TOPMANAGE: A HIGH RESOLUTION GIS DIGITAL TERRAIN ANALYSIS TOOL TO STUDY THE MANAGEMENT OF FLOW ON FARMS

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ABSTRACT
Runoff Management is a concept that involves understanding how flow is lost from farmers fields and how this can be changed for the purpose of pollution remediation and flood storage. In order to support this concept a software tool called TOPMANGE has been developed to simulate hydrological flow paths which include the effects of man made features. TOPMANGE is a high resolution GIS terrain analysis toolkit that allows the user to manipulate flows for the net benefit to the environment. This study involves a number of case studies looking at fields prone to overland flow lost and examples for fields dominated by subsurface flow and land drains. Man made features such as tramlines, tyre tracks, land drains and ditches all control runoff. These features can be altered to change the nature of the runoff on the farm, such as altering the cultivation direction. New landscape features such as ponds and new hedgerows can be used to simulate the effect of disconnecting polluting flows and increasing the buffering capacity of the land. Diffuse temporary storage ponds also offer opportunities to remediate flows, whilst still on the farm itself.

Key words: Runoff Management, terrain analysis, GIS

INTRODUCTION
TOPMANGE (www.ncl.ac.uk/TOPCAT/TOPMANGE) is a high resolution GIS terrain analysis toolkit for studying runoff processes at the farm scale. By using high resolution data (for example 50cm grid cells in ditches and channels and 2m resolution to represent an actual terrain within fields), it is possible to represent the local micro topography controlling runoff. Also, high resolution data allows the effects of man made features on runoff, including tramlines, tyre tracks, hedgerows, roads, land drains and ponds to be simulated. A combined strategy of using gridded terrain data and vector data (ie linear data for representing man made features) can be implemented in the ArcView GIS. Many crucial topographic features that control runoff are often lost with grid cells of 10m or above. With high resolution maps it is possible to add subgrid features to the map directly by manipulating the gridded terrain data.

By combining terrain analysis with hydrological knowledge of the dominant runoff processes the impacts of overland flow, land drains, subsurface flow, ditch flow and buffer zones can be studied. This is a key visualisations and educational component relating the sources of nutrient flows and how pollutants reach the receiving waters. Thus by understanding how flow is leaving the farm it is possible to envisage runoff management options that can reduce the risk of nutrient losses. The tool allows the user many opportunities to ask 'what if' options for controlling the runoff. Here a strategic runoff management plan can be created for the farm, which demonstrates how flow can be controlled, disconnected from receiving waters, stored, infiltrated and even remediated. There are many locations in the landscape where water can be redirected and ponded. However, an estimate of the volume of likely flows that need to be stored and infiltrated into the soil is also needed. There is still the need to understand the flow runoff mechanism, for example, a storage pond in a field would not be needed if there was no overland flow.

Here, a series of case studies are presented to show a range of differing flow conditions. The study also includes example suggestions for creating runoff management plans that most suit the local research sites.

METHODS
ArcView allows both gridded and vector to be used together to visualise and manipulate terrain data. ArcView GIS also has many added tools for analysing the land. The data that is imported to the GIS is derived from a Global Positioning System (GPS). A Leica 500 GPS is mounted on an all terrain vehicle which allows large series of fields to be mapped rapidly and accurately (Fig 1). For ditch networks and sites with difficult access are mapped with the GPS on foot. Suitable sampling regimes can be established to give a faithful representation of the land surface (fig 2A, B). If there is a need to map the actual size of a ditch then a higher sampling rate is required.

The terrain analysis theory is based on the multiple flow direction theory of Quinn et all 1991. This method differs from the single flow direction option available in the ArcView tools. The software can be downloaded from the TOPMANGE web site, though a number of ArcView compatible tools can also be downloaded from the ESRI website.

The key terrain attribute calculated in TOPMANGE is the upslope accumulated area 'a', which is calculated in m^2. Hence as flow concentrates the value of 'a' will increase. Thus areas receiving large amounts of overland flow can be clearly visualised. If a design storm is used to give the likely flow depth, for example 10mm of overland flow, then the 'a' term can be converted to a volume, thus the capacity of a design feature such as a storage pond can be estimated. In ditch networks the design storm runoff multiplied by the 'a' term can give an estimate of the total flow in the ditch.

Figure 1, GPS base station and the Green machine about to map a large agricultural field.

