

GIS in the field; introducing spatial analysis as a basic skill to agriculture students

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Abstract.

Agriculture is an activity driven by spatial decision making. To be successful, a farmer must have an intimate, accurate knowledge of the land that he or she is managing, whether it be for animal or crop production. In traditional farming systems, this knowledge came from living on the land but this is becoming less common. Many farms in developed countries are managed by employees or contractors, who are expected to manage the farm efficiently from the first day they encounter it. This is compounded by rapid developments in technology and agricultural sciences. How these will work in practice can be very difficult to predict, even in a well understood landscape. Software solutions to these problems have been sought, with mixed success.

Most current farm management software systems have been derived from accounting packages. They are not good at dealing with the spatial attributes of farm management. Some software companies are beginning to address this by introducing a digital mapping "add on" to their main programs. This approach has yet to prove satisfactory, as they often do little more than produce a map on the screen. Spatial querying, time series analysis, trend analysis and the like are rarely supported.

The answer to these problems is two-fold; to create GIS programs which are suited to agricultural practice, and to educate current and future farmers in spatial awareness and analysis. The first part can be answered by taking mainstream GIS programs and tailoring them to handle the type of data used by farmers. Educating agricultural students in GIS can be straight forward, provided they are not frightened off by the technology on their first encounter. Many agricultural skills are based on spatial awareness. By studying these skills first and then showing how GIS can help in their application, students can quickly become enthusiastic users of GIS. When this is coupled with recent developments in GPS based precision farming systems and the increasing availability of economically priced, high resolution satellite images, the use of GIS as a fundamental farming tool becomes apparent. The approach to teaching GIS to students at the Royal Agricultural College will be discussed in this paper.

Introduction

Agriculture, by its very nature, is an activity driven by spatial decision making. Where should a particular crop be planted? Which fields will be best suited to cattle grazing? Why do some parts of the farm suffer more from drought than others? How much land will be covered by a winter flood? To be successful, a farmer must have an intimate, accurate knowledge of the land that he or she is managing, whether it be for animal or crop production.

In traditional farming systems, knowledge of the land came from living on it, often for many generations. A farm would pass down through generations of the same family, and its characteristics would be learnt by the children as they grew. Whilst this still happens, it is becoming less common. Many farms, especially in developed countries, are now managed by employees or contractors, who are expected to manage the farm efficiently from the first day they encounter it. This is compounded by rapid developments in agricultural technologies and sciences, which mean that new techniques and systems are frequently becoming available. How these will work in practice can be very difficult to predict, even in a well understood landscape. Software solutions to these problems have been sought, with mixed success. The adoption of GIS as a farm management tool may help solve these problems and so it is being introduced to the syllabus of agriculture courses at the Royal Agricultural College in the UK.

The spatial nature of agriculture

Location in space and time is a fundamental driver in agricultural systems. Where something is done, and when it is done, will have critical impacts on the success of that action. Crops do not simply have to be planted in the right place at the right time. They can be planted a different times, but will then require different management systems to produce a successful harvest. Wheat can be sown in the winter or the spring, but a site suited to spring sowing, having good water retention properties, may be poor for winter sowing because it becomes water logged. A south west slope in the United Kingdom will benefit from high insolation levels during the summer, but will be exposed to strong prevailing winds in the winter.

Anyone running a farm, whether for crop or animal production, will always need a profound understanding of the spatial and temporal variables that define the environment of that farm. Traditionally that understanding would come from, literally, living on the land. Farming units would have been relatively small and would have been run by a single family. The farm would pass from generation to generation, so that the children would have grown up on the land and experienced all of its variations throughout the year and between years.

In contemporary agriculture this understanding is being lost, particularly in technologically developed economies. Farms have become larger, in some cases enormously large. This in itself makes it difficult for anyone to have more than a superficial understanding of the land. When this is coupled with the growth in salaried farm managers and contractors, who move onto the land rather than grow up with it, the understanding becomes ever more tenuous.

Because of these changes, agricultural education must recognise that students need to be taught how to learn about the land that they will manage. Some will be managing the family farm, but this is becoming less and less common. For this reason, one of the basic disciplines of agricultural education is the development of spatial reasoning. Students need to know why location is important and how to assess that importance. This means that not only can they benefit from learning about GIS, but that they have always been taught and already think in a "GIS way". This makes formalised GIS teaching relatively easy, provided it is introduced at the right stage in the syllabus.

