weather prediction and plant nutrient requirements and big data implications) and the socioeconomic and legal issues associated with data use (who owns the data?). This change can be summarised in the following way, in 1996 the industry was concerned with data as a value product of the farm and part of its legacy and using data as a tool of learning to publishing and collating high quality large data sets to do with agriculture and the environment, and systematic reviews of the literature, large data sets and meta analysis. This can be seen with the Secretary of State's move to release DEFRA's 8000 data sets (Gov.uk, 2015).

The need for a new a standardised ontology in precision agricultural data and data handling was put forward based on work carried out by Athenasiadis *et al.* (2009). As more and more data is produced through the use of precision systems in agriculture, a greater need will emerge for a standardised language. This will enable more meta analytical studies to take place as the common language will facilitate connectivity between studies. For example a meta-analytical study based on various data obtained during experiments throughout the USA shows that it is soil texture and available water that have greatest influence on available nitrogen and therefore, greatest impact on yield response measurements (Parent and Bruulsema, 2013; Tremblay *et al.*, 2012). It was by working hard to determine a common data language or ontology that comparative data sets could be determined and used to enable a meta-analysis to be carried out.

Session 2 - David Zach

David is a professionally trained 'futurist' and is full-time engaged in the delivery of thought provoking keynote and after dinner talks that encourage people not only to think about the future, but the attitudes and approaches required to make the most of the future. David is on the Board of the American Institute of Architects and the Board of the American Chesterton Society. He has acted in an advisory capacity on business development throughout the mid-West United States.

This talk encouraged the audience to ask more questions than provide answers and to think about the behaviours needed to embrace change and potential future opportunities in a productive manner. The following are notes taken from the talk combined with my own thoughts at the time:

Will the value of the data exceed the value of the produce? This is true in the way that American Airlines make more money from selling seating data than they do from passenger tickets. How will this phenomenon impact agriculture? Will it be sector/enterprise specific?

'If you can't measure it, you can't manage it' a quote attributed to Peter Drucker that is often used as a justification for the production of data, but Drucker did not say this. In fact, Drucker believed that it is the processes of measurement and management that are important, centred around 'conversations with colleagues' (Drucker Institute, 2016).

The thing is about the tools we use that the things we measure respond to the thing we use to measure, so to quote Maslow, 'when the only tool you have is a hammer everything starts to look like a nail'. When instigating standards by which all is measured, or has to be very careful that unintended consequences are avoided. Do we know how to count/measure/use the data? Much of the justification of data gathering is that we gather all data and figure out what it means later. This method of data management does not follow the scientific model and so, this begs the question, 'will the data have direction and meaning?'

Interconnectivity of data? Data can only be connected if those connections are apparent. This means that data may well be connected in some way, but it has to be clear to those analysing the data that it is connected!

STEM versus arts/humanities: these epistemologies need to 'dance' or interrelate. To use post-modern language, there needs to be more epistemological humility and a recognition that art, science and humanities all have something to give to each other. We need to avoid channelled thinking in the new 'big data' era – smartphones and computers reaffirm the reductionist view on an individual level (see figure 5.2). Protect your attention span to make links as this enabling approach has huge economic value.

Figure 5.2 My precious – using a tool or being used by it?

Much of industry, and farming is no exception (Beddington, 2012), is split by 80:20, 20% of businesses within a sector make 80% of the value-added/wealth and 80% of businesses make 20% of the value-added/wealth. The question is, what are the abilities needed to 'sit' in the 20% of those creating 80% of the wealth.

What are the great traditions that we hold on to in the change? The following might be a start:

1. Head in clouds and feet on ground – design and logistics
2. Think into other box – who is not here in this room?

3. Think like pirates
4. Be more curious
5. Change and tradition together may provide a stronger basis for change.

Our own individual approach to change and the future are vital. For example, Americans have moved from being definite optimists to indefinite optimists since the 1970s or from money = tool to money = goal. Much of the world can be classed as indefinite pessimists, including the UK. This means that people in the UK are generally pessimistic about the future, but unsure as to why!

The Google? Are the results of searches on the Internet real answers? What about design logistics, facts and things worth knowing? What constitutes Knowledge worth having against knowledge not worth having? You never know when a piece of knowledge will come in useful and does the fact that a piece of knowledge is useful or not make it worth knowing or not knowing?

Questions 'weaponise' curiosity; epistemic curiosity. Tradition leads us to believe that what we are doing now is 'the way' to do it. However, by adopting a questioning approach, we can question traditions and think of new ways to do things. How curious do you have to be to be successful in 2025? Should we not be curious about certain things?

> " . . . the idea of the future being different from the present is so repugnant to our conventional modes of thought and behaviour that we, most of us, offer a great resistance to acting on it in practice."
>
> John Maynard Keynes, 1937 (Global Trends, 2015):

Will 3D printing bring increased levels of efficiency? Does nanotechnology offer a real threat if used correctly or appropriately – what would nature do? Biosystems tend to be elegant – particularly when considering the nature of negative feedback loops. There is a case for bringing biology to manufacturing. How do we connect biology to manufacturing or computing to ecology? We need people who can see the links. We need polyglots to identify connections.

