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Decision support software for estimating the economic efficiency of grazingland production.

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Abstract

Decision support software has evolved in a number of disciplines to facilitate efficient allocation of resources. Such tools are especially useful where the response of complex systems to human activity are difficult to predict. Decision support systems empower managers to rapidly analyze the ecological and economic implications of alternative management strategies. The Grazingland Alternative Analysis Tool (GAAT), has been developed to estimate the economic efficiency of a wide range of grazingland production systems. Systems that can be analyzed, either individually or in combination, include livestock, wildlife, leased grazing, grain and forage crops, wood products and other non-forage crops. The planning horizon, discount rate, available forage, consumption by class of animal, herd management practices, product yields, product and input prices, and improvement investments must be specified by the user. The GAAT program calculates the resulting annual forage balance for all enterprises being analyzed and the net present value and internal rate of return for the specified management interventions during the planning period. Two examples are presented to demonstrate the flexibility of GAAT for analyzing the economic efficiency of grazingland production systems. The first example analyzes the use of prescribed burning to control Ashe juniper (*Juniper ashei* Buckholz) and the second determines the economic effect of changing a dairy from a concentrate-dependent to a grazing-dependent system.

Key Words: economic analysis, improvement investments, internal return rate, net present value.

The range, quantity, and quality of animal-based products that can be produced from grazinglands depends on the diversity and productivity of plant communities and the existence of animal species to exploit these communities. However, managing complex ecosystems for pre-selected levels of animal production and attainment of economic goals is difficult (Conner 1991).

Uncertainty and the dynamic, interactive nature of management effects on complex ecosystems has led to the development of computer-based analysis tools for estimating the ecological sensitivity and economic efficiency of alternative management inputs (Stuth and Lyons 1993). Such decision support systems range from computer models to expert and geographic information systems (Stuth and Stafford-Smith 1993) and have been applied to integrated forage/livestock systems, vegetation manipulation, and development policy issues in several parts of the world (Stuth 1991).

The Resource Systems Planning Model-RSPM (Stuth et al. 1990) and the resulting Grazing Land Applications software, known as GLA (Stuth et al. 1991), are important examples of an evolving integrated decision support software developed to facilitate rangeland management planning. One part of GLA consists of a simple economic analysis tool called ECON (Conner et al. 1990). It facilitates estimating returns to investments in range improvement and/or grazing management practices over a 20-year period. The principles for integrating economics into decision support software to manage grazinglands are discussed by Conner (1993).

The need for using computer-based economic analysis tools and the analytical principals incorporated in such tools are discussed herein. A description of the structure and operation of one such tool called GAAT (Grazingland Alternative Analysis Tool) that was recently developed at Texas A&M University, comprises the bulk of the presentation. Finally, 2 applications are described to illustrate the versatility of GAAT for use by ranchers, public land managers, extension specialists, and other rangeland management professionals to estimate the comparative economic efficiency of grazingland management alternatives. The first example compares mechanical and fire treatment of juniper and the second compares concentrate and grazing-dependent dairy production.

Economic Analysis

To be relevant, economic analyses must be directed towards questions that will help people decide on a course of action (Workman et al. 1986). In order to facilitate efficient use of limited resources, the analyses frequently entail comparison of the relative return to alternative investment opportunities. The specific reasons for applying economic analyses to grazingland management practices may include efficient land management planning, risk analysis, and analysis of policy effects, among others. For example, the long-run versus short-run economic optimum stocking rates for alternative livestock production systems may be of primary concern (Torell et al. 1991). Alternatively, if ecosystem response to herbivory is uncertain, economic analyses may be used to estimate the sensitivity of profit estimates to alternative animal production systems (Kreuter and Workman 1994a).

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government policy on the allocation of rangeland resources to various animal production systems (Kreuter and Workman 1994b) or for assessing the economic impacts of climate change on grazinglands (Conner 1994).

Regardless of the purpose for which economic analyses are conducted, certain concepts are central to all such analyses. Due to their subjective time preference, most people ascribe greater value to present rather than future consumption of resources (Workman 1986), though the extent of such time preference varies. In economic analyses, future benefits and costs should therefore be discounted by the opportunity cost of using resources to reflect human time preference. There is, however, no universal consensus about the opportunity cost of using biological resources, such as grazinglands. Workman (1986, pp. 198-206) discusses the selection of a "suitable" discount rate for conducting benefit/cost analyses of investments in natural resources and emphasizes using real rates (e.g., nominal interest rate net of risk and inflation). In addition to the discount rate, benefit/cost analyses also require specification of the likely longevity of investments or, alternatively, a relevant time horizon for the analysis.