There are two modes for the TOPMANGE toolkit, the first represents the 'effect' of a man made feature. The second mode is to map the exact hydraulic measurements of a ditch or river (or levee). Features such as tramlines and land drains are only a few centimetres wide and are still sub-grid scale even at 2m grid resolution. However, it is more important to capture the net effect of the feature and not its actual size and depth. Thus a vector overlay of tramline direction or drain position can be used to manipulate the existing elevation values. For the case of tramlines sufficient tramlines are added so as to capture their effect (perhaps every 10m). At the location where the vector crosses a grid cell the elevation is dropped to a lower value. By dropping the elevation by 1m then it is clearly demonstrating that one is only capturing the location and the effect of the feature and not its actual flow capacity. For the case of hedgerows or barriers the elevation is raised either by the desired height or by some nominal value.

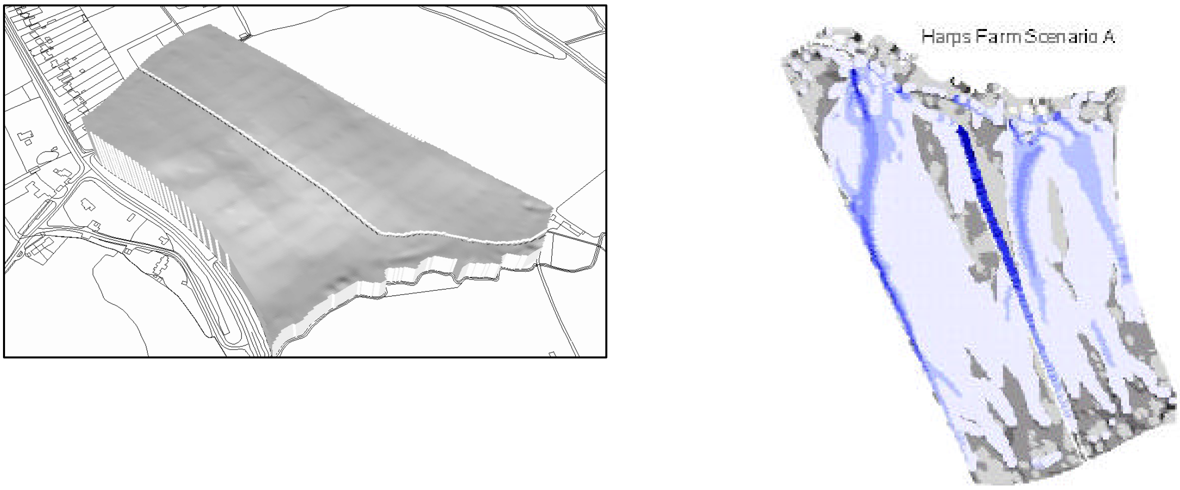

Figure 2 A 2m terrain map for a field prone to overland flow losses(left), and the flow accumulation map, where dark shades are zones of high overland flow accumulation.(right)

By adding your own man made features, the potential impact on the flow can be depicted. Hence TOPMANGE can be used as part of a runoff management plan (Quinn and Hewett 2003).

RESULTS AND DISCUSSION

Case Study 1. Here a field with steep slopes, silty soils, growing cereal crops is known to give large amounts of overland flow when the soil is bare. Figure 2A is the 2m grip map of the field where a track has been added that has deep tyre tracks (known to operate as channels during storm events). Figure 2B is the upslope flow accumulation map for figure 2A, which shows the importance of the track and two zones of flow concentration. However, it is also known that the farmer cultivates the field along the line of the steepest gradient. Fig 3A shows the impact of the current tramlines on the overland flow. Fig 3B shows the impact of changing the cultivation direction. For Fig 3B it is likely that the tramlines will spill at the locations of high flow accumulation seen on figure 2B.

In order to control the overland flow from this site it is proposed that the tramlines should be used to deliver the overland flow into the topographic hollows (Fig 4A). Secondly, it is proposed to create two diffuse storage ponds that can accept 10mm of overland flow (Fig 4B). These storage ponds should only fill for a few hours or days and they are designed to allow flow to either infiltrate or percolate through the barrier itself. These features also give an opportunity to sediment out material, to strip phosphate and buffer nitrate.