Agents of change and agents of tradition and agents of seasons and cycles. Pirates – to put to the test. All the rules are not set so how do we move this forward and exploit it! Innovating from small ideas: delusional, denial, democracy, Churchill, reality, new reality (Facebook). Safety vs Risk – being a pirate! What traditions will you ove away from? will you change and what will you keep? Ask why? The writer GK Chesterton said, 'before you tear down a gate or a fence, first learn why it was built in the first place, if that reason no longer exists then maybe we can tear down the gate'. New or different does not necessarily mean better!

Elegance and eloquence – presentation and a behind the scenes: utility and information architecture. It is interesting that there are a number of roles appearing, particularly in the US Corporate world, with titles like 'Information Architecture Manager'. These jobs are predicated on the notion that links between data sets and pieces of information are jus as important, if not more so, than the information/data itself.

Session 2

Data Synchronisation – Brandon Bule

Much of the InfoAg conference was concerned with the synchronisation and standardisation of data. Brandon talked about using automated processing to optimise data use or ecosystems of data. There is 30% retention of intellectual property. Agricultural service providers providing solutions to agronomists and consultants require standardised approaches. Standardised data requires standardised ontology, grammar and language to provide standard terminology for weeds, chemicals, products and soil data from different countries in order to streamline data sets and therefore, data use.

Examples of data set use are Sirrus – weather, soil, scouting can help to determine in season variable rate recommendations that is linked to yield by hybrid and subset by soil type.

However, to do this effectively we need farmers to give a data set that provides sensible aggregate data. Who owns the data? API Agreements have been signed so that technology and data can be shared, created and exchanged between companies: for example, JD, Climate Corp, Raven, SST Summit. However, but more connections than this; is this manageable?

Figure 5.3 The partners involved in the Apon Ag Data Alliance initiative.

This then leads to questions regarding synchronisation of the data, common ontologies with a central hub. For example, agX® is a Platform as a Service (PaaS) for the agricultural industry that provides the necessary geospatial infrastructure for a community of integrated precision agriculture products and services. It is a facilitating service that aims to connect all geospatial data in order to improve the utility of that data for farmers.This kind of system brings data together, synchronising it in order to gain an aggregate overlay on a field that enables a better interpretation.

Session 3

Future of Precision Agriculture: Marc Venacht

Two biggest challenges in global agriculture are to take good care of soil and water. For example, pears in Belgium; sap flow monitoring to get an idea of water need to programme irrigations systems. Remote sensing can enable sap flow measurement – fertility, drones, niche markets, value added. This then enables farmers to monitor and better control of their water resources during key growing periods.

It's is worth noting the following about technology:

- Tablets outsell laptops and desktops
- Internet advertising spend highest
- More mobiles than people
- Solar energy cheaper than oil fired.

These crossovers indicate, when they are vibrant and healthy, where investment in precision agriculture technologies takes place, as these are the basic tools and interfaces of precision agriculture. Therefore, precision agriculture flourishes:

1. Where economies grow
2. Where consumers want it
3. Where engineers flourish

World population growth is becoming linear not exponential and is therefore, not seen as a major driver of technological change. Precision agriculture requires bridge funding so that profit can be realised after the initial stages of investment, scale and quality. This leads to profitability and sustainability (only technology)

LEDs lighting and vertical enclosed farming requiring active sensors of plant performance. It is worth keeping in mind Haitz's law:

Precision agriculture and decision cycles: Data – decision – deployment
Measure – data – analysis – decision – action plan – deployment - but what do we measure? We could develop a dashboard of real time status of crop performance giving us an idea of what is going on, but how does that link with operations in real time? And how does that enable us to make decisions and deploy?

Drone data to indicate precise NPK applications during the growing season. NERCITA, Beijing, China – is an integrated system for data and big data applications in agriculture and this indicates that many governments are looking to develop intelligent templates for crop management.

Session 4

Agronomic lessons from data analysis – Dan Frieberg

Dan represents the company Premier Crop.

GPS gives get-spatial data and data layers on the same space. However, in order to apply this data questions need to be answered, such as, which layers are chosen and why? How is/are the data layer(s) analysed? How does this analysis lead to decisions? How far can the process be automated?

Premier Crop analyses the data In terms of how the it correlates to dry yield – variables are then ranked (NPK, soil type, SOM, CEC, pH etc.) In layering data – depth is better than width – 400 layers/data intensive. Aggregating data – 60’ x 60’ not very precise – soil variability?