Various parameters can be used to measure the economic efficiency of investments providing long-term benefits and/or costs (Workman 1981). The net present value (NPV) is often the measure of choice because it provides a monetary value of the estimated returns from an investment, facilitating comparison of alternative investment options. It is the difference between the cumulative discounted benefit and the cumulative discounted cost of an investment. If it is greater than 0, then, at the selected discount rate, the investment is economically efficient. However, since selection of an appropriate discount rate may not always be easy, some analysts prefer estimating the internal return rate (IRR) to estimate the economic efficiency of an investment. It is the interest rate that forces a future stream of net benefits to equal the investment needed to produce the flow of returns (Workman 1986). When the internal return rate exceeds the opportunity cost of making the investment (i.e., the yield of the next best investment), the investment is considered economically efficient. Since hand calculation of the economic efficiency parameters of long-term investments is laborious, particularly when investment environments are dynamic or when benefits and costs are sporadic, computer-based economic analysis tools have been developed to facilitate calculation. GAAT was developed by the Ranching Systems Group, Texas A&M University, to rapidly estimate the economic efficiency of a wide array of animal and non-animal production systems and grazingland improvement practices. It calculates both the NPV and IRR of practices or investments under consideration.

Grazingland Alternative Analysis Tool - GAAT

Purpose of GAAT

GAAT was designed to estimate the economic feasibility of investments aimed at increasing forage quantity, quality and availability, animal productivity and product value, and to allow changes in the herd structure and mix of animal and non-animal enterprises within the specified management unit over a 25 year planning horizon. GATT has the following specific objectives:

1. Accommodate the economic analysis of a wide range of animal enterprises, including extensive livestock systems, dairy and wildlife, and non-animal enterprises, including lease grazing, wood products, grain forage crops and other non-forage crops.
2. Allow herd structure in each livestock enterprise to be changed throughout the planning horizon by varying purchase, birth, sales, culling, death, and replacement rates.
3. Allow forage resources (specified in AUMs) allocated to each enterprise to be changed throughout the planning horizon.
4. Provide detailed specification of operating revenues and costs by allowing changes through time of product prices and expenditure on individual cost items.

Structural Framework

GAAT is a Windows™-based decision support tool written in Microsoft® Access® 2.0, a relational database management system. It is comprised of hierarchical input modules, encapsulated in cascading windows with pull-down operating menus. The 3-segment, hierarchical structure of GAAT and the various levels of input modules in each part are illustrated in Figure 1.

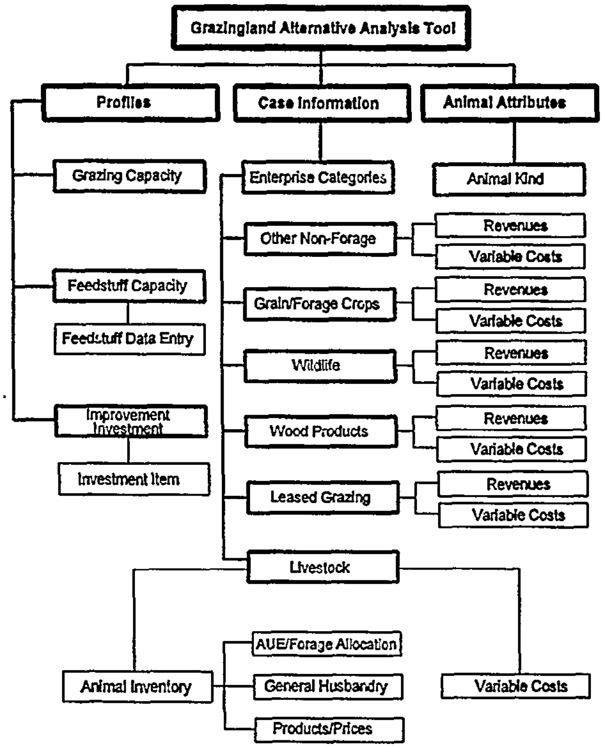

Fig. 1. Internal structure of GAAT.