Developments in agricultural technology

Changes in the spatial understanding of farmers is one aspect of industrialised economies which has an impact on the need for GIS education. The other is growth of advanced technologies. Some of these are specific to agriculture, such as developments in genetics and agro-chemicals. Others are part of the digital revolution affecting all aspects of communication and business management. Digital developments in agriculture include the use of computer based farm information management systems and GPS based precision agriculture. Both of these technologies have links to GIS, with precision agriculture in particular being dependent on digital spatial data and analysis. Other areas of which are increasingly influenced by GIS are, for example, vehicle management systems (where are your tractors?) and supply line management (which is the closest sugar beet processing plant which has spare capacity now?).

Interestingly, developments of genetically modified (GM) crops have required farmers to apply advanced spatial analysis to the planning of controlled field trials for these new and highly controversial plants. These trials must take place in areas which meet strict spatial criteria, covering their distance from other cropped areas, the direction of prevailing winds, the topography of the land and sterile margins of specified widths around the crops. This type of problem has been used as a case study exercise for students studying GIS at the Royal Agricultural College.

Agricultural management software

As in all industries, software systems have been used for many years to run the general business side of farming. These are often developed from accountancy systems which have been tailored for farming business. These are successful but they do have great limitations. The farming market is relatively small, which makes development and support costs high. For this reason, the functionality and flexibility of many farm management systems trail behind those of systems designed for larger industries. Updates and extensions to programs often take the form of add-on components, which are likely to be incompatible with hardware peripherals, or cannot be integrated with other programs such as word-processors and spreadsheets. A steady stream of software patches have to be issued which then create further problems. Eventually a major upgrade is needed, which often requires data conversion, which is rarely fully successful.

A typical example of this is the addition of “mapping” capabilities to farm management systems. This is a normal feature of most current systems, and has yet to prove satisfactory. In some cases, the system merely displays a map image, with no data linkages. Others will use commercially available digital maps, such as those provided by the Ordnance Survey in the UK, but require a separate program from the general management system to display them. Often there is no topology and features are cartographic rather than geographic. Updating the map is difficult, sometimes impossible. This is unsatisfactory as farms are dynamic systems in which fields will be regularly combined or sub-divided, and the farmer needs to be able to make these changes to the maps easily and regularly.

The smallness of the farming market also means that the providers of farm management systems often turn to small, relatively unknown digital mapping companies to provide their mapping add-on capability. This provides a new outlet for these companies, who offer their products at great discount. However, the file formats are unconventional and transfer to other programs can be difficult. The functionality of these programs is restricted compared to a full GIS. Whilst farmers often say that they only want a map viewing capability, the moment their farm map is displayed on screen, they start asking spatial queries. “How big is that field?” “What area is planted with wheat?” “Can I link my crop map to my soil map?” “Can I use my yield maps in this system?” The limitations of the mapping programs quickly become apparent. Farmers who are keen to take full advantage of digital farm data can be frustrated by this. They would have benefited from starting with a full GIS, despite the initial cost and complexity.

Precision Agriculture

Mention was made earlier of yield maps, which are one of the most common outputs of modern precision farming systems. These are techniques used for targeting farming inputs, such as fertilisers, herbicides, pesticides and irrigation only at those areas which require them. The technology has become common with the availability cheap and accurate GPS. The standard means of input application is to use a digital map, which shows areas of need, such as lack of nutrient or persistent weed infestation. GPS guidance on the spraying equipment then takes the farmer to the area of need and controls the rate of application.

A curious aspect of precision farming is that many practitioners will comment that they feel there may be use for GIS in this area, without realising that they are already using advanced GIS in their farming!

GIS education for agricultural students

It will be clear from the above that agricultural students will benefit from understanding and using GIS. Their chosen subject is spatially based and they are being trained to make spatial decisions in all aspects of their education. They need to know how to plan efficient tractor movements and harvesting patterns. They have to understand soil and nutrient maps. They must understand how rain water will move both above and below ground. They learn how

pathogens and pests move through a crop. They read meteorological maps and have to predict the movement of weather systems. They think spatially.

A vital feature of GIS education for these students is to introduce it at the right time in the syllabus. They see GIS as a tool to solve problems, not as a subject to study in itself. Until they have been introduced to those problems they will not know what the tools are for. GIS therefore needs to be introduced late enough in the syllabus for them to be ready for it, but early enough for them to have a chance to use it. In the UK higher education system, where three years are the norm for an undergraduate degree programme, late in the second year would be the ideal, although this may not often be achieved because of the pressures of other, more traditional subject matters which have to be covered at this time as well. Despite this, it is found that many students will realise the potential of GIS for their studies and will choose GIS based subjects for project and dissertation topics.

