

UTILIZING PRECISION FARMING TECHNOLOGIES TO IMPLEMENT AND MONITOR MANAGEMENT INTENSIVE GRAZING SYSTEMS

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ABSTRACT

Precision farming (PF) has become intensely studied in crop production with a minor concentration on animal production. The objective of this paper is to provide PF information in management intensive animal grazing (MIG) systems in a series of phases: 1) measure existing conventional and MIG pasture paddocks using PF, 2) design appropriate paddock or improve existing paddocks, 3) implement these paddocks with PF, 4) evaluate the effectiveness of each design. Current MIG design uses trial and error with aerial photographs, acetate overlays, and colored pens. This method can be integrated into a geographic information system (GIS) that has the capability of overlaying and analyzing paddock design information. Simultaneous development of MIG design criteria and GIS software algorithms was necessary. Algorithm tools developed in GIS were used to integrate MIG knowledge in designing optimal paddocks. Data indicate MIG designs optimized for a single criterion may not be optimal. This indicated a MIG criterion-scoring system needed to be developed for prioritizing existing design information. Existing tools were used to test hypotheses regarding factors influencing optimal paddock design. Results indicate PF is useful in MIG decision-making and production practices and is expected to maximize profitability.

Keywords: precision, management intensive grazing, MIG, GIS, livestock grazing, Avenue, script, rotational grazing

INTRODUCTION

Precision farming (PF) has been intensively studied over the past decade, primarily on site-specific crop fertilizer applications with minimal concentration on animal systems (Griffin, 1999). However, PF technologies have a potential to be used in animal systems. Management intensive livestock grazing (MIG) systems, which are known by many names: rotational grazing, managed grazing, prescribed grazing, management intensive rotational grazing and others (Henning et al., 2000) is a candidate for PF. The terms rotational grazing and MIG will be used interchangeably in this paper. The objective of this paper is to provide PF information in management intensive animal grazing systems in a series of phases: 1) measure existing conventional and MIG pasture paddocks using PF, 2) design appropriate paddock or improve existing paddocks, 3) implement these paddocks with PF, 4) evaluate the effectiveness of each design.

Rotational Grazing Background

Rotational grazing systems differ from conventional grazing systems. In a MIG system, livestock are frequently moved among pasture divisions or paddocks based on forage quality, quantity and livestock nutritional needs rather than allowing the animal to roam the entire pasture. The MIG approach to livestock management provides essential rest and recovery period for growing forage. Improved technology for fencing and watering systems has allowed many livestock producers to adopt MIG systems. Rotational grazing is not necessarily labor-intensive, but rather, a management-intensive system.

Management objectives for a particular forage and animal type must be clearly identified in production grazing systems. Frequency, intensity, timing, and duration of grazing as well as livestock stocking rate and class of animals appropriate for the particular ecosystem are blended to meet land management objectives (Henning et al., 2000). Rotational grazing stipulates controlling grazing animals and grazing pressure, or the height pasture is grazed. Controlling grazing pressure is crucial in maintaining desirable forage species and avoiding species shifts. Periods of extended low grazing pressure can reduce legume populations, due to being weakened by selective and frequent grazing. Periods of extended high grazing pressure may result in reduced pasture productivity and loss of desirable species. Better growth and persistence of desirable forages occurs with MIG. Rotational grazing systems usually have seven or more paddocks with grazing duration between one-half days to one week per paddock. Producers have greater control of animal intake in MIG systems. Overgrazing rapidly occurs when stocking rate to paddock area ratio is high, hence high grazing pressure. Producers must move animals to the next paddock before available forage falls below optimum range. When managing a MIG system, stocking rate and available pasture should be optimized.

Pasture growth rate varies with season, weather conditions, and soil productivity. While a lack of grazing management is the primary cause of pasture failure, a lack of fertility management is a secondary reason thus playing a significant role in MIG management. Consequently, forage growth rate varies among pasture areas in most grazing systems. Grid soil sampling is one option to

assess this variability (Brouder and Lowenberg-DeBoer, 2000). Rotation intervals and rest periods are based on forage growth rate, hence rotation timing must be flexible. Animals should be moved to paddocks that have reached optimum available forage quantity and quality, necessitating avoidance of rigid rotation schemes. Springtime management usually involves diverting pasture acreage to hay or silage production to store excess forage (Ohio Agronomy Guide – Bulletin 472).

