LNE 88-02 Final Report

SUSTAINABLE AGRICULTURE RESEARCH AND EDUCATION PROGRAM AND AGRICULTURE IN CONCERT WITH THE ENVIRONMENT

SECTION I

1. **Project Number:** LNE88-02
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2. **Project Title:** Improving Farm Profitability by Efficiently Using the Pasture Resource

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9. **Project Status:** Continuation

10. **Statements of Expenditure:** attached

SECTION II

1. Objectives

1. Plant. Determine sward dynamics, light relationships, net forage production, and seasonal distribution of white clover- and red clover-grass swards, under various frequencies and intensities of dairy or beef cattle grazing, and effects of postgrazing grooming (harrowing, clipping, soil aeration) and manuring on above aspects in a white clover-grass sward grazed by dairy cows.

2. Animal. Determine concentrate amounts to optimize milk production and profitability in dairy cows on pasture under controlled grazing management.

3. Soil. Determine soil biota populations, microcommunity structure, fertility levels, and compaction under controlled-grazed pasture.

4. Economics. Develop case studies of both year-round confinement dairy cow feeding farms and farms feeding cows on pasture under controlled grazing management, and develop models to determine the economics of incorporating controlled-grazed pastures into variable dairy and beef farm feeding operations.

5. Extension. Transfer practical, easily applied research information quickly to farmers and feed dealers, and inform farm loan officers about the potential financial benefits to farmers from incorporating well managed pastures into farm feeding programs.

2. Abstract
Mismanaged grazing has caused the vast pasture acreage of the United States to be an underutilized, wasted resource. In the Northeast, for example, 14 million acres of pastureland are being used at a level far below their potential. Applying management intensive grazing could greatly increase productivity of this land. Developing and incorporating this resource into livestock feeding programs can significantly reduce production costs and labor needs, thereby improving farm profitability and farm family quality of life.

Feeding livestock on pasture may also decrease soil erosion and agricultural nonpoint source environmental pollution from fertilizers, pesticides, and manure. These improvements could result from less row crops being grown, thereby lessening soil erosion and fertilizer and pesticide applications, and from livestock gradually spreading excrement over the land while grazing their feed, rather than concentrating it while in confinement feeding.

In this project we developed a Pasture User Support Group Network to help farmers help themselves in using management intensive grazing. Practical information about proper pasture management, supplementation of dairy cows on pasture, and economics of incorporating well managed pasture into farm feeding programs is being extended to farmers through the Network activities, including 48

Farm Walks and winter Group meetings per year, Field Days, conferences, radio and television programs, videos explaining proper grazing management, a monthly newsletter, and popular press articles.

We studied key aspects of management intensive grazing to help farmers benefit from its full potential. Based on our research results, we recommend that:

Dairy farmers probably can significantly decrease production costs by reducing concentrate supplementation to a level that allows cows to consume pasture forage dry matter at level of 3% of bodyweight, without loss of milk yield.

Dairy farmers should graze cows as two groups: lactating cows first, followed by dry cows and heifers to clean up remaining feed. Milking cows should graze pasture forage when it reaches 2400 lb DM/acre (6 inches tall), and graze it down to 1400 lb DM/acre (3 inches tall). Dry cows and heifers follow, grazing down to 1000 to 1200 lb Dm/acre (1-2 inches tall). Water must be available in all paddocks. Animals need to be locked in the paddock in which they are grazing so that nutrients from manure and urine remain in the padddock.

Beef cows with calves and stocker cattle should be grazed in the same way as lactating dairy cows, because they require similar high quality forage. Dry beef cows can follow stockers.

Ewes and lambs, goats and kids, and fallow deer should begin grazing when pasture forage reaches 2100 lb DM/acre (4 inches tall), and graze it down to 1200 lb DM/acre. When lambs or kids are weaned, they should only graze down to 1400 lb DM/acre, followed by dry ewes which graze down to 1000 to 1200 lb DM/acre. Milking goats also should only graze down to 1400 lb DM/acre.

Horses also can begin grazing when pasture forage reaches 2400 lb DM/acre, and graze it down to 1200 lb DM/acre.

Our economic model simulations showed that management intensive grazing can significantly improve the profitability of dairy farms through reductions in the variable and fixed costs associated with feeding cows at all levels of production.

We estimated that the aggregate effects of using management intensive grazing within a land resource area (122,000 acres) would be a soil loss reduction of over 12,000 tons per year, and net benefits to producers and society (i.e., taking into consideration the reduction in soil loss as a result of the alternative system) of almost $4 million per year.

3. Specific Project Results

A. Findings and Accomplishments

Objective 1. Plant.

New Zealand's highly profitable and productive, low-input agricultural economy is based on management intensive grazing of permanent pasture. In contrast, the pasture resource of the United States has been largely underutilized and wasted due to defective grazing management. By applying management intensive grazing, these millions of acres of pastureland can contribute significantly toward reducing livestock farm feed, machinery, and labor costs, thereby improving farm profitability and the farm family's quality of life.

Grazing management requires observation and flexibility, to harmonize animal numbers with plant growth so that optimum levels of plant and animal productivity may be achieved. All aspects of management intensive grazing have been researched well in other countries, but most research was done on perennial ryegrass-white clover or pure perennial ryegrass swards (pasture plant community) fertilized with high fertilizer nitrogen levels. For the complex, legume-based (no fertilizer nitrogen applied) permanent pasture swards (Kentucky bluegrass, orchardgrass, timothy, quackgrass, white clover, red clover) that predominate in the United States, information was lacking on intensity and frequency of grazing for optimum plant and animal production, distribution of forage production during the grazing season, and the need for clipping, harrowing, and soil aeration. Our research was done to help farmers convert maximum solar energy to saleable livestock product at the least possible cost and effort, by applying grazing management practices adapted to our conditions.

Pasture Management for Optimum Dairy Cow and Sheep Feeding.

Intensity and Frequency of Grazing

We found that pasture forage should be grazed every time the sward reaches an average accumulation of 2400 pounds of dry matter (DM) per acre (or average of 6 inches tall) for dairy cows, and an average of 2100 pounds (4 inches tall) for sheep. This means that the recovery times between grazings must vary according to growing conditions. Lactating cows and growing lambs should not graze down closer than 1400 lb DM/acre (2-3 inches tall). Dry cows, heifers, or dry ewes should follow milking cows or lambs and grazed the forage down to 1000 to 1200 lb DM/acre (1-2 inches tall).

These management practices change the pasture plant population to a more desirable mixture containing more white clover and less weeds. A consistently high forage quality results that can support high levels of livestock production with little or no costly grain supplements. Forage from intensively managed pastures contains an average of 23.5% crude protein and 0.72 Mcal net energy lactation/lb DM from May through October in Vermont.

Seasonal Distribution of Forage Production and Total Yield

During a grazing season from about April 15 to October 31 in Vermont, dry forage yields averaged 8433 lb/acre from permanent pastureland that had never been plowed, and 5378 lb/acre from pasture following corn production. Average rate of forage production (lb DM/acre/day) by month was: April 23, May 47, June 42, July 34, August 33, September 30, October 10. Average dry forage production (lb DM/acre) by month was: April 680, May 1447, June 1250, July 1044, August 1023, September 919, October 310.

Because of this distribution of forage production, farmers must be prepared to harvest excess forage during May or June, to maintain the pasture in good condition for grazing during the rest of the season. Since excess forage usually has never been harvested from permanent pastureland before, the farmer must be aware that it is necessary to set aside areas that are able to be machine-harvested.

Clipping, Harrowing, and Soil Aeration
Although clipping, harrowing, and soil aeration have been shown to be beneficial under long-term continuous set stocking of cattle elsewhere, none of the treatments alone nor in combination affected any sward component or pasture forage yield under proper grazing management. Therefore, if proper management is used, these practices are unnecessary, and the cost of machinery purchase and repair, fuel, and labor can be saved.

Pasture Management for Beef Cattle.
We compared six grazing management practices with yearlings on natural Kentucky bluegrass-white clover pasture in West Virginia. These six practices included three pasture forage heights at which grazing was initiated, and two forage heights at which animals were removed from paddocks.

We found that a 25% increase in forage dry matter consumed, with similar increases in protein and energy, is possible by changing the frequency and intensity of grazing. Grazing every time pasture forage reached 5 inches, and removing about 50% of the available forage (residual height 3 inches) produced the most forage of highest quality. This treatment was grazed 8 to 11 times per growing season. The medium grazing frequency (grazed every time pasture reached 6.0 inches) and high intensity (residual height of 3 inches), however, was not much lower in forage production. This treatment was grazed 6 to 9 times per season, and would require less fencing and water facilities than the more frequently grazed practice.

We also compared the effects of maintaining pasture forage within narrow height ranges on animal performance. Native pastures were grazed continuously with cows, calves, and steers, and maintained within different forage height ranges by adding or removing animals during the growing season. Most liveweight gain was produced by maintaining the pasture forage height at 1.5 to 2.5 inches tall:

Wide adoption of these grazing management practices will result in more efficient and profitable use of hill land for pasture. This means that either animal production will increase or costs of production will be reduced. Hill land farming will become more satisfying and rewarding. Soil erosion will decrease, with resultant environmental improvement.

Objective 2. Animal

Optimum Levels of Concentrate Feeding for Lactating Cows on Pasture.
The greatest advantage of pasture as a nutrient source for lactating cows is its low cost. A major question exists concerning how much concentrate should be fed to cows grazing intensively managed pasture. This question must be answered carefully, as it is of paramount importance to the economic survival of dairy farms.

During several experiments (1991-1993) we fed Holstein and Jersey lactating cows grain supplement levels based on forage nutrient composition, concentrate nutrient composition and pasture forage dry matter consumption at 1.5, 1.75, 2.0, 2.25, or 3.0% of bodyweight per day. This resulted in markedly different amounts of concentrates fed to cows in the different pasture forage intake treatments.

In the first experiment (1991) we found that increasing concentrate input from the lowest level (pasture forage intake = 2.5% of bodyweight) to the intermediate level (pasture forage intake = 2.0% of bodyweight) increased milk production 2.4 lb, but its value was only 26 cents, compared to 43 cents worth of increased concentrate fed. Thus 43 cents worth of concentrate produced 26 cents worth of milk.

In another experiment (1992) there was no net increase in fat corrected milk between the lowest and highest concentrate input, so the increased concentrate supplement cost was not justified in any way apparent from these data. In another experiment (1992) milk production increased 0.8 lb, but its value was 8 cents, compared with the additional concentrate input of 4.9 lb costing 47 cents.

In two 1993 experiments we lowered the concentrate input to make cows consume pasture forage dry matter at the level of 3% of bodyweight per day. This is a concentrate supplement level lower than what had been thought possible. Fat corrected milk yield was not reduced by decreasing concentrate input from the highest level (pasture forage intake 2.0% of bodyweight) to the lowest level (pasture forage intake = 3.0% of bodyweight). In one experiment 81 cents worth of concentrate returned only 2.4 cents worth of milk. In another experiment $1.21 worth of concentrate returned only 35 cents worth of milk.

These results are extremely important. The current recommendation for assumed dry matter intake of dairy cows grazing pasture is between 1.8% and 2.0% of bodyweight. This recommendation probably is based on poorly managed pastures, and appears to be invalid for cows grazing intensively managed pasture. Reducing concentrate supplementation so that cows increase pasture forage dry matter consumption by 1% means that each cow would eat about $1.00 less of concentrate per day, with no significant loss of milk yield. During a 180-day grazing season, the savings from reduced concentrate feeding could be about $180/cow.