Central to GAAT's structure is the Case Information segment. In this, the user must specify the management unit representing the physical bounds of the grazingland area to be analyzed. A specific data set assigned to a management unit is referred to as a "Case" and several cases may be considered per management unit.

The other 2 segments in GAAT are the profile and animal attributes segments. The profile segment is used to specify generic grazing and feedstuff capacity as well as improvement investment information. A user is thus able to change case information independent of the profile database or a user may, for example, change the improvement investment component of the analysis without changing herd dynamics. The animal attributes segment also allows the user to exogenously specify and label the age and sex classes of each animal species to be incorporated in the cases under consideration.

Data Entry

Understanding the data entry procedure is facilitated by reference to Figure 2, and is described in detail in the GAAT User Manual (Kreuter et al. 1993.). The first step is to create the case to be analyzed. Next, the animal attributes and the grazing, feedstuff, and improvement investment profiles to be used as the basis for the specified case or a series of associated cases should be defined. Finally, the user enters production and price statistics pertinent to the enterprises specified for a case.

The planning horizon (maximum 25 years), the discount rate to be used, and the enterprise categories to be included in a case are specified in the Case Information module (Figure 3). Each case may consist of 1 or more separate animal and nonanimal enterprises, each with its own set of inputs (forage/roughage allocations, variable costs, product yields and prices, etc.). The complexity of the input structure is greater in livestock enterprises than the wildlife and 4 nonanimal enterprise categories. This allows a user to differentiate between "intensively" managed livestock production systems and extensively managed livestock, wildlife, and non-animal enterprises. For example, a beef production system for which individual animal class data are available, would be defined under the livestock enterprise category while animal production systems where class specific information is not available can be included under the "wildlife" enterprise category.

Production and price data associated with each specified enterprise are entered in a sequence of cascading windows. For example, in the livestock enterprise, information about animal inventory, forage allocation, animal husbandry and products must be specified and product prices can be entered for 6 types of products, including live and slaughter sales, milk products, fiber, antler/horn, and manure. Production and price values can be changed over time. Changes can be made at 1 point in time by specifying a goal value and the year in which the goal is to be reached. Alternatively, parameter values can be changed annually by using the view/edit response box. The initial and modified parameter values are shown graphically within the view/edit box (Fig. 4).

Output Reports

After entering the data pertaining to the case to be analyzed, a user may generate several reports both for individual and combined enterprises. Enterprise level reports provide data summaries for the individual enterprises in a case for each year in the planning horizon. They include livestock inventory, annual revenue and cost, and actual and discounted annual net cash flow.

Case level reports combine the production and price statistics from all the enterprises in the case. They include investment cash flows and forage supply, demand and balance reports. The latter set of reports are provided both in tabular and graphic form. Perhaps the most important case level report is the NPV/IRR report which enables the user to determine the economic efficiency of the financial/management investments and production/price variable data specified for the case. The relative economic efficiency of a series of cases with different financial/management investments, production/price characteristics, and/or enterprise mixes can thus be compared using the NPV/IRR generated for each case.

The effectiveness of any computer decision support system in facilitating such comparisons is dependent upon the accuracy of inputs. The reliability of any NPV/IRR estimate of grazingland improvement investments is directly dependent upon the user's ability to account for enterprise revenue and cost streams, annual livestock carrying capacity, improvement investment costs, investment life, and salvage value.

