Using Geospatial Information Technologies and Field Research to Enhance Classroom Learning

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ABSTRACT

A focus of grazing management courses is the cause–effect relationships between grazing livestock distribution and environmental and management variables. A learning module for the classroom was developed to enable students to actively study livestock distribution by analyzing recently collected data from an on-ranch situation. Data were collected at the University of Nebraska’s Barta Brothers Ranch in the Nebraska Sandhills. Six cows (Bos taurus) were fitted with global positioning system (GPS) collars and grazed freely with a herd of cow–calf pairs. Their locations were recorded at 5- or 10-minute intervals during two summer grazing periods in 2003. Following each grazing period, the collars were removed and the data were transferred to a personal computer. A geographic information system (GIS) software program (GRASS) was used for data processing and analyses. A standard digital elevation model of the ranch property was imported into GRASS as the base topographical map. Software tools were used to create animations and present analyzed data in tabular and graphical form. The learning module has two lessons. The first lesson presents the principles of grazing distribution and the second lesson enables the student to analyze the GPS locational data. In analyzing the GPS data, students have numerous options and select the pasture, date(s), hours of the day, and the independent variable (e.g., topographical position or livestock water location) to be included in the analyses. Students can develop hypotheses concerning the relationship between these independent variables and livestock distribution, and test these hypotheses using the output from the module. Student evaluations indicate that the module is effective in engaging the students as learners and improving their ability to think critically.

Curricula in undergraduate and graduate programs associated with forage–livestock production systems typically have courses in grazing management, plant–animal interactions, and/or methods in grazing research. Fundamental to these courses is explaining the relationship between grazing animal distribution and environmental and management factors. Topography, grazing strategies, and livestock water locations are key factors affecting distribution of livestock grazing; and grazing distribution is an important factor affecting harvest efficiency, sustainable stocking rates, and revenue per unit area. Understanding these cause–effect relationships is critical to the study and management of livestock grazing systems. Classroom presentations dealing with grazing distribution generally are limited to lectures and indoor exercises that do not fully engage the student or demonstrate the dynamics of these cause–effect relationships. Taking students to the field to study these relationships is unrealistic in most situations because of time limitations and inadequate animal and land resources in the vicinity of the classroom.

The relationship between environmental and management factors and grazing livestock distribution has been studied for decades and is fundamental to understanding and improving management of grazing systems (Schacht et al., 1996; Valentine, 2001). Until recently, techniques used to record livestock distribution in the field have been labor intensive and largely based on visual observations by the researcher (Altman, 1974; Howery et al., 1996). Currently, many researchers are using Global Positioning Systems (GPS) and Geographic Information Systems (GIS) to improve the efficiency and effectiveness of quantifying the distribution of livestock grazing in response to various independent variables (Ganskopp, 2001; Bailey et al., 2004). Animals can be tracked on a 24-hour basis for weeks at a time using GPS receivers incorporated into collars placed around the grazing animal’s neck. The GPS coordinates are stored in the collar and can be transferred later to a personal computer (PC) for analysis. The GIS software program can then be used to analyze and summarize data collected from the GPS collars relative to such independent factors as topography. These automated systems greatly reduce the amount of time required to collect and process data that enhances data analysis options and capabilities.

Using GPS/GIS technologies has great promise for teaching basic principles governing grazing animal distribution. Data collected electronically in the field can be sent directly to the classroom where it is processed, analyzed, and presented to the students in a convenient and relevant form. The specific objective of this project was to develop an educational product, or learning module, that enables students to become actively involved in studying the effect of management and environmental factors on grazing livestock distribution. The module provided students with recently collected data from an on-ranch situation and the means to process and analyze these data on campus in a computer laboratory. A complementary objective was to expose students to field research and to become knowledgeable of the scientific method. The module was developed for integration into two resident courses (AGRO/RNGE 340 Range Management and Improvement and AGRO 940/ASCI 924 Forage Evaluation) taught in spring semesters at the University of Nebraska-Lincoln.