Integrated data systems indicating agronomically what is happening? The typical number of data sets required in each level or type of data are as follows:

8 harvest data
28 fertility
24 weather

There can be a total of 234 data sets on any one field. This then leads on to the development, through ground-truthed algorithms, management zone maps and prescriptions can be developed from there. Yield data is uploaded automatically and zones are altered on the basis of year-on-year yield data and this represented a low risk way to ‘stretch’ and improve the prescription. Good practice is to highlight one or two acres to analyse in depth in order to determine the effectiveness of the zoning and by extension, the prescription and this enables the grower to ‘ground-truth’ the process and develop ‘learning blocks’ to inform the rest of his/her practice.

1. Maps good to visualise data – legends matter. It is often seen in yield data maps that the range of yield that equates to each pixel is not reflected upon by growers/practitioners. It may be that the range of highest to lowest yield is very little, but the algorithm has set the ranges for colour giving the false impression of vast yield differences within the field. Set the ranges for each colour yourself!
2. Drainage – using geospatial maps to both map and detect problem areas for drainage installation will play a greater role in the future.
3. Agronomic synergy – making links and correlating data Is the key to good analysis and therefore, good prescriptions. For example, rooting depth, which is linked to compaction and soil type which is linked to K and N uptake and therefore linked to crop performance.

How do we use learning blocks or test plots on farm to inform and test products?

Test plots acts as a verification of technology to help the grower see whether it works. Surrogate data layers can prove problematic in that you may make a comparison, but this may not indicate a correlation for that particular comparison. The link is elsewhere. Another factor was the cause of the difference. Data is highly site specific and particular to any one farm. Large data sets may be able to point a grower in the right direction, but often it is the site or farm specific nature of the problem that drives potential solutions and therefore how the data is used making data gathered elsewhere useless.For example, planting speed as a surrogate for soil condition.Therefore, the local context is always going to take precedent.

Value creation depends on perspective – for example the plant breeding company versus grower. There can be a selectional bias in terms of the technology chosen – for example, in comparing CEC across N applied to avoid selectional bias. Make sure the data is comparative – are different data sets looking at the same thing?

It may be a good idea to apply a constraints based analysis – identify the constraining factors - K or P for example will constrain the impact of N. What are the spatial variabilities and their implications for traditional trials and research? Moreover, how can big data sets support or indeed, obviate the need for trials and how does this all link to the need to make prescriptions as local as is possible?

Session 5

Understanding, analysing and decision making from mapped data – Raj Khosla

Information of yield data includes scale, variability and location from yield maps. It is important to translate year on year yield data to normalise patterns and develop management zones

Changes in spatial data and temporal changes –capturing/acquiring data - require:

Accumulation
Analysis – algorithm
Summarising yield data by display – measurements taken every second

Yield monitors can be used to determine low yielding areas and overlaid with visual maps to determine compacted areas, eroded areas and water issues.

Kit:

1. GPS receiver above the cab
2. Grain flow sensor
3. Moisture sensor
4. Ground speed sensor - ultrasound

5. Header sensor
6. Display – after capturing information and processing it, displays it.

This kit and capability is enhanced with the following:

- Header switch – on/off toggle at headlands so not to replicate or 'drop' pixels.
- Slippery uphill terrain the ground speed sensor measure actual speed so that the data is not skewed or over/under estimates yield in that spatial zones.
- Grain flow sensor quantifies weight/force per unit of time – this is not fantastic way of doing this. Most plates measure displacement and equate that to amount

Yield data is calculated in the following way:

a) Calculate area
b) Calculate distance travelled every sec
c) Calculate pixel size – area travelled per sec
d) Measure flow rate
e) Measure yield in bushels or tonnes/hectare
f) Bushels or tonnes per hectare taken per sec divided by pixel area

Speed needs to be kept as constant as possible to avoid yield data errors

Other errors:

1. Out of range
2. Outliers
3. DGPS – differential GPS
4. Speed change – change of operator!

Cleaning yield data

The following steps are important to take:

- Table format for data collection – each row is one pixel (20 data layers)
- For loss of differential GPS – clean this out by removing from data set in the table.
- Outliers – set boundaries for low and high yield – remove this data to clean it up (erroneous data sets)
- Same for combine speed variation error –increase in speed can give decrease in yield in that second a decrease can give an increase in yield (+/-25% median can be removed according to speed).
- LOOK AT SPEED BY MAP AND COMPARE WITH YIELD BY MAP – this will help validate the data as a truly representative analysis of yield in the field.
- Mass flow delay errors – this is the required time for the grain to move from the header to the mass flow sensors. This is data to geolocation.
- Mass flow errors – raising the header at the margins. This can give 0 yield pixels.
- These errors can move the pixels along the rows, but identify the margins of the field and define it and remove the turning areas.
- Result of cleaning process – 46,000 to 40,000 pixels about 13% loss of data.

Normalising or stacking data – 7 years of data is good.

To normalise data the following procedure is followed:

1. Divide every pixel by the highest yield observed over 7 years
2. +/- 0.85tonne
3. Clustering data
4. Number of zones – look at frequency of yields and its distribution – this will highlight interesting data sets in field eg bimodal distribution.