Benefits of Rotational Grazing

Rotational grazing can be an economically and environmentally beneficial system. Economic aspects include lowering harvest costs by substituting livestock grazing for machine harvesting, lowering overall feed costs by increasing feed quality and quantity per acre of pasture, improving herd health, thus lowering animal cull rate and health treatment costs, and reducing labor costs. Increased forage management increases producer profits by controlling feeding costs and reducing land costs per head (Gerrish and Roberts, 1996).

Rotational grazing is an example of a sustainable conservation tool available to livestock producers. Healthy stands of vegetation and root mass reduce soil erosion, improve water infiltration, and reduce carbon sequestration. Naturally deposited manure rapidly decomposes into nutrients which remain in the soil. Aesthetic landscapes and recreational areas for camping, fishing, hunting, bird watching, hiking, photography, and sightseeing may also be created.

Rotational grazing benefits producers independent of farm size and can be implemented in existing animal production systems. Reduction of labor increases leisure time for personal activities. Rotational grazing reduces dependence on fossil fuels and chemical inputs. Rotational grazing is considered sustainable land use and supports rural communities, ultimately allowing lower-cost forage to produce food and fiber products for consumers.

Previous Rotational Grazing Research

This project builds upon research by Gerrish et al. (1995), Gerrish and Roberts (1996), and Henning et al., (2000) by adding the capabilities of GIS. Gerrish et al. (1995) suggest that distance to water issues have been largely ignored in the Midwest where distance to water has a greater effect on smaller paddock designs in humid temperate conditions than larger arid rangeland conditions where distance to water could be much greater. Gerrish et al. (1995) were inconclusive as to whether pasture utilization rate was influenced more by distance to water or by paddock geometry. Their recommendations for optimum grazing are water sources to be within 183 to 244 m of any grazing area. Consequently, their study indicates utilization rates within the 220 m wide square paddock were constant regardless of distance to water. Other primary factors influencing cattle grazing include topography, forage species and quality, paddock geometry, and stocking rate.

Consensus indicated a strong preference for minimizing geometric perimeter for forage utilization (Gerrish et al., 1995 and Henning et al., 2000). Minimizing the perimeter of a given paddock reduces forage trampling as livestock

instinctively examine boundaries. Minimizing perimeter may also minimize inappropriate deposition of manure. Geometrically minimizing the perimeter for any given area, a circle will be formed. However, curves are more difficult than straight lines to physically implement. Adjacent circular paddocks also create unused areas when placed side-by-side, reducing overall utilization. The alternative best shape with right angles for minimizing perimeter might be a square, however a 4:1 rectangle seems to be acceptable by animal scientists (Gerrish et al, 1995) as long as the proximity to the fence does not interfere with grazing areas. A square paddock offers a relative minimal perimeter to a rectangle, access ease to all areas of the paddock, cost effectiveness, and ease of construction. For these reasons, square paddocks except where the fence meet existing permanent boundaries is the design of choice.

Potential of Precision in Rotational Grazing

Grazing information exists, but no means of integrating spatial and temporal grazing data was feasible until recently. Improved desktop computer capability, desktop geographical information systems (GIS) software, and the advent of global positioning systems (GPS) allow agriculturalists to begin assimilating these data. Rotational grazing data collection, design, and implementation became feasible at the farm level as PF technologies became available. However, previous work was done on studies other than farm level pastures.

A review of the literature indicates that the use of GIS in MIG systems has been limited. The implementation of GIS in grazing studies has been applied to regional scales (Hill et al, 1996; Yool et al, 1997). Some studies examined GIS for predictive use modeling (Brock and Owensby, 2000) or for monitoring cattle movement within MIG paddocks (Turner et al, 1999). This project is one of the first to demonstrate the use of GIS in MIG paddock design and implementation.

Current methods of MIG paddock design use trial and error on printed aerial photographs and acetate overlays with colored pens (Henning et al., 2000). The current method of paddock design can easily be integrated into a GIS with the added benefits of data layering and mathematical analysis. Along with GPS, GIS is used to measure existing pastures, design appropriate paddocks, and used in the implementation of proposed designs. Once grazing cattle are introduced in paddocks, an evaluation of the design and process can begin.

Once these techniques are developed, layouts that are more efficient can be implemented leading to increased profitability and improved acceptance of PF and MIG, which has network externality benefits (Varian, 1996). This study is a first attempt in applying PF to improve the efficiency of design and implementation of MIG systems.