Abbreviations: DEM, digital elevation model; GPS, global positioning system; GIS, geographic information system; PC, personal computer.

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DEVELOPMENT OF THE LEARNING MODULE

Study Site and Data Collection

Data for the module were collected at the University of Nebraska’s Barta Brothers Ranch, a 2350-hectare ranch in the eastern Nebraska Sandhills. The ranch is located about 30 kilometers south of Long Pine in Rock and Brown counties, and about 420 kilometers northwest of Lincoln. The ranch is dominated by sand dunes laid down in a linear orientation from WNW to ESE. The dunes are covered by a relatively dense stand of tall and mid-grasses (Schacht et al., 2000). The ranch is stocked with four herds of beef cattle (Bos taurus) during the growing season from mid-May to mid-October of each year. In 2003, one of the herds was selected for the purpose of collecting grazing distribution data. The herd of 100 cow–calf pairs was rotated through eight pastures twice during the growing season. Each pasture was about 60 hectares with a centrally located water tank.

Six cows from the herd were fitted with Lotek GPS 2000 collars (Lotek Wireless, Newmarket, ON, Canada; Fig. 1). A collar is a leather belt with a mounted and hermetically sealed casing that encloses the GPS and data logging devices. Each collar has a temperature sensor, user-programmable GPS scheduler, and data storage capacity of more than 10 000 locations. The GPS receivers are capable of recording animal position with a positional accuracy within 5 to 12 meters after differential correction (Moen et al., 1997). A collared animal must be caught and the collar removed to retrieve the data. The six cows were fitted with the collars for two grazing periods during the growing season: once for 17 days from late May to mid-June and a second time for 2 weeks from late July to mid-August. The cows grazed freely with the herd and their locations were recorded by the collars at 10-minute intervals in the first grazing period and at 5-minute intervals in the second grazing period. Battery life and data storage capacity of the collars were considered along with other factors when selecting the sampling interval and the operational time for the GPS devices. Collars were placed on and removed from the cows in a set of portable pens that were set up in the pastures. After removing the collars from the cows, the data were transferred to a PC at the ranch by connecting the GPS device of the collar to a serial port on the PC.

Software Used and System Infrastructure

The GIS software GRASS was used in this project (www.baylor.edu/grass; verified 28 Apr. 2005). GRASS is an open source, free GIS software with raster, topological vector, image processing, and graphics production functionality. It operates on various platforms through a graphical user interface and shell in X-Windows. The capability of GRASS to accept commands through a shell made it easier to interface and make its functionalities available through a web browser. The engine that interfaces GRASS and the web server is written in Perl. Perl is a stable, cross-platform programming language with a strong capability of text manipulation and system interfacing.

The base topographical map of the pastures was obtained by importing a standard U.S. Geological Survey (USGS) Digital Elevation Model (DEM) file with formatted data of the region into GRASS. The exact locations of the pastures were then plotted by overlaying the GPS coordinates on the rendered map. To facilitate the analysis of cattle locations and their movements, the GPS data collected from the collars were parsed and stored in a structured query language (MySQL; www.mysql.com/; verified 28 Apr. 2005) database. The GPS database enables the system to perform complex analyses dynamically and to run selective queries made by the user. The outputs from the analyses are presented in a web presentable format using Macromedia Flash (www.macromedia.com/; verified 28 Apr. 2005) and Java Pтplot (http://ptolemy.eecs.berkeley.edu/java/ptplot/; verified 28 Apr. 2005). Macromedia Flash is a web animation standard and a widely used tool for creating multimedia rich content. It was used in this project to illustrate cattle movement on the base topographical map of a pasture during a 24-hour period. Java Pтplot is a two-dimensional data plotter and histogram tool implemented in Java. Pтplot enables web applications to visualize graphically real time data and analyses results.

THE LEARNING MODULE

Format and Usage of the Learning Module

The learning module is a web-based, user-friendly, online system that is comprised of two lessons. The first lesson concentrates on the principles and concepts of livestock grazing distribution. Basics of livestock distribution on rangeland and pastureland are taught through a combination of text, tables, figures, animations, self-study questions, and quizzes. The first lesson can be completed successfully in 50 to 60 minutes.