Generate zones – 2 to 5 zones per field is usually adequate in order to be manageable. Are the zones significantly different? If they are not significantly different then they may be able to be treated as a single zone for management purposes.

Session 7

Drone applications in modern agriculture: turning pictures into decision support – Kevin Price KSU and ISU

See biog: http://www.infoag.org/speaker/5/15933/

And

http://www.agpixel.com

Fixed wing is better for in field phenotyping and in growth selection and monitoring of performance. This can help change prescriptions, particularly for nutrient inputs. Large field data.

The drone product can fly with 6lbs of added weight and SLR cameras and take 1424 images over 300 acres of oilseed rape in pre-programmed straight flight lines.This kind of multi-platform remote sensing can count numbers of plants and therefore, establishment. The analytical tool used is NVDI – NIR+other wavelengths can detect the differences in chlorophyll density. The NVDI does this by measuring differences in NIR reflected. NVDI = NIR – visible red/NIR+red. This can help highlight healthy against unhealthy plants and their position in the field

Note: red is unhealthy and green is healthy.

This is a good crop walking tool as it gives an oblique view and 99% seen.

Further developments are based around the link between NVDI and yield. This indicates in field yield potential which would help develop management zones and hopefully, lead to better management. Some of the issues that could be highlighted with this technique include erosion, NPK and water need for irrigation purposes.

Where there are straight lines in NDVI analyses of fields then people did it, for example, it could indicate an uneven application of N. If uneven lines are detected then it could have been as a result of a natural cause; soil fertility for example. 93% of variation can be explained by the drone data including yield (NVDI mid season growth). NVDI can identify areas of weed infestation and may well be useful in the future for the description of herbicide application management zone.

High quality imagery is possible with drones and this is great for crop walking.This level of precision and accuracy can aid in the creation of management zones for nitrogen application or agrochemical application based on planting density.

This drone has been used in the determination of planting density for sugar cane, hail damage of soybeans for insurance purposes and lodging in WW. NVDI can detect standing against upright WW.

Session 8

Iowa Agstate report on digital agriculture – Matt Darr

http://www.iowacorn.org/documents/filelibrary/membership/agstate/AgState_Executive_Summary_0A58D2A59DBD3.pdf

This report (see URL above) was presented to the conference and indicates some of the challenges in the adoption of precision technology – some tools are seen as being useful and others give low or no ROI. The data included in the report is made up of:

1. Farmer survey
2. Precision agriculture products used?
3. Frustration in using precision agriculture tools?
4. Agronomist focussed questions – impacts of widespread adoption of precision agriculture?

5. Write in comments were taken from farmers indicating that there was some kind of textual analytical treatment.
6. Key challenges for the industry are: the skills needed, quality of data, access to data, better analytics and analyses.

The concept of technology drivers versus products and services was broached and some considerations for strategic vision and strategy development were put forward.

There seems to be an incremental change in the adoption rates of precision technologies year on year rather than a tipping point, where there are a flood of adopters after an initial slow period of adoption. The value of increases in adoption year on year is +/-5%.

There needs to be a clear demonstration of value otherwise adoption will be low.

The report also indicates that a more farmer-centric strategy will accelerate adoption and this can take the form of:

1. EDUCATION – farmers, agricultural retailers, local businesses
2. DATA WAREHOUSING AND SHARING – grass roots effort for data warehousing
3. ASSESSMENT – evaluation of products, services and business models: number of companies! Consolidation.
4. TECHNOLOGY PULL – is there a need for the technology in terms of enhancing business performance.
5. RESEARCH – create an institute for advanced farming

The above is seen as in continuum and in order of priority.

Session 9

Agricultural Educators breakout session – Terry Brase

http://www.infoag.org/abstract_papers/papers/paper_293.pdf

The following challenges were identified in precision agricultural education in colleges and universities in North America:

- Establishing a precision agriculture degree program
- Cost to provide adequate and appropriate software equipment
- Instructors with field experience in prevision agriculture and teaching
- Quantifying the need for technician level employees
- Assure and adequate number of students college programmes
- Specialisation of degree programmes
- Maintaining provision agriculture curriculum materials
- Accreditation of college programmes and certification
- Funding
- Leadership in this area - updated and champion to get it done
- Time – bank staff (adjuncts)

Many of the above issues are consistent with the problems faced in the UK. However, the standard of equipment and resources seen in Iowa far exceeded that often seen in the UK. UK College farms, however, are bigger and more lucrative as businesses in general that those in the US. This seems counter intuitive, but nevertheless, true, however, funding mechanisms and revenue streams for education, including funding for equipment, are clearly better funded in Iowa than in the UK.