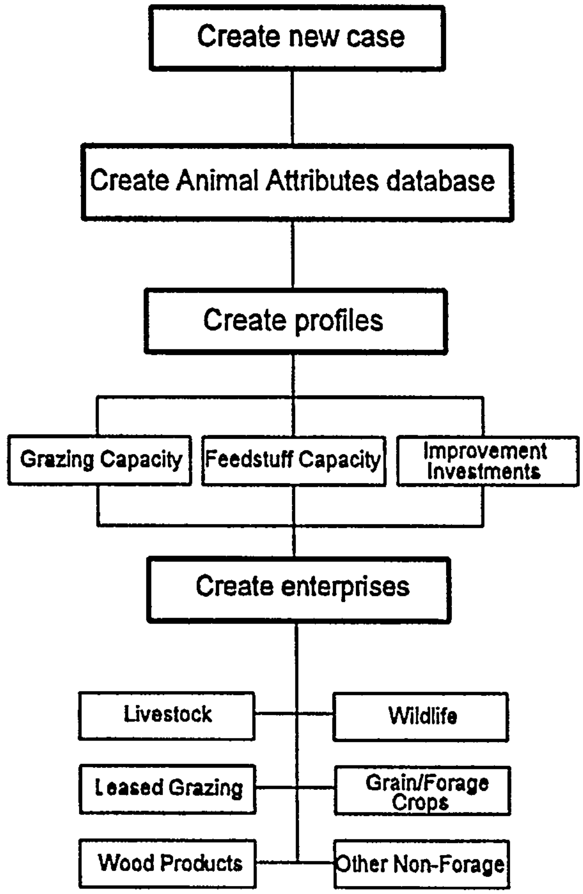

Fig. 2. Data entry procedure for preparing GAAT database.

Two Applications of GAAT

GAAT is capable of providing an economic analysis of almost any kind of investment aimed at improving grazingland production for which relevant input data are available. The kinds of information that must be supplied will depend upon the application for which the software is to be used. In addition, GAAT also allows the user to play "what if" games by changing investment schemes, input costs, or production and revenue streams. To illustrate how it can be used to compare the economic efficiency of alternative investment options, 2 examples emphasizing the program's versatility are presented.

The first example compares different Juniper control options and represents a low-data application of GAAT while the second describes the use of the software to analyze the change in the feed base of intensive dairy production and represents a high-data application. Both examples use numerical information from case studies and are not intended to represent rigorous research trials. The emphasis here is to demonstrate the diverse application potential of GAAT for grazingland management issues and not to draw conclusions about the feasibility of the illustrative improvements.