Our data clearly indicate that it is not justified to feed levels of concentrate supplements higher than what would be fed if pasture forage dry matter intake is at 3% of bodyweight per day. Two questions remain unanswered, however:
1) What is the upper limit of expected dry matter intake from intensively managed pasture feasible with cows at reasonable levels of production?
2) What are the long term effects of an entire grazing season with none or low concentrate supplement input on cows' body stores, ability to conceive, and productive longevity?

In-Barn Supplements and Bloat Inhibitor Fed Lactating Cows Grazing Intensively Managed Pasture on a Commercial Dairy Farm.
Intensively managed pastures can provide adequate crude protein for most cows, but supplemental energy usually is required for maximum milk yields. The amount and kinds of supplements fed must be based on the amount, quality, and kind of forage that the cows are grazing. High quality pasture forage is the cheapest source of

nutrients available, so supplements should complement the pasture forage, not substitute for it.

Highly digestible fiber sources are being explored for use to supplement energy in dairy cow rations. Theoretically, supplementing grazing cows with highly digestible fiber could be advantageous because the animal's rumen is already acclimated to digesting fiber. Using highly digestible fiber as an energy supplement may result in cows consuming more pasture forage, thereby increasing nutrient intake and milk yield.

Bloating of dairy cows grazing lush pasture with high alfalfa or white clover content can be a serious problem that is usually noticed when animals die. But chronic bloating at levels that do not result in death (subclinical) may limit milk production by inhibiting forage dry matter intake. Daily feeding of a bloat-inhibiting material such as poloxalene may minimize subclinical bloating, thereby allowing increased forage intake, and profitably increase milk yield.

In three experiments we found that although feeding a highly digestible fiber source (soyhull) did not result in greater milk yield than feeding a starch (grain) energy source, the fiber source could substitute for grain if the fiber source was less expensive. Feeding hay, corn meal, poloxalene, and pasture forage resulted in similar milk yield to feeding corn silage, corn meal, and pasture forage. Feeding corn silage and corn meal, combined with high quality pasture forage, was the least cost way of producing the milk on the farm.

Objective 3. Soil

Soil Organisms in Well Managed Pasture.

Soil invertebrates are extremely important in generating and maintaining soil biological tone. They function as regulators of microbial processes and are living tissue pools of energy and nutrients. As a result of their burrowing they form low-resistance air, water, and root channels in soil. They influence rates of humus formation and distribution of organic materials in mineral soils, which directly affect soil crumb structure. Crumb structure influences soil bulk density, aeration, moisture and nutrient holding capacities, and susceptibility to wind and water erosion.

Our research provided information for the first time about the effects of mixed grazing by cattle and sheep, and cattle stocking density and harrowing and soil aeration treatments on soil organisms.

Although none of the treatments significantly affected earthworm numbers or their biomass, machine postgrazing treatments tended to increase the numbers, but not the biomass, of earthworms present. Possibly by spreading the cow dung over a larger area through harrowing or aeration, more opportunity exists for earthworms to colonize other soil areas. Because increased grazing intensity decreases amount of dead plant material returned to the soil, lower populations of earthworms that depend on litter were expected in high stocking density treatments. The large amount of dung deposited during each grazing under both stocking densities, and the liquid manure that the farmer applied may have maintained earthworm numbers and biomasses, giving results that were inconsistent with differences in return of plant material.

Earthworm numbers and biomasses in the previously tilled soil of two of our experiments were lower than those observed elsewhere in Vermont (262 earthworms/m^2, 205 grams biomass/m^2) in a permanent pasture soil that had never been tilled. This possibly reflected long-term change in succession still occurring in the tilled soil, and indicates that pasture soils should not be tilled unnecessarily.

B. Dissemination of Findings

Pasture User Support Group Networking in Vermont.
To apply research results, they must be transferred to farmers in practical formats that fit easily into farming operations. In the case of new pasture and livestock management and economics information, because of past unfavorable experience with pasture feeding that American farmers had due to poor management practices, special efforts are needed to inform not only farmers, but also feed dealers, veterinarians, and farm loan officers about the potential benefits of feeding livestock on well managed pasture.

In April 1992 we began a Pasture Management Outreach program in Vermont, partially funded by the Kellogg Foundation, to work closely with 25 farmers. In 1993 with funding from this SARE project and increased funding from the Kellogg Foundation, we hired another pasture management person, and are now working closely with 50 dairy farmers. (In 1994 we intend to broaden this network to include producers of all species of livestock.) We directly assist dairy farmers to use pasture to its fullest potential in feeding cows, to help the farmers achieve optimum production and profitability, and a better quality of life. Achieving these goals should help farmers to remain in business, and encourage their children to go into farming as a valuable and enjoyable career. Both of these accomplishments are needed to sustain agricultural production and revitalize rural communities.

In cooperation with Extension agents, we formed four Pasture User Support Groups composed of 12 to 13 Demonstration Farms each. Each farm is visited at least every 21 days. We assist the farmers in all aspects of pasture management and balancing rations of cows on pasture, including among other things paddock layout and size, fencing, soil and forage analyses, pre- and postgrazing forage mass estimates, forage allowance, recovery periods between grazings, dry matter intake, supplemental feeding, feed planning, herd management, and business management.

Once a month we meet with the local Extension agent (s) and the entire Group in each area for a Farm Walk on a different group member's farm each time, to discuss any and all aspects of pasture dairy feeding, and mutually learn and help each other from shared experiences and observations. During the winter Group meetings are held at Extension offices. Any other interested people are welcome to attend the monthly farm walks and meetings, and usually other farmers, veterinarians, feed consultants, SCS personnel, and fence dealers attend. Over 350 people receive our monthly newsletter.

By networking, each farmer becomes an agent of change through a ripple effect that results around each farm. In this way pasture management information and technology is being transferred quickly and efficiently from farmer to farmer. Group members have progressively come to trust each other, and are willing to share experiences and discuss their problems. Clearly, these have become important support groups for the individual farmers.

Farm Walks and Other Group Meetings

We are now conducting four Farm Walks and Group meetings per month (28 during the grazing season; 20 during the winter) in Vermont. Winter meetings concern ration balancing, cow body condition scoring and importance, dairy farm enterprise analyses, pasture management, grazing behavior, livestock parasite control, seasonal dairying, and other aspects suggested by group members.

Conferences

A 2-day grazing conference was held on July 14 and 15, 1993 at Shelburne, VT. More than 220 people from Vermont, adjacent states and Quebec attended.

Professional Meeting Presentations

Condon, A. and J. Ashley. 1992. Comparative economics of intensive pasture rotation and conventional management practices on Northeast dairy farms: a case study approach. American Agric. Econ. Assoc. Meeting.

Lasat, M., W.B. Bryan, E.C. Prigge, T. Pasha, and G.E. D'Souza. 1990. Effect of grazing height and intensity on composition and productivity of native pasture. p. 133-136. *In* Proc. Amer. Forage Grassland Conf., Blacksburg, VA, 6-9 June.

McCrory, L.E., W.M. Murphy, and J.P. Silman. 1991. Grazing frequency and intensity effects on sward components and net forage production. Proceedings NEBASA Meetings, Rutgers, NJ. July 7-10. Abstract p. 6.

McCrory, L.E., W.M. Murphy, and J.P. Silman. 1992. Grazing frequency and intensity effects on sward components and net forage production. Proc. NEBASA Meetings, Storrs, CT. June 28-July 1. Abstract p. 7.

McCrory, L.E. and W.M. Murphy. 1993. Pasture management outreach. Proc. NEBASA Meetings, College Park, PA. June 20-23. Abstract p. 10.

Mena Barreto, A.D., W.M. Murphy, and J.P. Silman. 1990. White clover dynamics in a complex sward under controlled grazing by cattle and sheep. NEBASA. Meetings, Durham, NH. July 8-11.

Murphy, W.M., A.D. Mena Barreto, and J.P. Silman. 1989. Dynamics of a complex grass-white clover sward under Voisin controlled grazing with cattle and sheep. Northeastern Branch American Soc. Agron. Meetings, Burlington, VT. June 27. Abstract. p. 9.

Murphy, W.M., A.D. Mena Barreto, and J.P. Silman. 1990. Mixed animal species grazing effects on amount of rejected forage in a complex sward under planned, controlled management. NEBASA Meetings, Durham, NH. July 8-11.

Murphy, W.M., A.D. Mena Barreto, and J.P. Silman. 1991. Dynamics of a grass-white clover sward under controlled grazing by cattle and sheep. Proc. Eastern Forage Imp. Conf.. Charlottetown, PEI, Canada. June 26-29. Abstract p. 118.

Murphy, W.M., A.D. Mena Barreto, J.P. Silman, and D.L. Dindal. 1991. Cow and sheep grazing effects on rejected forage, soil compaction, and soil organisms. Proc. NEBASA Meetings, Rutgers, NJ. July 7-10. Abstract p. 3.

Murphy, W.M., A.D. Mena Barreto, and J.P. Silman. 1991. Livestock species effects on dynamics of a complex *Poa pratensis*-dominant sward. 10th International Meeting of the Working Group on Pasture Ecology. Lusignan, France. October 1-2.

Murphy, W.M., M. Hanson, T. Hanson, J. Cornell, L.L. Junkins, A.L. Schmitt, J.P. Silman, and F.T. Abdul-Wahid. 1993. Feeding high-producing Holsteins under rational grazing management. Proc. NEBASA Meetings, College Park, PA, June 20-23. Abstract p. 8.

Parsons, C.F. and W.M. Murphy. 1990. Fertilizer effects in renovating an abandoned pasture with sheep under Voisin grazing management. NEBASA Meetings, Durham, NH. July 8-11.

Schmitt, A.L., J.P. Silman, F.T. Abdul-Wahid, and W.M. Murphy. 1993. Grazing behavior of high-producing Holsteins under rational management. Proc. NEBASA Meetings, College Park, PA, June 20-23. Abstract p. 6.

Welch, J.G., R.H. Palmer, A.M. Bueche, and W.M. Murphy. 1990. Balancing rations (protein) for cows on pasture. Proc. Dairy Feeding Systems Symposium. Harrisburg, PA. January 10-12. p. 223-227.

Welch, J.G., R.H. Palmer, A.M. Bueche, and W.M. Murphy. 1990. Effect of rumen undegraded intake protein on milk production from pasture fed lactating dairy cattle. Proc. American Dairy Sci. Assoc. Meetings. Raleigh, NC. June 24-27. p. 282.

Welch, J.G., W.M. Murphy, R.H. Palmer, A.M. Bueche, and J.H. White. 1993. Concentrate feeding levels for lactating dairy cows on pasture. Proc. Amer. Dairy Sci. Assoc. College Park, MD. June 13-16. p. 216.

Publications

Journal Articles

Condon, A. and J. Ashley. The economics of intensive pasture rotation in northern New England: a mathematical programming approach. (will be submitted to J. of Sustainable Agriculture)

D'Souza, G.E., W.A. Fiske, J.J. Fletcher, T.T. Phipps, W.B. Bryan, and E.C. Prigge. 1992. An economic and environmental assessment of alternative forage-resource management systems. West Virginia Agric. and Forestry Exp. Stn. Annual Report.

D'Souza, G.E., E.W. Maxwell, W.B. Bryan, and E.C. Prigge. 1990. Economic impacts of extended grazing systems. Institute for Alt. Agric. 5(3):120-125.

Fiske, W.A., G.E. D'Souza, J.J. Fletcher, T.T. Phipps, W.B. Bryan, and E.C. Prigge. An economic and environmental assessment of alternative forage-resource production systems: a goal-programming approach. Agric. Systems. forthcoming.

