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Development of GIS-based Ecological Carrying Capacity Assessment System

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ABSTRACT

Earth ecosystems cover about 28% of our planet, but only 25% of these ecosystems are green, while the remainders are characterized by sparse vegetation cover that shows the color of the soil beneath. Much of the sparse vegetation is found in arid and semiarid deserts. Using the GIS-based approach, Ecological Carrying Capacity Model of Nutrition Resources (ECCNR) is based on grazing energy intake. This study focused on the identification and analysis of the components of the ECCNR during three years in the Bakkan distinct, located in Southern Iran. The objectives of the study were to identify and describe the current components of the highland range, crop production system, the grazing ruminant production system and their interactions. Based on the study objectives, an approach system was determined to be the best way of recognizing the effects of, and the relationships between the components and modeling and simulating them is the most effective way to study and assess this complex system. Surveys were used as a technique to gather data, from interviews with nomads and the heads of their groups over a period of three years. The observations validate the generalized structure of the ECCNR under the different feeding and production systems, and this model can be coupled with the appropriate models of feeds and feeding systems in rangeland, cropland, and hand feeding systems.

Keywords: Ecological carrying capacity, ecological modelling, grazing energy intake, nutrition resources, southern Iran.

INTRODUCTION

Many studies have recommended that environmental issues be absorbed into project planning and design and to fully incorporate environmental issues in the planning stage itself (Mc Donald and Brown, 1995). Incorporating environmental knowledge into planning contributes significantly to sustainable planning (Leitao *et al.*, 2002). Environmental planning (EP) occurs early in the planning process and can be incorporated into land use planning to address environmental issues. By addressing environmental concerns early in the project development cycle, environmental planning helps to mitigate environmental impacts. Site development suitability analysis is based on an environmental sensitivity assessment and considers constraining factors for certain developments in the site, for example a wetland of ecological importance or land having high slope. “Suitability levels” are first tested based on individual factors which are later overlaid to indicate overall development suitability. This approach considers existing natural resources at the site and aims to protect environmentally and ecologically sensitive areas. A GIS-based site suitability analysis on the environmental evaluation for urban land-use planning is illustrated for the urban area of Lanzhou City and its vicinity in Northwest China (Dai *et al*., 2001). GIS analysis helps in evaluating large data at landscape and regional level easily and helps decision makers to visually understand the environmental consequences of the project (Badjian, 2005). Environment planning and ecological planning can be incorporated into both large and small scale development projects and will help in choosing the best available land that helps to reduce environmental impacts and preserve biodiversity. Landscape ecological planning can provide a conceptual framework for the assessment of consequences of long-term development processes like urbanization and industrialization on biodiversity components and helps in evaluating and visualizing the impacts of alternative planning scenarios. In recent decades, GIS-based ecological and environmental planning has contributed immensely to sustainable development. GIS based environmental planning is being practiced in many developing nations now like Mauritius (Johnson, 2010) with developed nations already in advanced stages of using GIS in sustainable land use planning. In India, there have been many studies on land use planning for cities (Sudhira *et al*., 2003; 2004), townships, industrial areas, districts (Bobade *et al*., 2010) and watersheds (Chowdary *et al*., 2009).

The GIS- based Ecological Carrying Capacity Model of Nutrition Resources (ECCNR-GIS) software is a new approach based on rangeland assessment and the estimated energy content of forage. This software is derived from following studies on the ecological capacity model of livestock feed resources in Bakkan plain area, Southern Iran (Badjian, 2013). ECCNR-GIS software is designed to calculate the regional ecological carrying capacity based on available forage resources and considers the energy metabolism (ME) requirements in relation to livestock management to estimate the animal needs. ECCNR-GIS software is written in Visual Basic, as a set of mathematical equations that represent a system of relations between production subsystems. The software is based on conceptual models and measurements taken from rangeland, agricultural fields and animal herds of Joobkhale region in Southern Iran. These subsystems include rangeland production as the main forage resource of the region together with farm byproducts that also play a significant role in the area. The current status of the rangelands does not meet the needs of the animal and hence the need to incorporate agricultural crops and residues. The model estimates the amount of energy produced from agricultural residues to determine overall nutritional supplies and carrying capacity (Badjian *et al*., 2003; 2004).