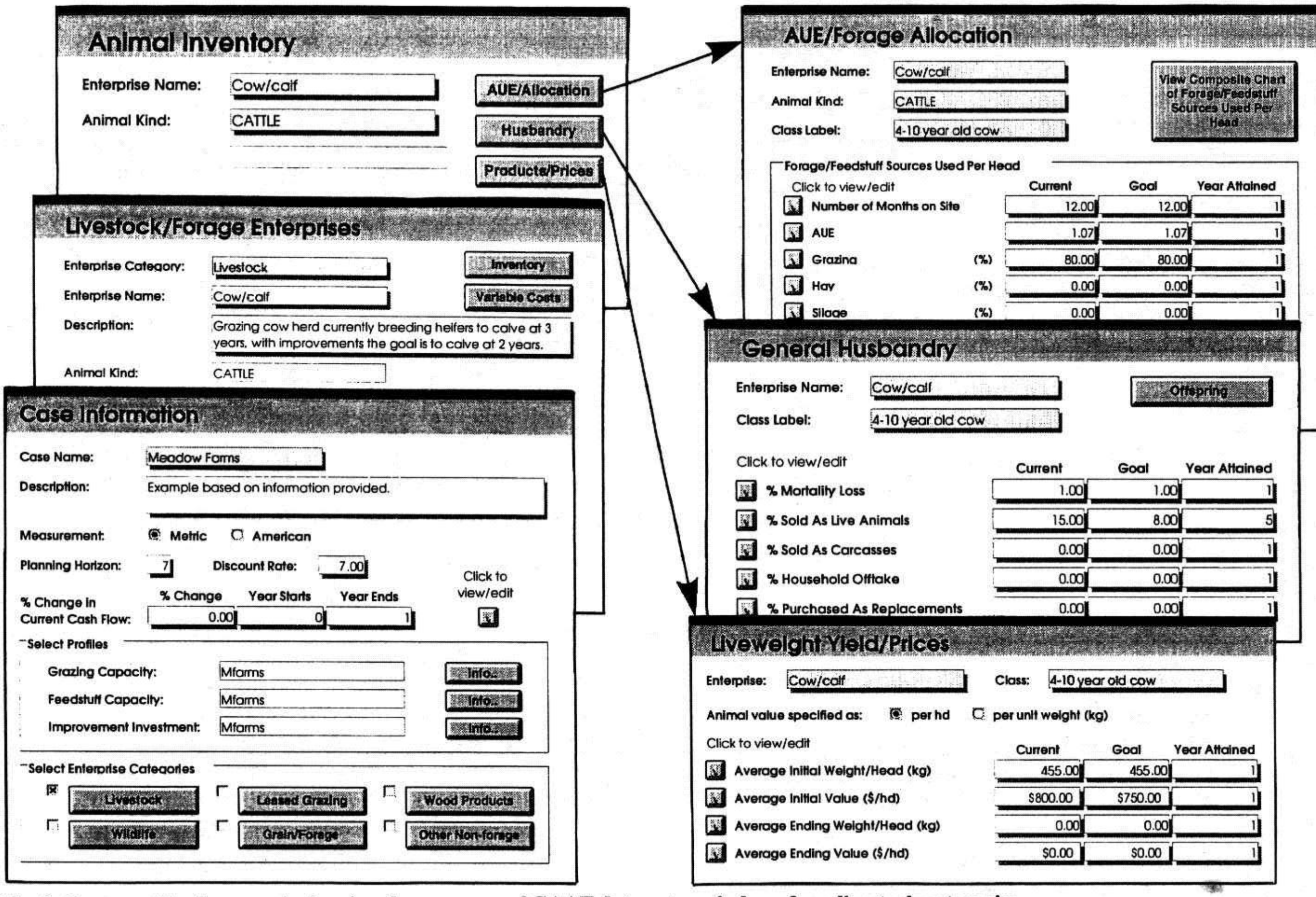

Fig. 3. Case specification panels showing the sequence of GAAT data entry windows for a livestock enterprise.

Mechanical and Fire Treatment of Juniper

Juniperus species have become a problem on much of the 22 million acres which it inhabits in Texas (Owens and Schliesing 1995). In 1 example, GAAT was used to estimate the economic effects of various mechanical and fire control options on Ashe juniper (*Juniperus ashei* Buckholz) in the Edwards Plateau of Texas (Rowan and Conner 1994). In order to calculate livestock carrying capacity, this example required information about the encroachment rate of juniper and the relationship between percent canopy cover and herbaceous phytomass production. Four initial juniper canopy covers were assumed (4%, 16%, 32%, and 100%) and, based on the herbaceous/canopy cover relationship from Fuhlendorf (1992) and data from Blomquist (1990) and Darrell N. Uekert (pers. comm. 1993), carrying capacities were calculated over a 12 year planning horizon with and without juniper control. Figure 5 represents the projected herbaceous production and livestock carrying capacity under an initial juniper canopy cover of 4% and the change in carrying capacity both with and without prescribed burning.

A simple way to determine the net present value and internal return rate for weed/brush control techniques is to assume that all forage production arising from investments in such techniques is leased on an animal-unit-month (AUM) basis. This requires only a single entry in the enterprise revenue input module (assuming no variable costs for the leasing operation), which is much easier than if the increased herbaceous production is marketed through livestock production. However, if the user wishes to reflect increased herd performance (e.g., calving percentage, weaning weights, etc.) due to herbaceous phytomass improvements resulting from brush/weed control, GAAT allows such changes to be incorporated into the herd structure modules. If opportunity costs are to be assigned to either pre- or post-treatment deferment, such costs may either be entered as variable costs to the livestock enterprise or added as part of the improvement investment profile.

The improvement investment profile should account for all initial improvement costs and any periodic costs for maintaining the improvement during the planning horizon. Other information needed includes the year within the planning horizon in which the investment is initiated, units of each improvement item (e.g., hectares, kilometers, days, etc.), cost per unit, and the longevity and salvage value of each item.

In our example of prescribed burning of immature juniper stands, the prescribed fire was initiated in year 2 (deferred in year 1) at an assumed average cost of $11.12 ha^{-1} ($4.50 acre^{-1}) for equipment, fuel, and labor requirements to clear fire lanes and burn an area of 405 ha (1,000 ac). The burn was assumed to have 0 salvage value after 10 years of the 12 year planning horizon. The opportunity cost of deferring leased grazing during year 1, in order to accumulate a fine fuel load for a fire, was estimated by converting expected pre-treatment forage growth to AUMs and charging $8.33 AUM^{-1} for a 6 month period.