Flack, S., J.P. Silman, L.E. McCrory, N. Mzamane, and W. M. Murphy. 1993. The relationship of light and plant response in a complex pasture sward with particular emphasis on white clover. *In* A. Davies (ed.) The Working Group on Detailed Sward Measurement Newsletter. Institute for Grassland and Animal Production, Plas Gogerddan, Aberystwyth, Dyfed, Wales, United Kingdom.

Murphy, W.M., A.D. Mena Barreto, and J.P. Silman. 1989. Cattle and sheep grazing effects on clover, grasses, and rejected forage in a complex sward. p. 16-18. *In* A. Davies (ed.) The Working Group on Detailed Sward Measurement Newsletter. Institute for Grassland and Animal Production, Plas Gogerddan, Aberystwyth, Dyfed, Wales, United Kingdom. No. 24.

Murphy, W.M., A.D. Mena Barreto, and J.P. Silman. Sward dynamics of a complex Kentucky bluegrass-dominant sward grazed by cows and/or sheep. Grass and Forage Science. (Submitted 5/1/92; still under consideration)

Murphy, W.M., J.P. Silman, and A.D. Mena Barreto. Estimation of herbage mass in a complex Kentucky bluegrass-dominant sward: comparative evaluation of clipped quadrat, capacitance meter, HFRO sward stick, and a rising plate. Grass and Forage Science. (Submitted 5/1/92; still under consideration)

Murphy, W.M., A.D. Mena Barreto, J.P. Silman, and D.L. Dindal. Cow and sheep grazing effects on net and rejected forage, and soil fertility, compaction, and organisms in a complex Kentucky bluegrass-dominant sward. Grass and Forage Science. (Submitted 5/1/92; still under consideration)

Teegerstrom, T., G. D'Souza, D. Colyer, and P. Osborne. Contract grazing of beef cattle: a decision theory/portfolio comparison. J. Agr. and Appl. Econ. (to be submitted)

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C. Site Information

Family farms, villages, and towns interspersed within rolling to steeply rolling hill land. Soils from glaciated and nonglaciated parent material, ranging from sands to clays. Humid temperate climate. Except for a minority of farms, cropping and livestock systems mainly are corn rotated with grass-legume hay crops to feed dairy cows in confinement, with permanent pastureland used mainly as exercise area. On farms incorporating well managed pasture into farm feeding systems, less corn is being grown as farmers realize the benefits of farming permanent grassland.

D. Economic Analysis

Objective 4. Economics

Farmers' experience indicated that feeding dairy and beef cattle on intensively managed pasture is an economically viable and attractive alternative to year-round confinement feeding. This research was done to examine how management intensive grazing affects labor and equipment use, cash flow, productivity, and overall farm profitability.

Dairy Farm Feeding and Profitability Effects of Using Intensively Managed Pasture: a Vermont Case Study of a Typical Farm

We compared winter confinement rations to those fed during the grazing season on two farms that use intensively managed pastures to feed lactating cows. Estimated feed savings of $14,485 due to pasturing was achieved on the Brigham Jersey farm in 1991, and $12,849 on the Hanson Holstein farm in 1992. These savings were for feed only and do not include savings from decreased labor, fuel, machinery use and repair, and electricity, from having to harvest, store, and feed out less forage than would have been done if the cows had been in year-round confinement.

Compared to their 1991 profit, the Hanson farm's profitability increased 32% in 1992, which was the first year that cows were fed on intensively managed pasture. Feeding cows on pasture reduced Mike Hanson's daily work hours in the barn 59%. Increased farm profitability and reduced labor requirements are absolutely essential to achieve sustainable, family dairy farming.

Harvesting, storing, and feeding activities on the Hanson farm are a good example of potential savings from using well managed pasture. Before 1992, Mike had to feed out 150 tons of haylage during May-October to his confined herd. During May -October, 1992, when his herd obtained most of their dry matter and nutrient requirements from well managed pasture, 150 tons of haylage that was harvested and stored in May did not have to be fed until needed for winter feeding.

The Hanson farm comprises 134 acres plus 30 acres rented land. Of these 164 acres, 60 acres are woodland that are not grazed. Soils range from extremely stony sandy loam to loamy sand, with steep-to-rolling topography. All of the forage is produced on the farm as corn silage, haylage, or hay. No small grains are grown. The

Hansons are discontinuing corn production. Manure is stored in a liquid manure lagoon, and is surface-applied in spring, midsummer, and autumn. The barn is a tie stall. Barn chores require 8 hours/day during winter confinement (11/1-4/30), and 4.7 hours/day during the grazing season (5/1-10/31). Until 1992 replacement heifers have been contract-raised at a cost of $5000/year. During the 1992 grazing season, all heifers were brought back to the farm to graze excess forage behind lactating cows, and will now be raised on the farm, achieving additional savings.

Mike Hanson was employed for 10 years on the farm before purchasing it in 1980. In an attempt to increase the farm's profitability, in 1987 he increased the size of the barn, added a silo, and added 16 more cows to his herd of Holsteins, for a total of 64 milking cows and 11 heifers. He now believes that increasing the herd size was a mistake, because it created too much work for one person to do, but not enough added income to hire a full time person. He feels that if he had known in 1987 what he knows now about feeding cows on well managed pasture, he would have kept his herd size at 38 cows, and he would not have had to incur the increased mortgage and machinery financial obligations that have made it very difficult for him to remain in farming.

Economic Linear Program Model of Vermont Dairy Farm Use of Intensively Managed Pasture

The representative farm was modeled on a monthly activity basis to capture differences in crop seasons as well as winter versus summer activities. Separate models were run based on herd type (Jersey versus Holstein), and production level (annual herd averages of 12 or 14000 lb milk/cow for Jerseys, and 13, 18, or 22000 lb milk/cow for Holsteins). In each model run the herd was broken into four evenly spaced seasonal herds. The division was uniform because little or no seasonality in production was noted in the surveyed farms. Milk production in each group was distributed across a 305-day lactation curve so that peak production and nutrient demand periods would be represented. A total of 1776 individual activities were incorporated into each model.

The clearest result from the model simulations is that management intensive grazing can significantly improve the profitability of dairy farms through reductions in the variable and fixed costs associated with feeding cows at all levels of production. The reduced demand for on-farm and purchased feeds results from using the pasture as a significant source of feed. Savings in feed costs range from 30 to 48%. For all production categories, management intensive grazing produces milk at a lower per unit cost. Farms using management intensive grazing also tend to use land more efficiently to feed cows than farms feeding in confinement.

Economic and Environmental Assessment of Alternative 12-Month Forage-Livestock Production Systems in West Virginia

Studies comparing producer decision-making alternatives often rely exclusively on a single criterion such as profits or risk. Yet, it is increasingly clear that additional factors such as potential environmental affects associated with alternative courses of action are becoming more important in public and private decision-making.

Thus, not only is there a need to consider these factors together with traditional criteria such as profitability and risk, but also to consider them simultaneously within a framework referred to as "multiple-criteria decision-making". Recognizing this, we undertook a study comparing alternative forage-resource production systems based on profitability, risk and environmental criteria. Soil loss was used in this study to represent the environmental effect. Risk was represented by the profit coefficient of variation. Experimental data were obtained for seven different forage-resource production systems for beef cow/calf production. These data were used to develop 21 enterprise budgets (a separate budget was developed for each system for three different farm sizes: 30-, 60- and 90-head cow/calf operations). Together with price data from secondary sources, information from these budgets was used as the input into a goal programming model that was developed for this study.

We found that a system involving management intensive summer grazing of pasture and extended fall grazing of meadow is optimal in terms of profit, risk and environmental criteria.

4. Potential Contributions and Practical Applications

A. If findings of this study are widely adopted, potential beneficial production, social, economic, and environmental effects could be significant and far-reaching. By reducing production costs, feeding dairy cows (and other livestock) on well managed pasture can increase farm profitability, and save farms from bankruptcy. It can give farmers the time and money to achieve a higher quality of life. Higher quality of farm life can in itself encourage farmers to remain in business, and can make farming more attractive to farm children so that they go into farming as a career. All of these improvements in farm life are needed to rejuvenate rural communities that have declined, due to farm financial, labor, and quality of life problems.

An example of how production costs could be reduced by feeding dairy cows on intensively managed pasture was described in our findings under Objective 2. Reducing concentrate supplement feeding so that cows increase pasture forage dry matter consumption by 1% means that each cow would need about $1.00 less of concentrate per day, with no significant effect on milk yield. During a 180-day grazing season, the savings from reduced concentrate feeding would be about $180/cow.

Assuming that most of the pasture within an appropriate Soil Conservation Service-defined land resource area (122,000 acres) such as in West Virginia is conventionally grazed, if management intensive, summer grazing of pasture and extended, fall grazing is used instead, we estimated the aggregate effects to be as follows: soil loss would be reduced by over 12,000 tons per year, and net benefits to producers and society (i.e., taking into consideration the reduction in soil loss as a result of the alternative system), would increase by almost $4 million per year in the land resource area. It should be noted that such results are for illustration only. Actual effects and benefits would depend on factors such as the existing forage management system as well as the number of producers - and acres - that shifted to the "more sustainable," alternative system.

It is impossible to know specifically what benefits will accrue to the United States if widespread feeding of dairy cows on pasture becomes a reality. One scenario that uses Wisconsin as an example, developed by Dr. William Liebhardt, Director of Sustainable Agriculture Extension, University of California (personal communication) provides an idea of the enormous potential benefits :

There are 1,700,000 dairy cows in Wisconsin, that produce an average of 15,986 lb milk/cow/year, or 7,993 lb milk/cow/6 month grazing season. That's 13,588,100,000 total lb milk/6 month grazing season. Wisconsin farmers currently feeding cows on well managed pasture achieve a milk:grain feeding ratio of 4.43:1. The state average (cows mostly fed in year-round confinement) milk:grain ratio is 2.7:1. The total grain feeding requirements are 22,846,642 lb for year-round confinement feeding, and 13,924,575 lb with 6-month pasture feeding. Tangible benefits that could result if all Wisconsin dairy farms switched to feeding cows on pasture for 6 months:

- 8,922,065 lb less grain needed
- 210,158 acres less land needed in corn production
- 25,026,750 lb less nitrogen fertilizer needed to be applied
- 1,271,359 lb less atrazine herbicide needed to be applied
- less soil erosion, which currently reaches 90 ton/acre/year on sloping Wisconsin soils planted to corn

These savings and benefits would be in addition to savings in fuel, machinery repair and replacement, labor, and veterinary costs due to improved herd health. Is it any wonder why there's resistance to funding the SARE program? Reducing farm input needs directly benefits farmers, society, and the environment, but not agribusiness. If these kinds of issues would be taken into account by economic enterprise analysis, then we could see how beneficial and profitable feeding dairy cows on pasture really is, compared to unnecessary year-round confinement feeding.

B. New Hypotheses or Paradigms

The research and outreach of this project lays to rest once and for all the misconception that pastures in the United States cannot be used to feed dairy cows profitably. The misconception resulted from the mismanagement of pastures in the United States, not from anything inherently bad about pastures. The alternative paradigm is that there are at least two ways of feeding dairy cows: on well managed pasture or in year-round confinement. Both ways need and deserve research and extension effort. Until the alternative paradigm of feeding dairy cows on pasture was accepted, farmers could not consider doing it, university researchers could not work on problems related to it, and extension agents had only misinformation about it to extend.