6. **Conclusions**

<u>Points taken from this study tour</u>

The following are the take home messages from the tour. The use of descriptive language to this point is deliberate, to enable the reader to draw their own conclusions in a way that is applicable to them. However, there are some key findings that are worth highlighting:

- Soil loss and degradation is of great concern in Iowa and enlightened environmental or conservation practices are being adopted throughout the State. Precision systems are thought to help in this and in particular in reducing nitrogen inputs to protect water quality.
- Cover crops like rye grass are in use to reduce soil erosion through surface run-off.
- Conservation tillage practices are in place throughout the State and good use is being made of RTK systems in the application of strip tillage approaches.
- Many precision technologies are standard in Iowa and there is a drive to develop variable rate application, individual row planter controls, electric drive seed meters, multi-variety planting in field, management zones and big data interpretation.
- Many farmers are active on levy boards and use this to good effect to develop their own and others' understanding of the avilabe technology.
- The extension service is active in encourages a cross-linking of ideas from private sector to University to farmer.
- GM crops are used throughout the State.
- Water logging and associated nutrient deficiency issues are recognised long term issues and tile drainage is used to alleviate it. Simple and relatively inexpensive precision technologies are being used to draw up drainage maps and plan new drainage.
- Compaction is not taken that seriously by all farmers in Iowa event though it can reduce yields by up to 22% in maize. Now the technologies exist to map the problem, more farmers may begin to take the problem seriously to enhance their production systems further.

- Some of the best farmers are using precision systems to help improve soil structure and health so that crop growth in enhanced.
- Precision systems are being used to detassel maize when bulking seed for the following growing season.
- Moisture and yield sensors are standard throughout the State and yield monitors in particular are being used more fully to develop mature data sets for interpretation.
- The construction of management zones using a sophisticated array of data sets including yield, soil analysis, nutrient mapping and local knowledge have been constructed on many farms and are being implemented.
- A number of companies have developed software capable of analysing in field data and producing prescription maps. This is a 'crowded space' and it will be interesting to see how many of these companies survive and flourish and how much of this technology is consolidated.
- Planters have been developed to plant different varieties in the same field in accordance to a predetermined prescription map.
- Planters are able to vary the rate of seeding per row and ensure that only one seed is planted during any one planting event.
- Planters are able to ensure a consistent down force is achieved to ensure that all seeds are planted at the correct depth.
- A number of companies have developed a mix and match approach to their products whereby customers can 'cherry pick' the different products on offer to suit their system of production.
- Educators, including community colleges (equivalent to the UK's colleges of further education), have developed a sophisticated educational provision for precision agriculture, which is backed up by significant investment in teaching tools and precision hardware.
- Remote sensing systems are becoming increasingly sensitive and can give insights into within season crop growth and performance and compaction mapping across farm. This will further equip the farmer with information that can be used to inform management practices such as nutrient applications and compaction alleviation strategies.

- Silos of knowledge need to be breached in order to gain maximum synergy and benefit of the precision technologies available to agriculture.
- People from a variety of backgrounds and those 'enablers' able to understand a number of different subject specialisms are essential if the necessary connections are to be made to make the technology work in the best interests of producers.
- A standard ontology (common data language) in precision agricultural data and data handling is necessary to facilitate connectivity between applications.
- Data connectivity needs to be made clearer to the end-user, often the farmer, that is, data connections are only useful is it is known that the data is somehow connected. The links between big data sets are just as important as the big data sets themselves.
- More work needs to be done on precision agriculture and decision cycles so that farmers are fully aware of where they are in the cycle and what that means to their business.
- The United States Government is focussed on a farmer-centric approach to precision technologies that includes the following aspects: education, data sharing, product evaluation, drivers for change in terms of technology and research.

Reflections on management zones

The concept of management zones has become an increasingly popular idea as it seeks to draw together a number of factors that can affect crop performance. A management zone can be defined as a sub-region of a field that expresses a combination of yield-limiting factors for which a single managerial approach (husbandry) is appropriate (Doerge, 2015). This classifies spatial variability within a field in a way that a farmer can more easily manage. A management zone strategy must be based on the principles of cause and effect to be at all useful.

What are the factors that affect crop performance that should be included in a management zone strategy? This is the key question and will vary from soil type to soil type and farm to farm. However, some key ones are soil moisture, soil type, pH, soil nutrient levels, pest and disease incidence, topography, drainage, as well as yield data. Yield maps will need added information in order for the correct interpretations and management decisions to be made. Things to consider when defining management zones include, the relationship of the data with crop yield, the cost of the data, is the data quantitative and repeatable, how densely packed the data is (some soil analyses can be carried out across large distances and may include whole zones that have not been measured) and scale of the data (scaling for wheat yield would not be the same as oilseed rape - Brassica napus).

Management zone strategies have the capacity to maximise economic return by optimising the farmer's ability to impact on yield limiting inputs in any one given field. An evaluation of any strategy adopted must take place so that its value to the farmer can be assessed. There are three methods of evaluating a management zone strategy (Doerge, 2015):

1. Historical – compare with husbandry approaches taken in previous years to indicate whether the changes brought about through the introduction of management zones have been successful.
2. Indirect – this is taken from scientific evidence that indicates factors that are highly correlated with crop performance and yield. This will determine some of the variables that should be taken into account when producing a management zone.
3. Direct – using multiple side by side comparisons of data accrued on the farm, yield advantages can be assessed between zoning and non-zoning strategies.