In the example shown in Figure 5, the herbaceous layer under the juniper canopy (4%) would produce about 2,242 kg ha^{-1} yr^{-1} (2,000

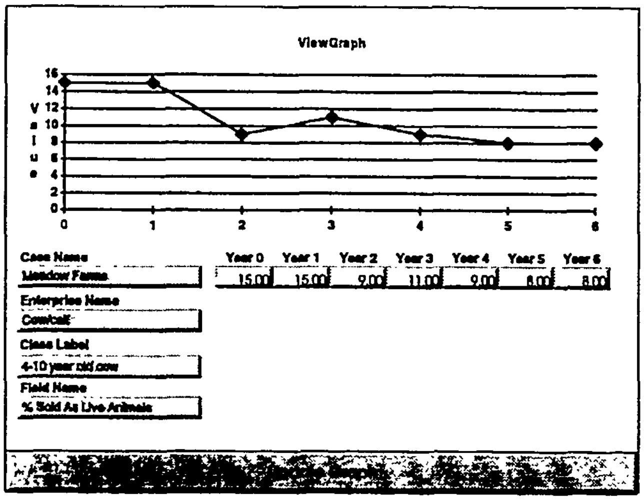

Fig. 4. Example of a view/edit window attached to each parameter field to view and edit initial, goal and intermediate parameter values.

lb ac^{-1} yr^{-1}) air-dry herbage (Dye et al. 1995). If left untreated, less than 1,794 kg ha^{-1} yr^{-1} (1,600 lb ac^{-1} yr^{-1}) of herbage would be produced by the end of the 12 year planning horizon and the juniper canopy coverage would have increased from 4% to about 29% (Blomquist 1990, Fuhlendorf 1992). Carrying capacity over the planning horizon would have correspondingly decreased from 54 to less than 42 animal unit years (AUY) per 405 ha.

In analyzing the investment in prescribed burning, a real discount rate of 8% was used. It was also assumed that the fire treatment halts further invasion of juniper in the short-term and results in full potential herbaceous phytomass production after year 3. Based on these data and assumptions, the net present value of investment in prescribed burning was estimated to be –$663.39 (IRR = 5.70%) when Federal Government cost-share subsidies for juniper treatment were included. In this case, prescribed burning was found to be economically unprofitable. However, if pretreatment grazing deferment of the rangeland is an integral part of an annual grazing rotation scheme, it would be reasonable to assume that the deferment of forage to build up a fuel load has no opportunity cost. In this case, GAAT calculated a net present value of $1,742 (IRR = 17.98%) indicating that investment in a prescribed burn to control juniper would be economically efficient.

Changing a Concentrate-Dependent Dairy To A Grazing-Dependent Dairy

Due to increasing concerns about point-source pollution, the environmental impacts of confinement dairies have received considerable attention. One possible method for reducing the waste disposal problems associated with confined animals is to spread those wastes over a larger area by using a grazing system that allows in situ nutrient cycling and reduces nutrient importation. Changing from concentrate-dependent milk production in a confined area to a grazing-dependent dairy operation is, however, also likely to result in reduced milk production per cow and reduced herd size. Economically, the key question would be whether the reduced variable costs, associated with the diminished use of purchased concentrates (Williams et al. 1987) would be sufficient to off-set the investments required to produce forage for cattle and the reduced revenue per cow due to lower per animal production (Parker et al. 1992).

The necessary information for analyzing such a change with GAAT are herd structure and dynamics (e.g., death loss and conception and replacement rates), forage requirements and milk production per cow, price of dairy products, and variable costs per cow (e.g., on- site produced forages, purchased concentrates and veterinary services). Such information is required for both the concentrate-dependent confinement system and the grazing-dependent system. In addition, an improvement investment profile must be defined for converting the area used for producing harvested forages and concentrates under the confinement system to grazeable forages. This should include sufficient purchased feed for feeding animals during the establishment period for seeded forages and machinery required to produce fodder.

The example presented here is based on information from several field studies conducted by Dr. Joe Outlaw in 1994 in East Texas (pers. comm. 1994). A 900-cow confinement dairy operating on 260 ha (640 acres) used for hay and grain production was changed to a grazing-dependent through a 4-year phased establishment period by using a high-quality pasture, such as orchardgrass (Weiss and Shockey 1991), fencing land into numerous 3.24 ha (8 acre) paddocks, and developing watering facilities in each paddock. Total improvement investment costs were estimated at $192,640 spread equally over the first 4 years of a 10-year planning horizon. The herd structure was changed over a 5-year period from one in which all replacement cows were purchased, to one in which replacement heifers were kept and transferred to the milking herd after initial calving at 26 months of age. Variable operating costs were estimated to be $2,364 (Parker et al. 1992) and $1,239 cow^{-1} (Joe Outlaw, pers. comm. 1994) for the confinement and grazing-dependent operations, respectively. To off-set deferment of land-use during pasture establishment, feed costs during years one to four were estimated to increase by an average of $267 cow^{-1}. Assuming the use of 1 bull per 25 cows at $1,433 bull^{-1}, the purchase cost of bulls in the first year was estimated to be $56 cow^{-1}. Additional feed required for replacement heifers increased the variable costs per breeding cow by