The year-round confinement feeding practice has received overwhelming attention by university researchers funded by agribusinesses that had a vested interest in continual increase of farmers' purchases of production inputs. With relatively small grants to university researchers, agribusinesses have been and are able to leverage for their benefit the use of public-funded personnel and research facilities. Widespread feeding of livestock on well managed pasture benefits farmers, society, and the environment, but does not directly or sufficiently benefit individual agribusinesses, since it aims at reducing off-farm purchases of inputs. Therefore, funding of research to reduce farm production inputs by feeding livestock on pasture had to come and must come from government. Before SARE (LISA) significant amounts of such funding did not exist.

5. Farmer Adoption and Direct Input

A. Changes in Practice

We are working closely with 50 farmers in Pasture User Support Groups (plus additional farmers who attend the monthly meetings), and over 360 people receive our monthly newsletter. These people are adopting the new pasture management technology. (Many more people are adopting it than we know about personally.)

B. Operational Recommendations

Dairy farmers probably can reduce concentrate supplementation to a level that allows cows to consume pasture forage dry matter at level of 3% of bodyweight, without loss of milk production. This should be done cautiously, because long term effects on cows' body stores, ability to conceive, and productive longevity are still unknown.

Dairy farmers should graze cows as two groups: lactating cows first, followed by dry cows and heifers to clean up remaining feed. Milking cows should graze pasture forage when it reaches 2400 lb DM/acre (6 inches tall), and graze it down to 1400 lb DM/acre (3 inches tall). Dry cows and heifers follow, grazing down to 1000 to 1200 lb Dm/acre (1-2 inches tall). Water must be available in all paddocks. Animals need to be locked in the paddock in which they are grazing so that nutrients from manure and urine remain in the padddock.

Beef cows with calves and stocker cattle should be grazed in the same way as lactating dairy cows, because they require similar high quality forage. Dry beef cows can follow stockers.

Ewes and lambs, goats and kids, and fallow deer should begin grazing when pasture forage reaches 2100 lb DM/acre (4 inches tall), and graze it down to 1200 lb DM/acre. When lambs or kids are weaned, they should only graze down to 1400 lb DM/acre, followed by dry ewes which graze down to 1000 to 1200 lb DM/acre. Milking goats also should only graze down to 1400 lb DM/acre.

Horses also can begin grazing when pasture forage reaches 2400 lb DM/acre, and graze it down to 1200 lb DM/acre.

C. Farmer Evaluations: Attached

6. Producer Involvement
Number of farmers in attendance at (Vermont):

__ Workshops 220 Conferences 250 Field Days

20-25 at each of 48 Farm Walks and User Group meetings in 1993, for a total of 960 to 1200 people; in 1992, 24 Farm Walks and User Group meetings were held, for a total of 480 to 600 people; during 1988-1991 several Farm Walks were held each year, with similar number of people attending

7. Areas Needing Additional Study
The amount of study devoted to pasture management in the United States is small compared to work that has been and is being conducted in countries where grassland contributes to livestock production in a major way, such as in the United Kingdom, Ireland, and New Zealand. While we have and can learn much from research in other countries, we must do some basic and much applied research on grassland management under our local and regional conditions. These areas need study:

- Changes in sward components in pastures receiving liquid manure application during the grazing season
- Animal grazing behavior and pasture dry matter intake following liquid manure application
- Weed control in pasture, especially Canada thistle and buttercup
- Grain and concentrate in-barn feeding levels to achieve optimal milk production and profitability of dairy cows grazing well managed pasture; experiments need to include nonsupplemented cows to once and for all be able to truly test for any benefits of supplementation; the reproductive and milk production performance of these nonsupplemented cows need to be followed to determine long-term effects
- Calf rearing on intensively managed pasture
- Parasite load and need of control of livestock grazing well managed pasture
- Economic analysis of producing milk on forage from well managed pasture without supplementation
- Identify environmental costs and benefits of pastures
- Determine role of pastures in recycling wastes such a municipal sludge and poultry litter
- Use of relatively new computational techniques such as geographic information systems in conjunction with economic models in determining optimum land use

Economic impacts of extended grazing systems

G. E. D'Souza, E. W. Maxwell, W. B. Bryan, and E. C. Prigge

Abstract. *Extended grazing is a management system in which the usual grazing season is lengthened by utilization of hay fields for pasture. Extended grazing systems are a low-input alternative to conventional systems to the extent that they decrease the reliance on inputs such as machinery and energy to harvest forage. Substituting pasturing for harvested forage can therefore potentially decrease production costs and enhance the profitability of livestock production. However, the farm-level economic impacts of such a substitution are not well known. This analysis quantifies these impacts for beef cow/calf production. Specifying alternative meadow management systems for different grasses and using an economic-engineering approach, we have found that extended grazing can be a more profitable option for cow/calf production. Other findings suggest that, in an extended grazing system, the type of meadow, the hay baling method and the associated hay spoilage level also have important effects on production costs and profitability.*

Key words: meadow management, cow/calf production, reduced inputs, economic impacts

Introduction

Extended grazing is a management system whereby hay fields (meadows) are grazed by livestock during portions of the year when hay traditionally is fed to the herd. The greater the duration of pasturing, the less the amount of forage that must be mechanically harvested to maintain animals over the winter. This can reduce input use and production costs and enhances profitability and is consistent with the reduced-input or low-input trend in agriculture.

The technical feasibility of extended grazing management has been established (Baker and Nestor, 1979; Baker et al., 1988; Wilman and Griffiths, 1978). However, the farm-level impacts of such an approach on cow/calf production costs and profitability have not been quantified. This study attempts to fill this gap.

We used a combination of primary data from grazing trials at West Virginia University and secondary economic data to analyze alternative meadow management systems. The systems, consisting of different grasses and length of pasturing, were used to determine the optimum extent to which pasturing can be substituted for wintering. These systems, the analytical procedure and data used, the results of the analysis, and some implications for decision making, are described in the following sections.

Meadow management systems

Four meadow management systems were evaluated. These are: (1) two cuttings of hay, no grazing (HH); (2) one cutting of hay and late fall grazing (HG); (3) early spring grazing and two cuttings

Table 1. Description of meadow management systems analyzed and winter feed requirements for cows

System	Description	Wintering
HH	two hay cuttings over summer, which are either sold or used to winter cows; no grazing	9.1 kg hay/day/cow for first 90 days; and 12.4 kg hay/day/cow for last 60 days
HG	one hay cutting in summer, followed by late fall grazing	9.1 kg meadow grazing/day/cow for 60 days; followed by 9.1 kg hay/day/cow for 30 days; and 12.4 kg hay/day/cow for 60 days
GHH	early spring grazing, followed by two cuttings of hay	9.1 kg hay/day/cow for 90 days; followed by 12.4 kg hay/day/cow for 40 days; and 12.4 kg meadow grazing/day/cow for 20 days prior to usual turnout
GHG	early spring grazing, one hay cutting, and late fall grazing	9.1 kg meadow grazing/day/cow for 60 days; followed by 9.1 kg hay/day/cow for 30 days; 12.4 kg hay/day/cow for 40 days; and 12.4 kg meadow grazing/day/cow for 20 days prior to usual turnout

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of hay (GHH); and (4) early spring grazing, one hay cutting, and late fall grazing (GHG). These systems, in turn, were compared for two grasses, orchard grass (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* Schreb.).

The meadow management trial covered a 3-year period from 1981-84. A 5-month benchmark wintering period beginning in early December and continuing until late April was assumed for the systems. The winter feeding requirements for the systems that were analyzed are shown in Table 1. These requirements, based on National Research Council (1976) recommendations for pregnant and average lactating beef cows, resulted in a total dry matter requirement of 1,563 kg/cow over the 150-day wintering cycle.

Dry matter production for the meadow management systems analyzed is shown in Table 2. Total dry matter production (hay and grazed combined) per hectare was highest for the HG system and lowest for the GHH system, for both orchard grass and tall fescue. Further, production of tall fescue was consistently higher than orchard grass in hay and grazed dry matter. A more detailed description of the production data (including the experimental design, statistical methods, and differences among treatments) is reported in Baker et al. (1988).

Analytical procedure and data

The first step in the economic analysis was the development of enterprise budgets for the production of calves under each system. A total of eight budgets were constructed, one for each meadow management system and grass. The technical production coefficients were obtained from the meadow management trial mentioned earlier. Hay harvesting costs were obtained from secondary sources (Eagan, 1986), and costs of production were compared for both round- and square-baling methods. Other secondary data sources include Baker et al. (1981), Layton et al. (1970), and the West Virginia Department of Agriculture (1986). All cost and revenue data

Table 2. Dry matter (DM) production for alternative meadow management systems, West Virginia, 1981-84 averages[a]

System[b]	DM Production (1,000 kg/ha) Hay	Grazed	Total
Orchard grass			
HH	6.95	0.00	6.95
HG	5.16	2.32	7.48
GHH	5.33	0.72	6.05
GHG	3.42	3.59	7.01
Average	5.22	1.66	6.88
Tall fescue			
HH	7.26	0.00	7.26
HG	5.12	2.69	7.81
GHH	5.99	1.12	7.11
GHG	3.53	4.22	7.75
Average	5.48	2.01	7.49

[a] Statistical differences among treatments and other statistical measures are contained in Baker *et al.* (1988)
[b] See Table 1 for a description of the systems

Table 3. Variable costs of production for alternative meadow management systems, by method of baling hay, West Virginia, 1986

System[a]	Costs: 23 kg (50 lb) Square Bales				682 kg (1,500 lb) Round Bales			
	$/ha	$/ton hay	$/ton DM[b]	$/kg calf	$/ha	$/ton hay	$/ton DM[b]	$/kg calf
Orchard grass								
HH	244	32	32	1.03	161	21	21	.95
HG	164	29	20	.92	103	18	12	.86
GHH	203	35	30	1.03	140	24	21	.95
GHG	121	32	16	.90	80	21	10	.84
Average	183	32	25	.97	121	21	16	.90
Tall fescue								
HH	252	31	31	1.03	165	21	21	.95
HG	163	29	19	.92	102	18	12	.86
GHH	220	33	28	1.01	149	22	19	.92
GHG	123	32	14	.88	81	21	10	.84
Average	190	31	23	.97	124	21	16	.90

[a] See Table 1 for a description of the systems
[b] Total DM produced

Table 4. Optimal solutions for alternative meadow management systems, West Virginia, 1986.

System[a]	No. of Cows	No. of Calves Sold	Returns above variable costs ($)
Orchard grass			
HH	72	63	2,206
HG	78	68	3,966
GHH	63	55	2,066
GHG	71	62	4,097
Average	71	62	3,084
Tall fescue			
HH	75	66	2,355
HG	81	71	4,271
GHH	74	65	2,745
GHG	74	65	4,361
Average	76	67	3,433

[a] See Table 1 for a description of the systems

pertain to West Virginia and represent 1986 estimates.

The analysis is of a hypothetical representative farm engaged in cow/calf production. The farm has 16 ha of meadowland, all of which is to be allocated to one meadow management system at a given time. We assumed that sufficient summer pasture exists for the maximum number of cattle over-wintered. The basic question is which meadow management system will maximize profits (returns above variable costs) to the cow/calf producer. In this study, the farmer is assumed to use existing equipment and other fixed resources but can produce under any one of the four management systems and either of the two grasses.