GIS based projects and dissertations

The following paragraphs give some idea of the projects that students at the Royal Agricultural College have undertaken with GIS. Some are set case studies, others are chosen dissertation topics. In all cases GIS is just one of several tools which were used to carry out the work. Most importantly, students were required to apply their experience of their subject to the problem.

Site selection

One of the simplest spatial queries is finding a suitable site for a specified development which must satisfy a number of given or assumed criteria. At its basic level, this is a simple Boolean sieving of data, throwing out unsuitable land and keeping suitable. At a more advanced level, land is ranked by a McHarg overlay process, from most good to least good. This latter is of the most value, as students are required to establish the ranking of the qualities of the land based on their own understanding of the needs of the development and the limitations of the land.

Generally two types of developments are looked at, choosing a site for a new building and choosing an area of a farm most suited to a trial of a new crop. This latter case study has increased in importance with current concerns over trials for genetically modified crops. Not only must the land be suitable for the crop, it must also be at specified distances from other crops and from the boundary of the land owned by the farmer. This presents a range of spatial criteria which must be met.

Choosing a site for building is more straight forward, with the criteria being the type of land that *must not* be used, distance from services, distance from roads and so on. The problem is usually rendered harder by supplying less than ideal data, so that students have to make educated guesses or choose surrogate data, which they then have to justify.

In each case the student has to carry out two processes. First, the site selection process has to be modeled as a flowchart, based on the available data. This model is theoretical, so that it can be used in any GIS program. They then have to run the model using, in the case of the Royal Agricultural College, *ArcView 3.1*. The purpose of this modeling is to get them to study the problem and think how they intend to solve it, before they look to using a specific program. This way they will be able to construct models when they start work, regardless of which GIS program they may encounter in practice.

Landfill mapping

Two other projects are ones chosen by students as dissertation studies for their postgraduate masters degrees. The first is a fairly straightforward site visualisation exercise. The student had to present a series of posters at a public inquiry into the extension to a landfill refuse site to the south of the city of Bath in South West England. She used this work as the basis of her master's dissertation in rural land management (Webster 1999). The site was in a rural valley, half of which had already been used for landfill and had been re-landscaped. The inquiry wanted to see the visual effect of filling the rest of the valley. To do this, the student purchased rectified aerial photographs of the area from the National Remote Sensing Centre and imported these into ArcView. Road map data from ESRI for the United Kingdom was then overlaid on this photograph to give the context to the image and indicate extent of public access and visibility. Additional data layers showing site boundaries, before and after outlines of the extent of the fill and plans for final landscaping were then added in ArcView itself. These were then printed out in colour as the posters for the inquiry.

Image analysis in flax retting

The second project is a much more unusual one, and can barely be described as GIS. It does help to illustrate how ingenious students can be in achieving their ends. The student in question was completing a masters degree in agricultural engineering (Henderson 1999). His dissertation topic was the development of an automated means of determining the stage flax had achieved in the retting process. (The stems of some linseed plants, called flax, are used to produce the fibres for linen thread. In order to separate out the fibres, the stems of the plants must be *retted* to loosen them. Traditionally retting was a natural decaying process, carried out by steeping the flax in water until it was sufficiently rotted. The smell was obnoxious! Contemporary retting is a more chemically controlled process and not quite so aromatic.) The critical problem with retting is that it must be allowed to progress only for long enough. Too short a time and the fibres cannot be extracted, too long a time and the fibres have decayed. Judging the stage of retting is done by visual inspection of the change of colour of the decaying stems. This is a skilled and expensive process.

The student's approach was to take digital photographs of similar sized bundles of stems and analyse the images for colour range and percentage of different colours in the images. As he did not have ready access to image analysis software, but he did have experience of using *ArcView*, he used this to measure the relative areas of the different colours of the stems. Even more surprisingly, it worked really quite well! (We are now encouraging him to develop this

work further in a Ph.D. degree, using more appropriate image analysis software, which may then form the basis of a commercial process.)

Conclusions

Students in agriculture and related subjects are used to thinking spatially and they take to spatial querying with GIS very readily. It is important not to introduce it too soon in their studies, as they need to develop expertise in subjects before they can truly benefit from its use. It is also important not to frighten them off with the technology of GIS. By introducing it as a quicker and easier way of tackling problems they have already tackled by paper based traditional the are quickly won over and the technical problems are quickly overcome.

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