MATERIALS AND METHODS

The production data from rangelands used in ECCNR-GIS software was estimated from plant species derived from digital plots and maps of slope, soil, pasture, palatability class status and trends at a plot level, with digital point location using GPS. Digital plots showed distribution of species in vegetation types. These were used as input information in the GIS environment. After weighing the dried samples, the amount of energy based on dry matter digestibility (DMD) was determined. Available forage AF, ME, DMD and the production rate (P) of species were also estimated. A mathematical relationship between the amount of DMD and ADF (Acid Detergent Fiber) in ECCNR-GIS was established.

In the laboratory, samples were dried and ground and ADF value was measured to estimate the amount o f DMD (Badjian *et al*., 2008).

The software estimated the total energy produced compared with the amount of energy needed for the livestock subsystem in the area. Hand feeding systems of the animals was taken into account for by including rangeland and farm by-products through the calculation of the amount of energy. The software consists of all the relationships of herd type and composition of the herd as well as the relationship between grazing and rangeland, ranging from topography, class, slope class, soil rating palatability of the status (Badjian *et al*., 2004; 2005). The trends in the pasture with the loss of energy are also given in the mathematical equation.

DISCUSSION AND RESULTS

Properly managed grazing is ecologically sustain-able. But because long-term sustainability is linked closely to social values, the greatest challenges to the development and implementation of fully sustainable rangeland agriculture systems are social rather than ecological. As such, rangeland agriculture in the United States and other economically developed countries will continue to be threatened if rangeland agriculturalists do not respond to changing social values in a positive, proactive, and understanding manner. This is in contrast to those regions of the world where economic development is severely limited and current human population is at or in excess of ecological carrying capacity. In those situations, we suggest that it's folly to attempt to develop sustainable agriculture systems, including rangeland agriculture systems, before addressing and rectifying the ecological and social challenges arising from unsustainable human populations.

Introduction of ECCNR-GIS features and its abilities can be described in following outputs:

I- Vegetation layer accompanied with ecological rangeland assessment is based on evaluated digital plots including the type of plant species in each vegetation type, slope, soil, pasture conditions, trends, range and class of palatability. Clearly the greater the number of digital points, is the more accurate the result in a model.

II- Measuring the vegetation-types area is based on the species canopy in plots. A digital vegetation-type area layer is produced in GIS.

III- Based on topography of the region, soil classes can be determined. Compliance with the layer level of the digital environment, GIS, soil surface of each class can be obtained. The digital domain not only shows the location and condition of species on soil, but also in other parts of the region. In other words, the user can determine the state of the soil in the region.

IV- Based on topography of the region, steep class types can be determined. These levels are defined in terms of the classification model. As before, the user can recognize the entire class gradient in the study area that would assist in planning.

V- Domain combination of rangeland condition and trend in digital is defined in ECCNR-GIS. This combination would be compared in determination of the PUF (Proper Use Factor) coefficient. This factor helps the user to determine the combination level of grazing management in the region.

VI - Palatability as a factor in determining the amount of reducing multiple PUF is defined in the placement of digital surface in ECCNR-GIS. This map would help the user to make the necessary decisions for grazing management in the region.

VII - Range of plant-level production based on the different types of digital harvested forage production levels is defined in ECCNR-GIS. Certainly, compared to the levels obtained in the previous steps, this factor would be an important rangeland grazing management decision-making factor.

VIII – Rangeland trending and condition, vegetation class, steep, slope and soil classes are factors that affect palatability and animal preference or PUF in ECCNR-GIS. Domain information would help the user for the aforementioned factors and optimal management to apply.

IX – Available forage (AF) of the rangeland related to PUF can be obtained in ECCNR-GIS. AF level helps the user to generate an optimal utilization (a maximum of 50% forage production).

X - Determination of metabolic energy (ME) of digitally located species in vegetation types that is based on DMD.

XI - Determination of DMD layout and levels in ECCNR-GIS can be estimated by the ME.

XII - The final ECCNR-GIS output am ME level in digital vegetation map of the region. This map shows the ecological factors that impinge on sustainable ME production with consideration of the region's livestock. This map shows the ecological balance between livestock and rangeland.

CONCLUSION

Work with ECCNR-GIS software is easy and with a little education, most experts familiar with GIS can benefit from it. Changing the input data to the ECCNR-GIS, it can predict, on the basis of a herd of productive resources, provision of productive resources based on vegetation change in circumstances such as drought and subsequent ecological capacity of livestock feed resources in different conditions.

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