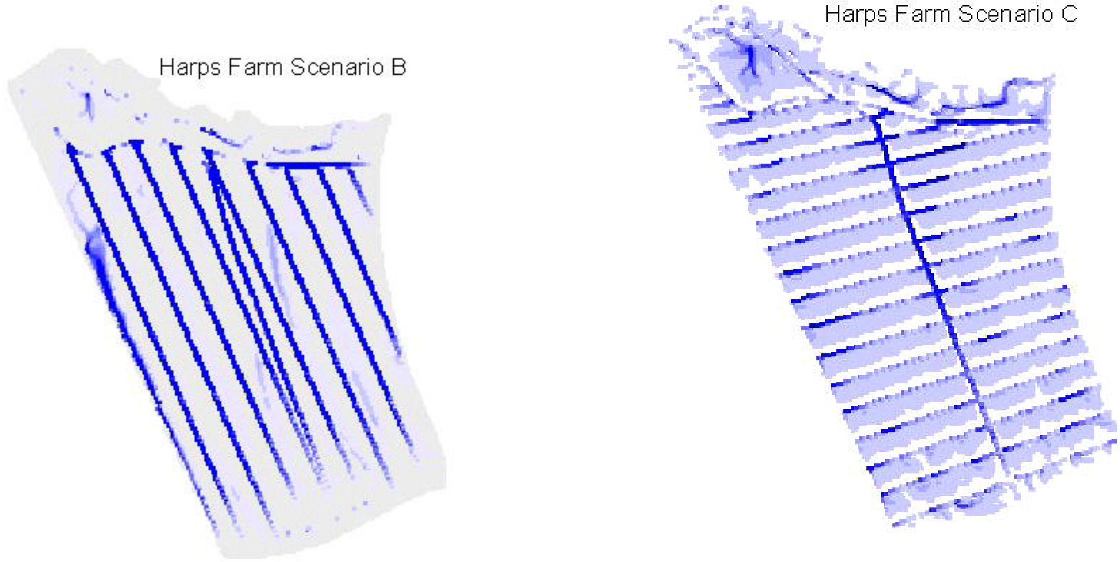

Fig 3A, The effect of tramlines on the overland flow when they follow the topographic slope. Fig 3B, The effect of cultivating in the opposite direction.

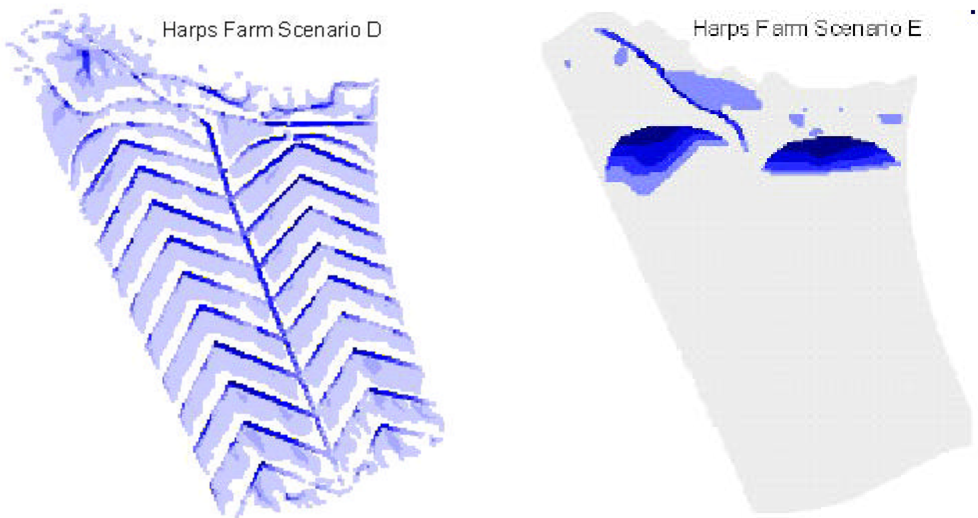

Fig 4A, the deliberate channelling of overland flow towards the natural topographic hollows. Fig 4B, the creation of 2 temporary diffuse overland flow storage ponds that will hold 10mm of overland flow.

Case study 2. Here the site is known to be dominated by shallow subsurface flow and some land drains. Fig 5A shows field draining into the main ditch, and a high resolution map of the ditch itself has been created. At this site the best opportunity to intercept, store and remediate flow is in the ditch, before the flow enters the main channel (and leaves the farm). It is important that runoff management occurs on the farm. Fig 5B shows a series of diffuse storage ponds and their storage capacities were 30m^3, 30 m^3, 20 m^3, 40 m^3, 60 m^3 when moving downstream respectively. It is worth noting that a number of temporary ponds would be needed in order to capture the bulk of the flow from these fields.

Similar case studies have occurred for land drains, hedgerow manipulation and for the strategic locations of field gates.

CONCLUSION

TOPMANGE is a high resolution tool for addressing the problem of nutrient pollution by representing the natural and man made features that dominate runoff processes on farms. The tool, when combined with other hydrological knowledge and agronomic information, can highlight obvious opportunities to disconnect polluting flows from receiving waters whilst on the farm itself. Runoff management and proactive intervention can be quite cheap, and does not have great impact on the profitability of the land itself.

REFERENCES

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Fig 5A, The network of fields draining into the main ditch. Fig 5B, Zooming into the mapped area, to show how the ditch can be mapped at high resolution (50cm grids) and analysed to find out how much flow can be stored and buffered/treated in the ditch itself.