MATERIALS AND METHODS

This project was part of a larger research study at the University of Illinois Orr Center near Perry, Illinois investigating the effects of different forage mixes on animal performance and pasture ecosystem dynamics (Dahlquist, 2002). The Orr Center is located on rolling terrain in the loess hills of Western Illinois where there is a large interest in grazing lands issues. Being part of a larger study, the

overall MIG design was subjected to the following two constraints: 1) paddocks were required to be of equal area, and 2) the number of water sources must be minimized, but accessible to animals in each paddock.

Measuring Existing Pastures

Either a Magellan 330X GPS with WAAS Differential Correction or a Trimble GPS with Coast Guard Differential Correction was used to collect geospatial information. FarmWorks SiteMate Scouting software installed on a Compaq iPAQ 3650 handheld computer or AgView installed on a Lynx computer was used for data logging and paddock implementation.

All permanent manmade and natural boundaries were mapped by physically traveling the boundary or by geo-referencing corners. Areas identified as being not suitable for grazing such as woodlands and streams were measured so that these areas could be excluded from paddock design. Areas of available water, shade, and forage species composition and quantity were geo-referenced in a similar manner.

Design of Rotational Grazing Layouts

Once the permanent border point data were entered into a GIS database (ArcView GIS 3.2), design criteria were used to divide the pastures into six paddocks of equal size and similar shape. While useful for many agricultural projects, standard GIS functions were unable to do many necessary functions including erase smaller polygons from larger polygons and split existing pastures into appropriately sized paddocks. An aftermarket ArcView Extension named XTools was added into the software to facilitate creation and deletion of selected portions of polygons via Clip and Erase functions. Non-productive areas were erased from the original pasture layers in GIS creating new polygons of available forage area. To subdivide existing polygons into equal area polygons, Avenue script subprograms were added to the working project file (Huber, 2002).

Once the available forage polygon layers were developed in GIS, the polygons were subdivided into six equal area polygons or proposed paddocks (Huber, 2002). Despite equal size of usable forage area, the resulting paddocks demonstrated considerable variability in geometry and length of perimeter. For example, many of the resulting paddocks were extremely elongated, resulting in greater perimeter lengths. A design of this type is not suitable because cattle would need to cross the same paddock more than once in a single MIG rotation. Also, equal area paddocks without regard to geometry violated the constraint of each paddock having access to available water sources. However, distance to water was always less than 183 m to the water source regardless of paddock design.

In order to modify the geometry of the paddocks, new polygon theme layers were manually created, then modified with Clip and Erase functions. The manual system of GIS paddock design does not provide improvement over the conventional method using acetate overlays and grease pencils, but still offers the area calculation tool. The Clip and Erase functions of XTools became a significant tool at this stage of development. XTools was used to create or modify

many intermediate polygons with ease, but only a handful was ultimately used in proposed paddock implementation. New GIS theme layers were created in approximately the appropriate position. Clip and Erase functions were used to shape and position themes. Once the theme was suitable in shape and position, it was measured using the Calculate Area Avenue Script that is standard on ArcView GIS. All six paddocks were examined to determine if each had exactly the same area and likeness of perimeter was accommodated as much as possible given the location of the water sources.

Implementation of Proposed Paddocks

Once all paddocks were adjusted to meet the project constraints, implementation of paddock layout was achieved using a Trimble GPS system with Coast Guard Differential Correction and a Lynx computer with AgView software on an ATV to locate paddock corners in the field. Lines of sight were marked between corner posts and the fence was installed. These steps finalized the implementation of MIG using PF.

DISCUSSION AND SUMMARY

The use of GIS was discovered not as user friendly as originally anticipated. An earlier intent of this project was to supply producers with modified GIS scripts to allow ease of MIG design. The GIS template developed in this project presents the capabilities of dividing usable forage areas into paddocks of equal size in a two-dimensional view, but slope, elevation, shade, surface area, fencing costs and other design criteria were not evaluated. Capabilities such as calculating areas and automated polygon splitting were especially beneficial. Although some techniques in GIS still required methodology using trial and error, layout of paddocks designed with GIS was much easier given that the geo-referenced layout could be implemented in a relatively short period of time.

Future Work

Adjust existing Avenue Scripts to account for other grazing criteria should be developed and integrated into the template developed for this project. For instance, aspect, degree of slope, shade, and forage species are known to affect grazing factors, which in turn influence site-specific profitability. Before GIS is widely used even at the research level, scripts and project modifications should be developed to automate several steps. Untrained GIS users may become frustrated, make human errors, and ultimately quit using GIS, making training of the use of PF technologies critical to the acceptance and adoption by practitioners.

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