Accordingly, eight linear programming (LP) models, corresponding to each system and grass, were used to determine the optimal meadow management system for the representative farm. The objective function was set up as follows:

maximize $Z = (R_{cf}) - (C_{cw} + C_m)$,

where Z represents revenues above variable or operating costs, R_{cf} represents revenues generated from calf sales, C_{cw} is the cost of maintaining cows during the year, and C_m represents the cost of operating and harvesting meadows for a given system and type of grass. Negative levels of all activities were precluded, consistent with the usual assumptions of LP. Further details on the budgets, procedure, and data can be found in Maxwell (1988).

Results

Results from the economic analysis of the meadow management systems are presented below for the following categories: production costs for each system corresponding to two methods of hay baling, the LP model solutions for the representative farm, and the impacts of hay spoilage on production costs.

Production costs for alternative systems

The costs of production pertaining to each meadow management system for both round and square hay-baling methods are presented in Table 3. With the exception of costs on a per ton of hay basis, where the costs of system HG were the lowest, GHG was the least-cost system. This result is especially significant because, even though grazed dry matter was the highest for the GHG system, hay and total dry matter production were not the highest (Table 2). On the other hand, except for system GHH, which was associated with the highest costs on a per ton of hay basis, system HH was the highest cost system with respect to all other criteria, such as costs per hectare, per ton of dry matter, and per kilogram (kg) of calf produced. In general, except for costs on a per hectare basis, average production costs were lower for systems with tall fescue than those with orchard grass. Further, in all cases, production costs were lower for 682 kg (1,500 lb) round bale systems than for comparative 23 kg (50 lb) square bale systems. However, differences between the two methods of baling in spoilage and waste during feeding may partially offset these cost differences. The impacts that hay spoil-

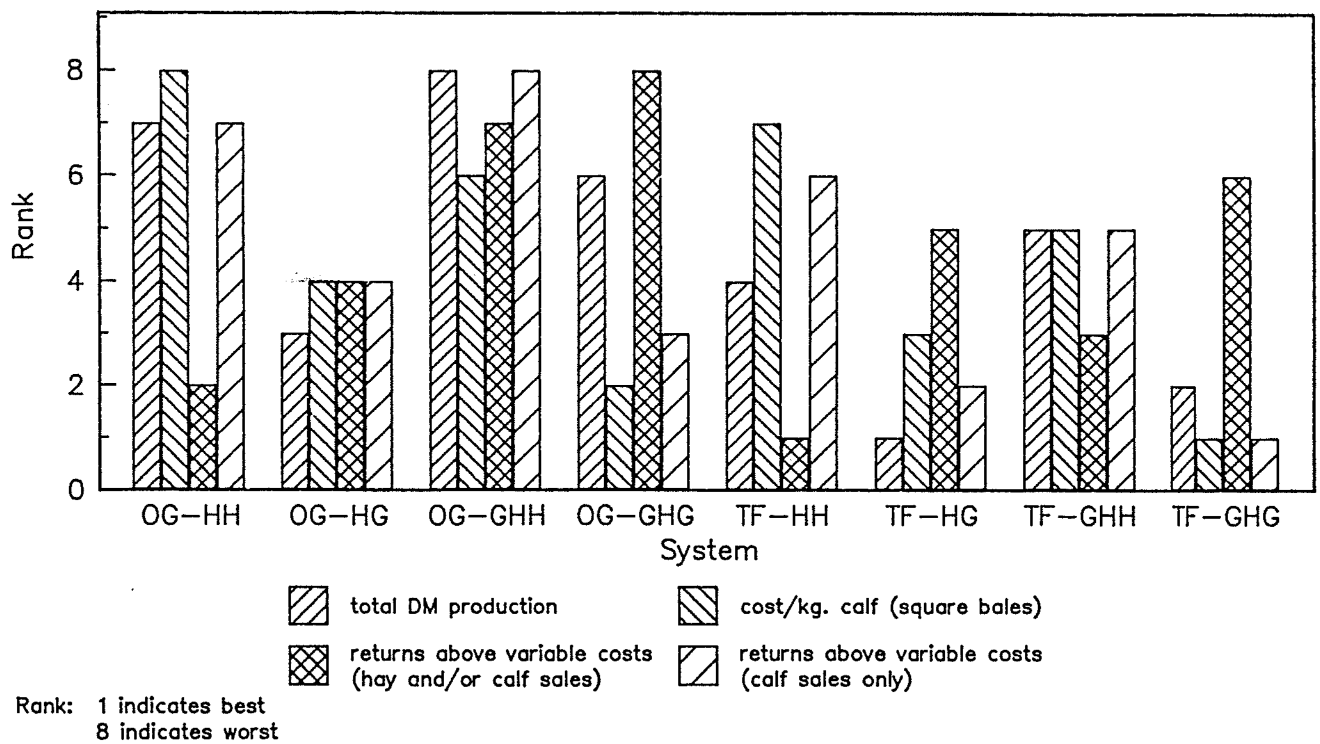

Figure 1. Rankings of alternative orchard grass (OG) and tall fescue (TF) meadow management systems with respect to dry matter production, costs and returns.

age with round and square hay baling have on calf and hay production costs are addressed in a later section.

Optimal solutions

The LP model solutions for specific meadow management systems and grasses for the representative farm are shown in Table 4. System HG resulted in the greatest number of calves sold. This is consistent with the dry matter production results (Table 2), where total dry matter production was greatest for the HG system. However, the most profitable system in terms of returns to fixed resources was found to be the GHG system for both orchard grass and tall fescue, and the least profitable systems were GHH for orchard grass and HH for tall fescue. The average optimum solution value was higher for systems with tall fescue.

The relative rankings of alternative systems with respect to selected criteria such as dry matter production, costs per kg of calf produced, and returns above variable costs are summarized using an illustration (Figure 1).

Impacts of hay spoilage on production costs

This analysis of the meadow management systems assumes there are no differences between the round and square hay-baling methods other than cost. In reality, spoilage (used generically here to include shrink or other dry matter losses such as wastage during feeding) could result in other differences between these methods, the estimation of which is beyond the scope of this study. However, this analysis was extended to shed some light on the potential impact on calf and hay production costs of different levels of hay spoilage using square and round hay-baling methods. Since spoilage differences between alternative hay-baling methods were not measured, we evaluated cost impacts at different spoilage levels. The results are illustrated in Figures 2 to 5. Only the values pertaining to meadow management systems using tall fescue are shown and discussed, since

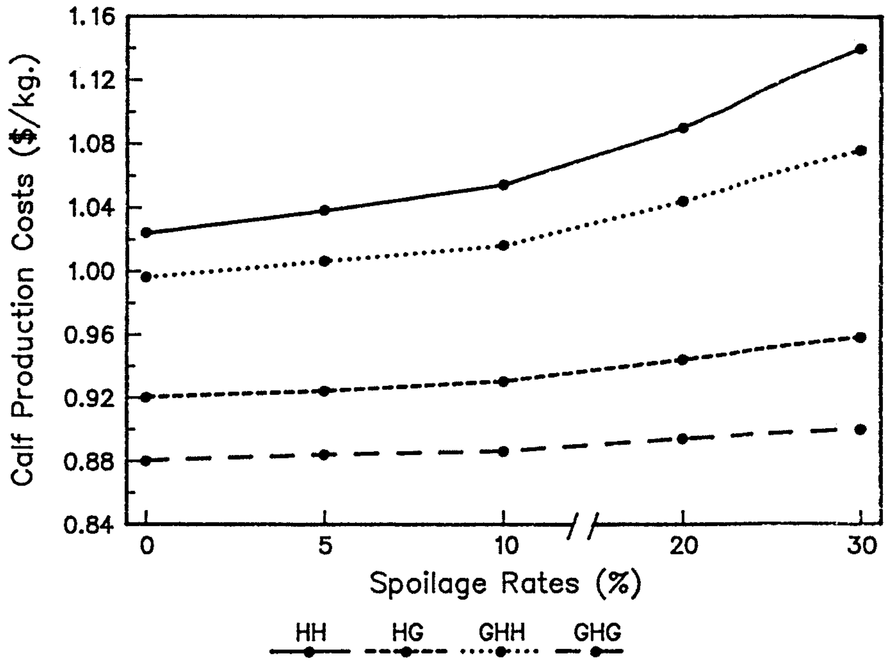

Figure 2. Impact of different levels of hay spoilage on variable calf production costs for alternative meadow management systems using tall fescue and square bales, West Virginia, 1986.

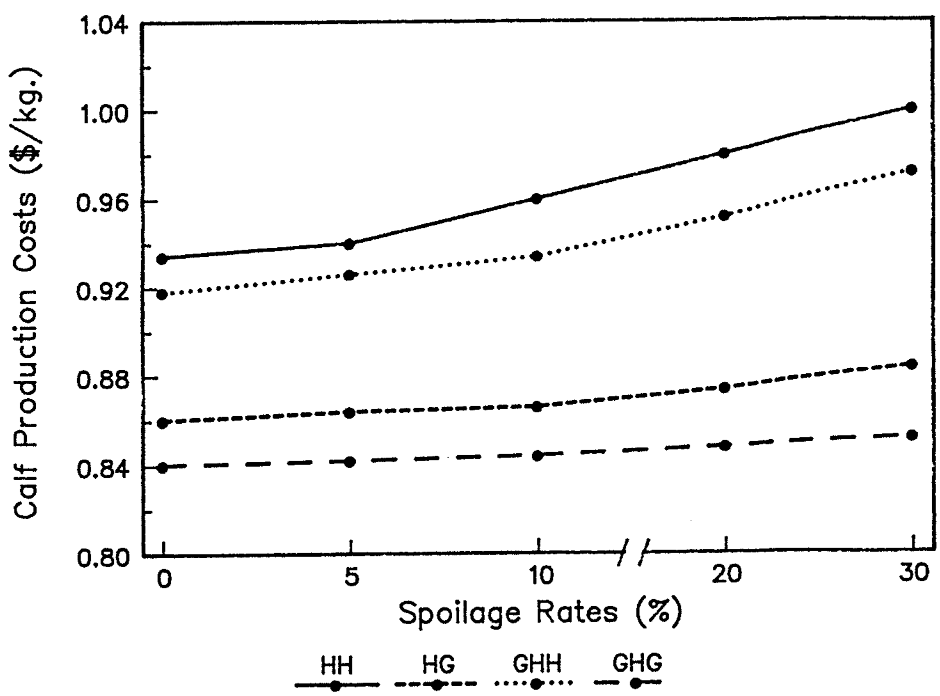

Figure 3. Impact of different levels of hay spoilage on variable calf production costs for alternative meadow management systems using tall fescue and round bales, West Virginia, 1986.

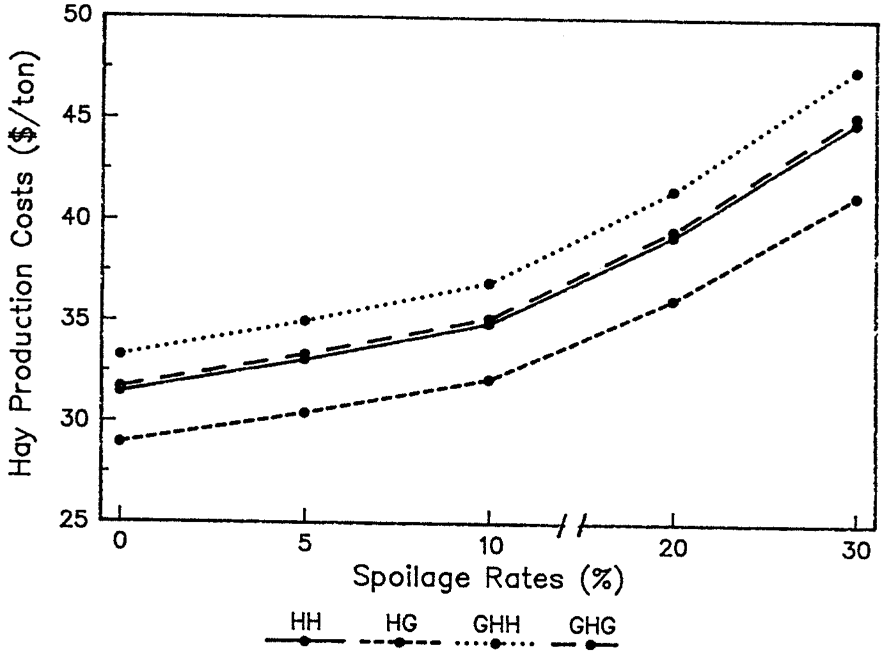

Figure 4. Impact of different levels of hay spoilage on variable hay production costs for alternative meadow management systems using tall fescue and square bales, West Virginia, 1986.