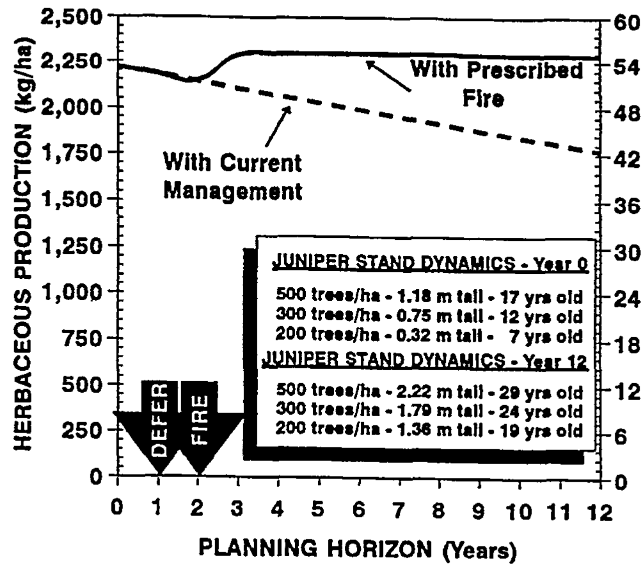

Fig. 5. Herbaceous production and livestock carrying capacity under initial canopy cover of 4% and the change in carrying capacity both with and without prescribed burning.

$101 in the fifth year. The average daily milk production per cow was assumed to decrease from 26.3 kg (58 lbs) in the concentrate-dependent dairy to 19.5 kg (43 lbs) in the grazing-dependent dairy.

The supply and demand of hay and concentrates were equalized throughout the planning horizon. This "balancing capability" in GAAT is made possible through estimates of annual nutritional needs of the dairy herd based on the specified operational changes and by allowing the user to make improvement investments to meet changing feed demands during the planning horizon.

A different discount rate is used in this example to reflect potential differences in nominal interest rates, inflation factors and investment risk factors used to calculate a discount rate. Based on the preceding information and a discount rate of 7%, it was found that changing from a confinement dairy to a grazing-dependent dairy would result in a net present value of $59,930 (IRR = 8.17%) by the end of the 10 year planning horizon. Thus, if the opportunity cost of investing in the operational change is less than 8.17%, then the change would be considered economically efficient.

Advantages and Limitations of GAAT

GAAT is user-friendly decision support system that provides the planner with the ability to define and economically analyze a wide range of dynamic single enterprise or multi-enterprise grazingland production systems. The juniper control example represents a relatively simple improved forage production scenario with no livestock component. At the other end of the complexity scale is the example of transforming a confinement dairy to a grazing-dependent dairy. The structure of individual enterprises and the mix of enterprises can be changed throughout the specified planning horizon.

One of the few aspects that is not automated in GAAT is the transfer of animals between separate enterprises. For example, transfers of weaner steers from a cow/calf enterprise to a stocker operation must be done manually on an annual basis. This is an inconvenience that is to be eliminated in the next version. In addition, herd production parameters such as mortality loss, animals bought, sold and consumed, and offspring information such as weaning rates must be specified as a percentage of the total number of animals in each animal class within an enterprise. Unless these percentages are calibrated, the number of animals in each class or in the whole enterprise may fluctuate or change at unrealistic rates. In the next version, the user will be able to specify these parameters either as percentages or as whole numbers of animals. Finally, GAAT ignores tax issues.

Given the complexity of many ecosystems, the increasing concerns about the relative environmental effects of alternative grazingland-based production systems, and the dynamic nature of animal production systems based on grazinglands, the use of computer-based decision support software is becoming increasingly important. Despite its current limitations, GAAT currently provides one of the most dynamic decision support systems for use by planners, economic analysts, and policy makers interested in the use and management of grazingland resources.

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