The development of a management zone strategy for management on any given farm should include the following steps (see Figure 6.1):

1. The use of simple spatial information such as local farmer knowledge, bare soil photos, soil survey or traditional soil analysis maps, field topography and cation exchange capacity maps.
2. The management zones once established can be refined through the use of yield mapping data that indicates yield variations within a field. Suitable data sets include multiple-layer yield maps, crop canopy reflectance and high intensity soil nutrient maps and geo-referenced crop walking reports.

3. Measure the effectiveness of the strategies by using sound agronomic and financial reasoning. Include a spatial and temporal awareness of yield, quality, in-field crop performance and financial return.

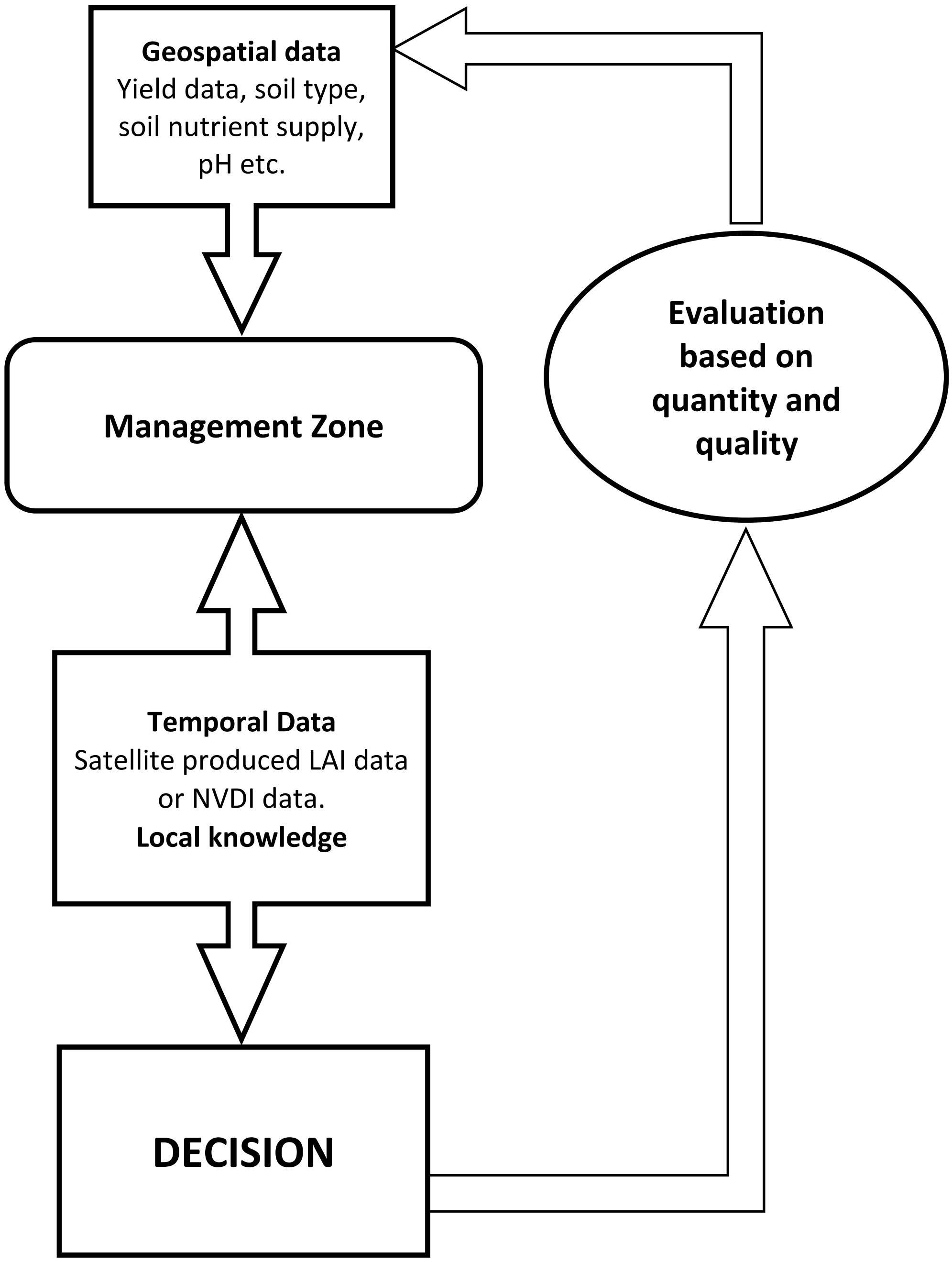

Figure 6.1 A flowchart showing the process of decision making in the use of precision data in creating and evaluating management zones in field.