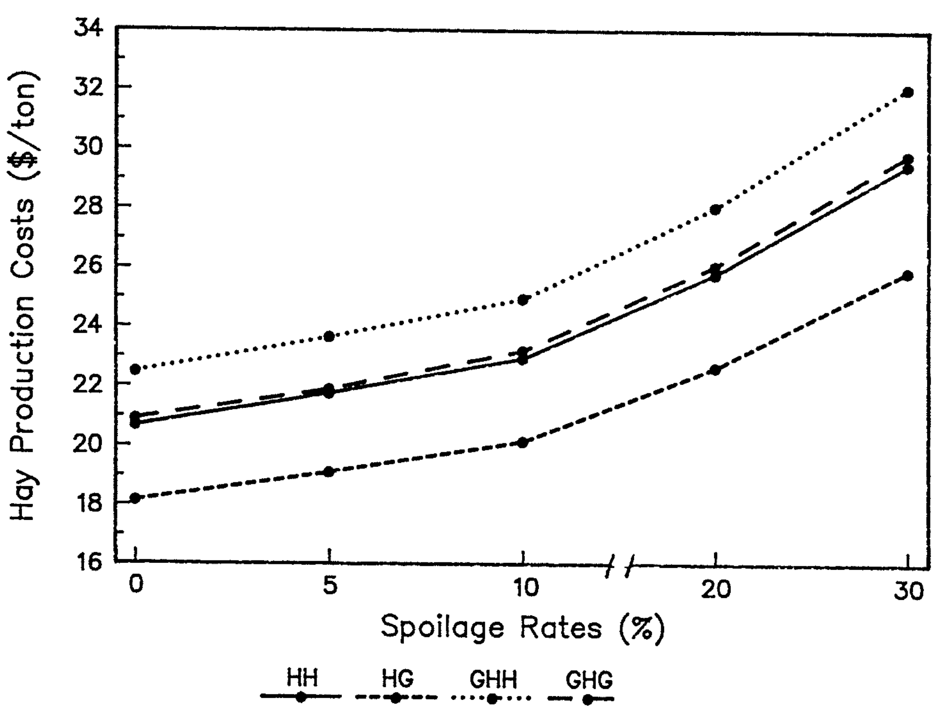

Figure 5. Impact of different levels of hay spoilage on variable hay production costs for alternative meadow management systems using tall fescue and round bales, West Virginia, 1986.

the same general relationships hold for the systems using orchard grass.

Calf and hay production costs are directly proportional to the amount of spoilage regardless of the hay-baling method. Again, system GHG's lower calf production costs and HG's lower hay production costs are obvious from these illustrations. Less apparent is the absolute production cost superiority of the round-baling method. For instance, costs of round baling for a given system at the highest spoilage level evaluated (30 percent) were always lower than those for the square-baling method for the same system with no spoilage loss. Therefore, in this analysis, these results show that round baling is more economical than square baling. It would also seem that, in systems with lower "need" for hay (HG and GHG), calf production costs are little influenced by spoilage loss (Figures 2 and 3). Further research is needed to quantify the physical and cost differences in spoilage between alternative hay-baling methods.

Decision-making implications

Although the absolute, and in some cases the relative, profit values will change in response to changing physical conditions, prices, and costs, our findings have implications for producer decision making. They indicate that certain extended grazing systems are among the low-input systems that can reduce production costs and enhance profits compared to conventional systems that do not include early or late grazing. When combined with other production and management practices, it is possible that profits can be further increased. For example, D'Souza et al. (1988) show that grazing systems incorporating warm-season grasses can increase profits from beef cattle production, especially in temperate, hill-land areas. Thus it is quite possible that a cow/calf production system incorporating both extended grazing and warm-season grasses, among other innovative approaches, can realize sizable increases in profit and possibly also in environmental quality. This is an area needing further research.

Conclusions

We have examined the farm-level impacts of extended grazing on production costs and profitability of cow/calf production. Alternative meadow management systems and grasses were analyzed using a combination of primary and secondary data and an economic engineering approach. The analysis showed that extended grazing can be a more profitable option for cow/calf production.

However, since costs, prices, weather, and other conditions vary, the relative profitability of alternative production systems also varies. On one hand, flexibility to shift among management alternatives, depending on relative costs and prices, could enhance long-term profitability for producers willing to change their operating strategy. On the other hand, the biological constraints associated with agricultural production could make it difficult for producers to adjust input and output levels rapidly in response to changes in price and other variables. Furthermore, the timeliness of labor and equipment use should be considered, since haying and grazing have different labor demands that may affect their suitability for different farming systems. Flexibility to shift among systems is not easily captured in models, including LP. To the extent that it is omitted, an analysis based on LP has limitations. Still, it can provide useful information on allocation of constrained resources to guide decision making, as is demonstrated here. This information should be viewed in the context of the mechanism used to generate it: it is subject to modification when conditions change and new information becomes available.

This analysis reveals that GHG, a system involving early spring grazing, one hay cutting, and late fall grazing, is the optimal extended grazing system for cow/calf production. Furthermore, tall fescue was found generally to perform better than orchard grass with respect to production, cost, and profitability criteria. Although this study is based on West Virginia data, the results have implications for cow/calf production in other hill-land areas. In addition, similar types of analyses can be used to evaluate other low-input systems or practices.

Incorporating extended grazing or other innovative grazing methods into the farm plans of cow/calf producers may not be a panacea for the low and often times negative net returns characterizing many such operations. However, the potential for reducing wintering costs and increasing profits does exist--a potential that can be further magnified if complementary innovations besides extended grazing are also incorporated into the farm system. To the extent that such innovations are environmentally sound, the potential for maintaining or increasing environmental quality can be realized together with increased profits.

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Sward dynamics of a complex Kentucky bluegrass dominant-white clover sward rotationally grazed by cattle and/or sheep

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Abstract

Very little information exists about North American complex grass-legume swards grazed under controlled rotational management with paddocks, recovery periods that vary according to plant regrowth, high stocking densities, and short grazing periods. This experiment was done to study how sward components (particularly white clover, *Trifolium repens*) respond to such management with cattle and/or sheep grazing of a low-input (no N fertilizer), complex natural sward dominated by Kentucky bluegrass (smooth-stalked meadowgrass, *Poa pratensis*). This kind of information is needed to feed livestock efficiently and profitably on 10 million ha of pastureland currently producing far below its potential due to defective grazing management in the northcentral and northeastern United States.

Treatments during two grazing seasons (1989-90) were cattle grazing alone (C), cattle followed by clipping (CC), cattle followed by sheep (CS), and sheep grazing alone (S). Since cattle (especially dairy cow) feeding on pasture is of most interest in these regions, clipping or sheep following cattle treatments were included to groom the pasture for subsequent grazings by cattle. Mean target pre- and postgrazing herbage masses were 2200 and 1100 kg DM/ha, estimated by single-probe electronic capacitance meter (Pasture Probe). Sward component dynamics were monitored with turf dissections, marked white clover stolons, and ring-toss white clover leaf counts.

Component and sward data for the C, CC, CS, and S treatments, respectively, were: white clover growing points m^{-2} 587, 609, 705, 435 (s.e. 41); leaves m^{-2} 1295, 1384, 1408, 900 (s.e. 108); leaves growing $point^{-1}$ 3.2, 3.4, 3.0, 2.8 (s.e. 0.2); stolon length (cm m^{-2}) 1945, 1965, 2201, 1558 (s.e. 176); stolon growth (mm d^{-1}) 0.9, 1.0, 0.7, 0.8 (s.e. 0.1); grass tillers m^{-1} 6879, 7711, 6145, 6849 (s.e. 264); % (all % by ash-free weight)

white clover leaves and petioles 6.8, 6.3, 8.4, 5.2 (s.e. 0.44); % white clover stolons 10.0, 5.3, 9.0, 4.5 (s.e. 0.9) % grass 73.7, 78.9, 77.0, 79.3 (s.e. 1.4); % forbs 11.8, 10.3, 7.5, 11.8 (s.e. 0.9); and forage accumulation (kg DM ha^{-1}) 5164, 5017, 5865, 8282 (s.e. 75).

Number of growing points, leaves m^{-2}, and percentage of white clover leaves and petioles in the sward were greater under cattle grazing than where sheep grazed alone. This was especially notable where cattle were followed by clipping or sheep grazing, possibly due to decreased shading of white clover by associated grasses in the shorter swards of the post-cattle grazing treatments. Paddocks grazed by sheep alone contained less white clover, but regrew quicker and produced more forage than other treatments. This may have occurred because of grass growth being stimulated more by nutrients from sheep dung and urine, which were spread more uniformly (and probably the dung decomposed more rapidly) than cattle dung and urine. Because of the slower growth of plants in the cattle-grazed treatments, more pasture mass accumulated in paddocks grazed only by sheep (sometimes reaching as high as 3400 kg DM ha^{-1}) before the mean target pregrazing mass for all treatments was reached. This larger amount of pasture mass may have shaded white clover excessively and decreased clover content of the sward in paddocks grazed only by sheep.

Similar swards need to be kept considerably shorter than is traditionally recommended in the United States, and probably should not reach pregrazing forage masses greater than 2200 to 2500 kg DM ha^{-1} to avoid shading out white clover. Close clipping or grazing by sheep following dairy cattle grazing would maintain the sward in better physical condition with more white clover in the sward than no post-cattle grazing treatment.

Introduction

Grasslands deteriorate and produce very little animal product per unit area under uncontrolled domestic livestock grazing. Planned and controlled rotational grazing management increases grassland plant and animal productivity, by allowing plants adequate time to recover between grazings, and reducing selective grazing and wasted forage (Murphy *et al.*, 1986; Savory, 1988; Sheath *et al.*, 1987; Voisin, 1959).

In addition to using appropriate grazing management, pastures can be improved by increasing the content of legumes such as white clover (*Trifolium repens*) in swards, which in itself usually results from improved management. Grass-white clover swards have better feeding value than pure grass swards, and animal product output compares favorably to grass swards receiving 150 to 280 kg N $ha^{-1}y^{-1}$ (Frame, 1985; Frame and Newbould, 1986; Harkess and Frame, 1986; Laidlaw and Frame, 1988). Nitrogen contributions from white clover and overall improvement in pasture forage productivity and quality under appropriate grazing management can help reduce farm production costs.