The second lesson is based on the processed data from the GPS collars. Students are guided through the lesson as they select the data to be analyzed and the type of analysis to be conducted. The lesson design enables the student to freely investigate the relationship between several independent variables (e.g., topographical position or livestock water location) and cattle distribution. The first feature of the lesson that can be viewed by the student is an animation of cow movement in a selected pasture, day, and hours of the day. When viewed on the screen, the cows appear as dots, fast forwarding their...
Fig. 2. Screen capture of the three-dimensional animation representing the movement of the cows in a pasture for a selected time period.

Fig. 3. Screen from which students select date(s), hours of the day, and independent variable for analysis.
way over a three-dimensional image of the pasture (Fig. 2). This feature gives the students a quick view of the cows’ distribution for the time period selected and prepares them for making up-coming selections concerning data analysis.

In analyzing the GPS data, the student has numerous options and selects the pasture, date(s), hours of the day, and the independent variable to be included in the analyses (Fig. 3). The independent variables include livestock water location, topographical position or aspect (i.e., north-facing slopes, south-facing slopes, dune tops, and basins), air temperature, and time of day. Students can investigate if the proportion of time cattle spent in a certain area (i.e., dependent variable) is correlated to water location, topographical position, or time of day. Other investigations can examine relationships between distance traveled and time of day or air temperature. Results of analysis are presented in tabular or graphical form (Fig. 4), allowing the student to view the relationship between grazing distribution and selected environmental or management variables.

In a more structured exercise, the students can develop hypotheses based on the type of data available (e.g., mature cows prefer lowlands during daylight hours or distance traveled by cows declines with increasing temperature) and test them using the output from this system. This exercise goes beyond the students learning about factors affecting grazing distribution. The students learn about the scientific method as they identify researchable questions, develop hypotheses, select the appropriate variables for analysis, and interpret results of analysis. Overall, the module provides the students with an interactive overview of field research, advanced technology systems, and data analysis.

The module also can be used in extension programming. Livestock producers on range and pasture obviously have an appreciation for grazing distribution because of its effect on stocking rates and potential return per hectare. The module is an excellent tool for demonstrating to livestock producers the environmental and management factors that affect grazing distribution. Livestock producers are fascinated by the technology and recognize the potential of GPS/GIS systems to enhance the management of livestock/forage enterprises.

**Evaluation of Module**

An evaluation form was available on the Website to students who worked through the module as an assignment in AGRO/RNGE 340 (20 students) or AGRO 940/ASCI 924 (14 students) in the spring semester of 2004. Responses to evaluation questions were on a 1 to 5 scale with 1 being a strongly
disagree response and 5 being a strongly agree response. The questions focused on evaluation of (i) presentation quality of the text, animations, glossary, self-study questions, and other learning tools; (ii) level of subject matter knowledge following completion of the lessons; and (iii) effectiveness of the second lesson as an exercise in higher learning. All students agreed or strongly agreed that the module was well constructed and an effective experiential tool for learning the cause–effect relations in grazing distribution of cattle. The evaluation indicated that the module was effective in engaging the students as learners, in stimulating their curiosity about the subject matter, and in improving their ability to think critically.

The module can be used effectively in a number of different learning environments. The principles and concepts presented in the first lesson can be self-taught by a student at the computer or be a group activity. The second lesson of the module appears to be used most effectively as a group activity in a computer laboratory/classroom. The lesson requires students to critically think and make decisions about dynamic and interrelated variables. Students generally stimulate each other to explore and investigate possibilities, resulting in a greater number of students engaged in the learning process. Instructor involvement is necessary to provide structure and direction, especially in situations where educational objectives are focused on higher levels of learning (e.g., critical thinking and data interpretation) and application to research. Overall, this module met our main objective of creating an environment in which students actively learn to apply principles and concepts to a field situation. Moreover, the module can be used as a template for developing educational products based on field research data and advanced technology systems.

REFERENCES