7. **Outcomes**

Knowledge gained on this tour has significantly contributed towards the development of new degree provision at Easton and Otley College. This was borne out through the successful validation in February 2016 of a B.Sc. (Hons) Agribiosciences and a B.Sc. (Hons) Agriculture with specialisms in precision management, business, crop science and livestock science.

Contributed to a workshop held at Easton Campus, Easton and Otley College for a delegation of Chinese extension workers on the theme of precision technologies for farming.

Information gained during the visit has been embedded into the delivery materials of the degree programmes at Easton and Otley College.

7. References

AgLeader (2016). *SMS Software*. Available at: http://www.agleader.com/products/sms-software/basic/

Athanasiadis, I. N., Rizzoli, A.-E., Janssen, S., Andersen, E., Villa, F. (2009). Ontology for Seamless Integration of Agricultural Data and Models, 3rd Intl Conf on Metadata and Semantics Research (MTSR'09), CCIS, **46**: 282-293, Springer-Verlag.

Beddington, J. (2011). *The Future of Food and Farming: challenges and choices for global sustainability*, UK Government Office for Science.

DEFRA (2015). *Environment Secretary unveils vision for open data to transform food and farming*. Accessed at: https://www.gov.uk/government/news/environment-secretary-unveils-vision-for-open-data-to-transform-food-and-farming

Dick, E., Jangula, J., Pecka, J., Christianson, M.P., Lykken, T., Machinery, T. and Bora, G. (2012). *The Development of a Seed Singulation Device*. Accessed at: https://www.ndsu.edu/fileadmin/aben/Seed_Singulation_2012.pdf

Doerge, T. (2016). Management zone concepts, Site Specific Management Guidelines, **2**, International Plant Nutrition Institute. Accessed at: http://www.ipni.net/

Gartner (2014). *Gartner's 2014 Hype Cycle for Emerging Technologies Maps the Journey to Digital Business*. Accessed at: http://www.gartner.com/newsroom/id/2819918

Jensen, J.R. (2007). *Remote Sensing of the Environment: An Earth Resource Perspective*. Pearson Education, Inc., United Sates.

Khosla, R. (2015). *Understanding, analyzing, and decision making from mapped yield data*, InfoAg 2015, St Louis, Missouri, July 28 – 30 2015, viewed 8th September 2015.

Kinze (2016). *Multi-hybrid planter*. Available at: http://www.kinze.com/planter.aspx?id=17&4900+Multi-Hybrid+Front+Fold+Planters

Lee, D. G. (2006). *What do grain moisture meters measure and how are they calibrated?* Available at: http://www.nist.gov/pml/wmd/pubs/upload/C-004.pdf

Morris, N. (2016). Strip tillage, definition and description of use: in what circumstances could it replace ploughing? Accessed at: http://www.controlledtrafficfarming.com/downloads/StripTillage-Nathan-Morris.pdf

Monsanto (2016). *Learning center at Huxley, Iowa*. Accessed at: http://www.monsanto.com/products/pages/huxley-iowa-learning-center.aspx

Murdock, L.W. and James, J. (2002). Compaction in no-till corn and soybeans, *Agronomy Research Report: Kentucky Agricultural Experiment Station Bulletin*, **464**: 29 – 30.

Murphy, C. and Vanderleest, Z. (2015). *Remote sensing: a bespoke seminar*, Biocentury Farm, Iowa State University, USA.

NRCS (2016). Iowa Soils Regions Map, Natural Resources Conservation Service, USDA. Accessed at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/ia/soils/

Nelson, D. (2015). *The power of precision agriculture - using tomorrow's tools today*, Oxford Farming Conference 2015 presentation.

Parent, L. E., & Bruulsema, T. (2013). Networking soil fertility studies at the agro-ecosystem level using meta-analysis, *Better Crops with Plant Food*, **97(1)**: 13-15.

Pocock, J. (2005). Not Your Daddy's NCRS, Corn and Soybean Digest. Accessed at: www.cornandsoybeandigest.com/not-your-daddy's-NCRS

Risius, N. W. (2014). *Analysis of a Combine Grain Yield Monitoring System*, M.Sc. Dissertation, Iowa State University. Accessed at: http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=4806&context=etd

Ruark, M.D., Panuska, J.C. and Cooley, E. T. (2009). Tile drainage in Wisconsin: understanding and locating tile drainage systems, Fact Sheet No. 1, University of Wisconsin Extension.

Scheiderer, D. (2015). Creating accurate management zones for reliable variable seeding results. Accessed at: http://past.infoag.org/abstract_papers/papers/paper_329.pdf

Straub, E. T. (2009). Understanding technology adoption: theory and future directions for informal learning, *Review of Educational Research*, **795**: 625.

Tremblay, N., Bouroubi, Y. M., Bélec, C., Mullen, R. W., Kitchen, N. R., Thomason, W. E. and Vories, E. D. (2012). Corn response to nitrogen is influenced by soil texture and weather, *Agronomy Journal*, **104(6)**:1658-1671.