Besides increasing farm profitability, using legume N-fixing ability in crop and livestock production is important to decrease the drain on nonrenewable fuel involved in the manufacture of fertilizer N, and widespread nitrate environmental pollution resulting from applied fertilizer N (Magdoff, 1991). Clear evidence exists that grass-white clover swards are safer for the environment than grass heavily fertilized with N. Losses of N through nitrate leaching and ammonia from grass-clover swards are only one-fourth of the losses from grass (perennial ryegrass *Lolium perenne*) swards fertilized with N. Retention of N in the soil organic matter under grass-clover swards is four times greater than under N-fertilized grass swards (Frame, 1987).

White clover performance in mixed swards has been inconsistent, however, because it is more sensitive than grass to adverse soil and climatic factors, as well as to management practices. Also, N fixed by white clover eventually stimulates grass growth, thereby increasing competition against the clover, unless grazing management controls competitiveness of associated grasses. Understanding the interactive factors of weather, soil, sward, animal, and grazing management that influence white clover performance can provide production reliability that gives grass-white clover swards an advantage over N-fertilized pure grass swards (Frame, 1988a).

Very little information exists about plant relations in complex grass-legume swards grazed under controlled rotational management with paddocks, recovery periods that vary according to plant regrowth, high stocking densities, and short grazing periods in North America. The aim of this study was to improve understanding of white clover, grass, and forb responses to grazing manipulation with cattle and sheep so that objective guidelines for management of low-input (no N fertilizer) complex natural swards dominated by Kentucky bluegrass (smooth-stalked meadowgrass, *Poa pratensis*) can be developed. Such swards potentially can produce as much or more dry matter (DM) and crude protein than selected grasses such as perennial ryegrass at low-to-moderate input levels of N fertilizer (Frame, 1985, 1988b, 1991; Harkess and Frame, 1986). This kind of information is needed to feed livestock (especially dairy cows) efficiently and profitably on 4.5 million ha of permanent natural pasture, and 5.5 million ha of ley pasture currently producing far below their potential due to the defective grazing management generally used in the northcentral and northeastern United States, (US Department of Commerce, 1987).

In succeeding papers of this series we will consider effects of cattle and sheep grazing and clipping treatments on net forage production, amount of rejected forage, and soil compaction, fertility, and organisms. We will also consider the use of four sward measurement techniques (cut quadrat, capacitance meter, HFRO sward stick, and a rising plate) for estimating forage mass on complex swards.

Materials and methods

Details of sward culture

This study was conducted during 1989 and 1990 on a complex natural sward that had been grazed rotationally only by sheep during the latter half of 1987 and all of 1988. A uniform sward resulted that was composed of 81% grass, 9% white clover, and 10% forbs. Kentucky bluegrass comprised about 70% of the grass. Other grasses present were orchardgrass (*Dactylis glomerata*, 20% of the grass), timothy (*Phleum pratensis*, 5%), and quackgrass (*Agropyron repens*, 5%). The forbs were dandelion (*Taraxacum officinale*, 5%) and chicory (*Cichorium intybus*, 5%). Inoculated white clover seed cv. 'Grasslands Huia' was surface-broadcast at the rate of 5 kg ha^{-1} in all treatments on 5 April 1989.

Experimental design

Treatments were: cattle (18-month-old Holstein heifers) grazing alone (C), cattle followed by clipping with a rotary mower to 2.5 cm from the soil surface (CC), cattle followed by sheep (CS), and sheep grazing alone (S). When treatment paddocks accumulated a mean target forage mass of 2200 kg DM ha^{-1} in actively grazed areas, animals were allowed to graze. Animals were removed from paddocks at a target forage mass residual of 1100 kg DM ha^{-1} in actively grazed areas.

Pasture forage mass was estimated with a single probe electronic capacitance meter (Design Electronics Pasture Probe). (Pasture mass also was estimated with clipped quadrats, HFRO sward stick, and a rising plate; the use of these methods and the capacitance meter will be considered in a succeeding paper.) At least thirty capacitance meter measurements were made of the sward in actively grazed areas of each treatment before and after grazing (Boswell, 1986). Measurements also were made near the end of grazing each treatment to determine when to remove animals from paddocks.

The experimental site was on a Winooski very fine sandy loam (coarse-silty, mixed, mesic, Aquic Fluventic Dystrochrept) near Colchester, Vermont. The design was a randomized complete block, replicated three times.

Treatments were grazed simultaneously within each replicate, which were grazed in succession. Thirteen 2-year-old Holstein heifers and 120 sheep consisting of ewes, lambs, and yearlings of various breeds were used to graze treatments. Paddock sizes were 0.16 ha for cattle-grazed areas, 0.05 ha for sheep following cattle, and 0.08 ha for sheep grazing alone. Stocking densities were approximately 80 animal units (AU) ha^{-1} each for cattle and sheep, and 130 AU ha^{-1} for sheep following cattle. A higher stocking density of sheep following cattle was used so that sheep would eat forage that had been rejected by cattle quickly without having time to select for white clover. These stocking densities were chosen to represent average stocking densities currently being applied by dairy farmers. Grazing periods were 24 hours per paddock, except for sheep following cattle, when sheep grazed for 1 hour. Grazing began on 15 May and ended on 21 September in 1989, and began on 20 May and ended on 25 September in 1990.

Sward structure and dynamics

Sward component changes were monitored weekly and at each grazing in actively grazed areas by measurements made according to Hodgson *et al.* (1981) and suggestions made by A. Davies, A.S. Laidlaw, and T. Nolan (personal communications). Measurements made from dissected turves and permanently marked stolons at each grazing were: number of white clover growing points and leaves per growing point, stolon length and growth over time; number of grass tillers; and grass, clover, and forb percentage by ash-free weight. Weekly measurements made with tossed rings and temporarily marked stolons were: number of white clover leaves, number of leaves per growing point, and stolon growth over time.

Just before animals grazed paddocks, ten 2.5-cm deep turf samples were taken per treatment. Samples were selected through systematic randomization along transects in paddocks. Turves were removed with by cutting with knife within a 10-cm square quadrat in 1989, or with a 10.5-cm diameter golf-hole cutter in 1990, and were either dissected the same day as sampled or refrigerated until dissected. All sample components were dried at 55 C , weighed, and ashed at 600 C for 2 hr (Jones, 1984) to remove soil contamination for botanical composition percentages based on ash-free organic matter.

Every week white clover leaves per unit area were counted to calculate number of growing points, based on number of leaves per growing point determined by turf dissections. This was done using 7.5-cm inside diameter rings tossed randomly 40 times per treatment. Only undamaged leaves with distinguishable midribs were counted.

Stolon growth

To estimate stolon growth over time, during 1989 stolons were permanently marked and monitored throughout the grazing season. Since this technique limited observations to older stolons, temporarily marked stolons were used in the second year. In the first year five stolons were selected at two randomly picked locations along transects in paddocks. Stolons were marked by placing a hair pin with a piece of blue yarn attached behind the last open leaf near the growing point, and the distance from the marker to the growing tip was measured. Stolon growth was monitored at weekly intervals by measuring from the hair pin to the growing point tip. The pin was moved to just behind the last leaf after the measurement was made (Davies, 1981).

During 1990, three stolons per treatment were selected each week using tossed rings. Stolons were marked as described above. Flags were placed near the marked stolons to facilitate finding growing points. One week later, the length of stolon from the hair pin to the tip was measured and subtracted from the previous measurement, to obtain growth over time. Then different stolons were selected. This measurement was made beginning 1 week after grazing until just before the next grazing. Flags and hair pins were removed before grazing.

Results

Sward structure

The sward contained 473 white clover growing points m^{-2} at the beginning of this experiment. During 1989 the number of growing points decreased under all treatments except CS, where the number of growing points increased above the initial level. Grazing treatment interacted with time of season ($P<0.02$). In 1990 the number of growing points increased in all treatments, particularly in cattle-grazed paddocks. Time of season influenced the number of growing points in 1990 ($P<0.001$). The greatest mean increase occurred in CS. The mean number of growing points remained essentially the same in S (Table 1a and Figure 1a, b). When both years were considered together, there were significant effects of time of season ($P<0.005$) and a treatment x time of season interaction ($P<0.08$).

The sward initially contained 2089 white clover leaves m^{-2}. The number of white clover leaves decreased in all treatments during 1989, especially in CC and S. In 1990 the number of leaves increased somewhat in cattle-grazed treatments, but remained near the low level of the previous year in S. Periodically during each year the number of leaves reached or exceeded the initial level, but subsequently declined. The greatest number of white clover leaves was maintained in cattle-grazed treatments (Table 1b and Figure 1c, d). Time of season affected number of leaves during both years ($P<0.0001$, 1989; $P<0.02$, 1990).

Coinciding with the changes in number of growing points and leaves per unit area noted above, the number of leaves per growing point decreased from the initial level of 4.7 white clover leaves per growing point in all treatments, and especially in CS and S (Table 1c and Figure 1c). Time of season influenced the number of leaves per growing point during both years ($P<0.0002$, 1989; $P<0.06$, 1990).

Stolon length increased above the initial level of 1020 cm m^{-2} in all treatments except S in 1989. During 1990 stolon length became more than twice the initial level in all treatments. Stolon length increased most in cattle-grazed treatments (Table 1d). Time of season influenced stolon length in 1990 ($P<0.04$), and treatment interacted with time of season in 1989 ($P<0.02$).

Time of season had more influence ($P < 0.0001$) on stolon growth rate than grazing treatment. Usually most rapid growth occurred early in the season, and declined as the season progressed in temporarily marked stolons. The growth rate of permanently marked (probably older) stolons more than tripled under all treatments during August (Table 1e).

Grass tiller numbers remained relatively constant at the initial level of 6000 tillers m^{-2} in treatments C and S, but tended to increase in CC, while decreasing in CS during 1989. Tiller numbers tended to increase in all treatments during 1990. Mean tiller number was highest in the CC treatment (Table 1f). Time of season affected tiller number in 1990, with greatest number of tillers being present in spring, decreasing in midsummer, and increasing in autumn (P<0.02).

Botanical composition

The percentage of white clover leaves in the sward varied about the initial level of 5% of organic matter in 1989, but increased markedly in the cattle-grazed treatments, especially in CC and CS, in 1990. The highest mean percentage was in CS. The S treatment remained on average the same as the initial level (Table 1g). Time of season influenced the percentage of white clover leaves in the sward in 1990 (P<0.001).

The percentage of white clover stolons in the sward increased in treatments C and CS above the initial level of 4% in 1989, and increased in all treatments in 1990 (Table 1h). During both years time of season influenced stolon percentage (P<0.0002, 1989; P<0.05, 1990). Treatment interacted with time of season in 1989 (P<0.07).

The percentage of grass in the sward remained relatively constant during both years, decreasing slightly in the cattle-grazed treatments (Table 1i). During both years, time of season influenced the percentage of grass in the sward (P<0.001).

The percentage of forbs varied somewhat during both years, but changed little on average. The C and S treatments tended to gain forbs on average, while CS decreased slightly in forb content (Table 1j). Time of season influenced forb content in the sward in 1989 (P<0.01).

Forage accumulation

Forage accumulation (unadjusted for rejected area; discussed in succeeding paper) was greater during both years in S than in cattle-grazed treatments (Table 1k). Time of season influenced forage production in both years (P<0.01). Treatment interacted with time of season in both years (P<0.01, 1989; P<0.07, 1990).

Discussion

Sward structure

One of the main aims of this experiment was to learn about white clover's behavior over the season in a typical complex sward, as a first step in refining grazing management recommendations that will increase and maintain high percentages of white clover in the sward. An adequate white clover sward content is absolutely essential, both to fix the N needed by the sward and the entire farm, and to improve overall feeding value of the forage. White clover N and DM contribution varies within and between years, mainly due to poor grazing management, cultivar, and environmental and biotic factors. The biotic factors that interact with white clover are the companion grasses, *Rhizobium* bacterium, and grazing animals (Collins *et al.*, 1991).