Virginia Corporate Extension Service (2016). *Precision farming tools: global positioning system (GPS)*, Available at: http://pubs.ext.vt.edu/442/442-503/442-503.html

Wehrspan, J. (2014). Next big thing for planters: electric seed meters, *Farm Industry News*. Accessed at: http://farmindustrynews.com/planters/next-big-thing-planters-electric-seed-meters

Zak, P. (2013). Measurement myopia. Accessed at: http://www.druckerinstitute.com/2013/07/measurement-myopia/

Appendix

Tour Itinerary

Day	Activity	Further information	Details
14.7.15	Visit Dave Nelson Farm	http://nelsonff.com	Tour of Dave Nelson's farm and neighbouring farm. Mr Nelson farms some 2,500 acres and owns a supply business. He has been at the forefront of precision agriculture and its use on farm and is often an early adopter. Particular attention was paid to the use of GPS guided precision planting equipment, agronomic benefits of the systems in use, assessment of crop growth using NVDI and other crop sensing techniques for use in fertiliser programmes and the use of data to develop in field management zones was discussed. A visit to a neighbouring farm highlighted the importance of storage to access the alternative bioethanol market for corn (maize)
15.7.15	Attend Precision Planting Conference		Precision Planting is a company recently purchased by Monsanto. The conference took place in the impressive Huxley Centre just South of Ames, Iowa. Topics addressed by the conference included: consistency and repeatability in planting, row control, depth control, avoiding skips or doubles in planting (singulation) to encourage maximum emergence and resource use in-field. The use of multiple data sets to develop zones of management for seed rates and fertiliser applications was addressed, as well as weather data to aid in the application of nitrogen. Root health was also discussed as a means of assessing crop performance against the traditional use of growth stages.
16.7.15	Visit Ellsworth College	http://www.iavalley.edu/ecc/ecc-news/090814_usda_precision_ag_grant.html	Meet and discuss precision agricultural teaching methods with Professor Kevin Butt at Ellsworth College. Curriculum was discussed and resource need. Ellsworth has invested in a four-wheel drive vehicle equipped with GPS, computer-controlled spraying technology and auto-steer to enable students to use and understand how the equipment works. Both fixed wing and 'helicopter'

			drones have been purchased complete with analytical software to aid in teaching and prepare students for a rapidly moving workplace.
17.7.15	Visit Iowa State University - use of unmanned aerial vehicles	http://www.abe.iastate.edu/wp-content/blogs.dir/19/files/2013/07/Darr-2011.pdf	Note: spent the weekend at Lansing, on the Mississippi river. All work and no play…….!
20.7.15	Tour Ag leader	http://www.agleader.com/	AgLeader is a major precision agriculture company in the USA with a business portfolio in Europe, including UK. An introductory presentation was given to the business of AgLeader and a factory tour was carried out. EOC has been offered a reduced educational rate to purchase AgLeader software for interpreting in-field data. This software is in use at both Iowa State University and Ellsworth College.
21.7.15	Tour Kinze Manufacturing	http://www.kinze.com/article.aspx?id=26	Kinze is a large family owned international business making corn planters and other machinery. A tour of the factory was conducted, an infield demonstration of the equipment was carried out. The cutting edge technology currently being marketed by Kinze is their multi-hybrid planter which is able to plant two different types of hybrid corn depending on the soil type and yield potential of the zones within a field.
22.7.15	Using precision tools to improve soya bean husbandry	Dennis Friest - area farmer	Dennis is a farmer who has several years experience of using precision agricultural methods to improve his soya bean husbandry. He collaborates with the Soya Bean Growers Association and has proven the use of the precision tools particularly in relation to nutrient inputs.
23.7.15	Precision tools and drainage	Hansaker Family Farm - area farmers	The Handsaker are innovative farmers who have adopted precision agricultural methods for the planning and building of drainage tiles. Iowan soil is extremely rich in organic matter and is an alluvial, silty loam. It freezes each winter and undergoes a freeze thaw effect that alleviates compaction, however, the soil suffers from drainage problems and the Hansakers have developed a system of mapping using precision imagery that negates the need for surveying.

24.7.15	Reducing compaction and encouraging biological activity in the soil.	area farmer	David Granzow is concerned about compaction, nutrient cycling and root health. He employs the closest thing I saw during my tour to a controlled traffic system. Using GPS for controlled traffic is not common in the USA, but David is keeping to 'tram lines' as far as is possible. He has found that by strip tilling and alternating between soya beans and corn (maize) each year on the same rows he has encouraged both microbial activity and nutrient cycling. This has been because over half of the field remains uncropped. David had, by far, the best crop of soya beans I saw during my visit.
27.7.15	County Fair at weekend		An excellent chance to see some of the wider agricultural activity and enjoy the showing of animals american style.
28 - 29.7.15	InfoAg Conference	http://www.infoag.org/	An excellent three day conference dealing with issues as diverse as future scoping precision agricultural technologies, yield mapping and its uses, water use and how precision data can help reduce the demand on water resources and big data use.
30.7.15	return		