Number of growing points is an important determinant of white clover performance, because it indicates the potential for further branching (Jewiss, 1981), and therefore the potential for further stolon and leaf production. In addition, the number of growing points determines the population density (Grant, 1981), which influences the amounts of N fixed and clover forage yield. White clover population density also influences forage feeding value and amount of grass forage produced on N fixed by clover.

Curll and Jones (1989) showed that the defoliation effect is more pronounced than either treading or return of excreta on content and stolon density of white clover in a mixed sward. Close grazing favors white clover growth and production, by decreasing shading from companion grasses.

This conclusion seems to have been borne out in this study, most clearly in the first year. While all swards were grazed down to a pasture mass of 1000 kg DM ha^{-1} in each rotation, it was unavoidable that in the CS treatment sheep would graze the overall sward somewhat shorter, resulting in less shading of white clover stolons and more growing points. During the second year, plant regrowth was much faster in the S treatment than cattle-grazed treatments. (The reasons for this are considered in a succeeding paper.) In retrospect, it might have been better to have grazed the S paddocks whenever they reached the target pregrazing pasture mass. As it was, to be consistent, all treatments were grazed during the same short period. By waiting until a mean target pregrazing mass was reached for all treatments, however, the S-treatment swards sometimes reached excessively high pregrazing forage mass levels of 3200 to 3400 kg DM ha^{-1} , with consequent heavy shading of white clover during some rotations of the second year. These differences in herbage mass accumulation between cattle-grazed and S treatments probably resulted in differential shading of white clover, which was reflected in the numbers of growing points in treatments in 1990. More than likely, if sheep had begun grazing at a lower pregrazing mass, the S-treatment sward would have contained more clover (stolons, growing points, and leaves per growing point and unit area), because of the lower level of shading and better light conditions that would have existed in the sward.

The number of white clover leaves m^{-2} tended to be higher during midsummer in all treatments. This may have resulted from less shading and competition for nutrients from companion grasses during midsummer due to slower grass growth at that time. Coinciding with less competition from associated grasses, the rate of white clover leaf appearance generally increases at higher temperatures (McWilliam, 1978). Also, during summer months the greater amount of light available and longer day lengths result in more differentiation and larger white clover leaves (Sheath and Hodgson, 1989).

Although treatment CS contained the most white clover growing points per unit area in 1989, it had the least leaves per growing point, and had the same number of leaves per unit area as other treatments. This may indicate that white clover plants adjust the number of leaves per growing point to accommodate an upper limit of leaves per unit area that can be supported under a given set of conditions. Leaves per growing point varied with time in the season. The highest number of leaves per growing point developed during midsummer, probably because of reduced competition from associated grasses.

Stolon length per unit area is another indicator of white clover production, complementing the measurement of number of growing points. This is because stolon development and replacement have a strong influence on survival of white clover (Hay, 1987). The forage yield of white clover in spring is determined by various factors, including how much stolon survived the winter. Change in stolon length over winter can be used to estimate white clover winter hardiness (Collins *et al.*, 1991).

In this study stolon length increased to more than twice the original length during the second year. This may have been in response to the more intensive grazing with lower pre- and postgrazing pasture masses of the experiment, compared to previous grazing. Lower herbage masses would result in more favorable light conditions for white clover growth. This was reflected in the greater stolon lengths of the cattle-grazed treatments, which generally had lower herbage masses than the S treatment.

That temperature and light conditions influence stolon growth (Frame and Newbould, 1986), was demonstrated by the main period of stolon elongation generally occurring in midsummer, in response to long day lengths (Jewiss, 1981). The important effect of light on stolon growth was reflected in the significant treatment x time of season interaction in 1989, and the significance of time of season in 1990.

The number of grass tillers in the sward at the outset of this experiment ($6,000 m^{-2}$) was considerably less than the number of tillers ($40,000-60,000 m^{-2}$) reported by Parsons and Penning (1988) to be present in pure, N-fertilized perennial ryegrass swards grazed by sheep in the UK. These tiller numbers reflect the very different character of complex swards in this region of the United States. So little information exists about these kinds of swards, that it is unknown if 6000 tillers m^{-2} is a low, medium, or high level of tillers for existing growing conditions, under appropriate grazing management. Judging from the increase in tiller numbers that occurred in all treatments in the short time of this study, it seems likely that a higher level of tillers is possible to achieve, while increasing or maintaining an adequate white clover component in the sward.

Botanical composition

The balance between individual grass and white clover plant performances, as affected by morphological and physiological differences, abiotic factors, and grazing animals, ultimately determines species composition of grass-clover swards (Marriott and Grant, 1990). Change in any aspect can result in change in composition. The increase in clover leaf percentage in the sward (previously grazed by sheep) that occurred in the cattle-grazed treatments reflects the different effects that animal species have on individual plants and their environment. The more intensive grazing that was imposed during the study, compared to previous grazing, may have created better light conditions in the sward that resulted in more tillering of both grasses and white clover.

Practical implications

Grazing must be timed to avoid deterioration in sward structure (Parsons and

Penning, 1988), while taking into account livestock forage intake and quality needs for production. Intensive grazing reduces the growth of erect species such as orchardgrass, but increases the growth of prostrate species such as Kentucky bluegrass and white clover. Lax grazing results in selective, patchy grazing with high levels of pregrazing herbage mass that increases shading of lower plant parts and low-growing plants such as white clover. Shading results in reduced contribution by white clover, death of lower grass leaves and tillers, and thinning of the sward. Shaded leaves continue to respire, drawing on photosynthate that could be converted to animal product under appropriate grazing management. Intensive grazing, by reducing shading, decreases the amount of dead material in pasture, and also the amount of herbage that is wasted through decay and decomposition (Holmes *et al.*, 1984).

In this study pregrazing herbage mass seemed to have more effect on white clover content of the swards than postgrazing mass. Pregrazing herbage masses of 2500 to 3000 kg DM ha^{-1} apparently do not decrease white clover content of perennial ryegrass/white clover swards in New Zealand (Korte *et al.*, 1987). Those swards are more dense, however, than the complex swards of this region. Consequently, swards containing perennial ryegrass attain a greater pregrazing mass at a lower sward surface height than occurred in the sward of this experiment. Less shading probably occurs in shorter swards, even though the shorter swards are more dense than taller swards. The shading that occurs in complex swards of this region results in excessive petiole extension, which increases shading even more, without contributing much to accumulating a target pregrazing mass. Our results suggest that complex swards in this region, such as the one used in this experiment, should not be allowed to accumulate pregrazing forage masses greater than 2,200 to 2,500 kg DM ha^{-1} before being grazed down to 1,000 to 1,200 kg DM ha^{-1}. This should encourage desirable sward structure development and result in optimum production of net high-quality forage.

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Table 1. Effects of grazing treatments on sward structure and forage production.

Observation	Cattle	Cattle/clip	Cattle/sheep	Sheep	SEM	P
	Treatments					
White clover						
a. growing points m^{-2}						
1989	368	329	545	308	19	<0.1
1990	805	888	864	561	39	<0.08
Mean	587	609	705	435	41	NS
b. leaves m^{-2}						
1989	1207	984	1201	942	64	NS
1990	1382	1784	1614	858	70	<0.03
Mean	1295	1384	1408	900	108	<0.08
c. leaves growing pt^{-1}						
1989	3.9	4.1	3.3	3.5	0.2	<0.06
1990	2.4	2.7	2.4	1.8	0.2	<0.03
Mean	3.2	3.4	3.0	2.8	0.2	<0.03
d. stolon length, cm m^{-2}						
1989	1147	1169	1553	972	141	NS
1990	2743	2760	2849	2143	188	NS
Mean	1945	1965	2201	1558	176	NS

Table 1 continued.

e. stolon growth, mm day^{-1}

Temporarily marked						
1989	0.9	1.0	0.7	0.7	0.1	NS
1990	0.6	0.8	0.6	0.9	0.1	NS
Mean	0.8	0.9	0.7	0.8	0.1	NS
Permanently marked						
1989	1.1	1.1	0.8	0.7	0.2	NS

Grass

f. tiller numbers m^{-2}

1989	6038	6910	5192	5926	249	NS
1990	7719	8511	7097	7772	285	NS
Mean	6879	7711	6145	6849	264	NS

Botanical composition, % by ash-free weight

g. white clover leaves

1989	6.2	3.5	7.1	4.3	0.4	<0.03
1990	7.4	9.0	9.7	6.0	0.6	NS
Mean	6.8	6.3	8.4	5.2	0.4	NS

h. white clover stolons

1989	11.7	4.0	10.0	3.9	2.0	NS
1990	8.3	6.6	8.1	5.1	0.8	NS
Mean	10.0	5.3	9.0	4.5	0.9	NS

Table 1 continued.

i. grass						
1989	74.2	84.4	79.1	84.8	2.3	NS
1990	73.3	73.5	74.9	73.8	2.0	NS
Mean	73.7	78.9	77.0	79.3	1.4	NS
j. forbs						
1989	12.7	9.7	7.7	8.6	1.3	NS
1990	11.0	10.9	7.4	15.1	1.0	NS
Mean	11.8	10.3	7.5	11.8	0.9	NS
Forage accumulation, kg DM ha^{-1}						
1989	5534	5465	6470	7346	57	<0.01
1990	4794	4569	5260	9218	105	<0.01
Mean	5164	5017	5865	8282	75	<0.01

Figure 1. White clover dynamics in a complex Kentucky bluegrass dominant sward grazed rotationally by cattle and/or sheep in Vermont, USA. a: white clover growing points m^{-2}, 1989; b: white clover growing points m^{-2}, 1990; c: white clover leaves m^{-2}, 1989; d: white clover leaves m^{-2}, 1990.

Kellogg Foundation Evaluation 1993

EPIC Evaluation--DRAFT

Pasture Management Program

The pasture management program has been indisputably successful in making progress toward the fundamental EPIC goal of reweaving the fabric of rural Vermont.

Innovation in Sustainable Agriculture

As stated in the original EPIC application, sustainable agriculture is a vital part of the future of rural Vermont. While "sustainable agriculture" has been endorsed by many organizations, including the University of Vermont, there has been little substance behind the endorsement. The Pasture Management Program goes beyond talk to actually implement an innovative program on real farms run by real farmers.

Improving the Quality of Life for Farmers

When asked about the most important part of the pasture program, most participating farmers talked about quality-of-life improvements rather than herd health, grain bills, cash flow, or their bottom line.

"The best thing is I enjoy my cows much more," one farmer said. "They're healthier and happier and I'm happier."

"I don't consider myself a touchy-feely-type person," another farmer said. "There's been a change of attitude in our cows in the last two years, and we find we're happier."

"I'm happy and enthusiastic," another farmer said.

Others mentioned having more time to have a life.

These comments are somewhat unusual from farmers, partly because the farm situation has been fairly bleak recently and partly because it is much easier to talk about production numbers or condition scores than it is to talk about being happy.

This is probably attributable to two parts of the program: pasture management really does enable the farmers to feel better about their lives; and the program's support groups and recognition of life beyond-the-barn may make people more willing to talk about their feelings.

Economic Viability

Although the literature indicates that rotational grazing can improve the bottom line, it seems that none of the farmers interviewed were actually sure whether or not that had happened or would happen in the future. It seemed their calculation was confounded by uncertainty over milk prices, their own record keeping, and the short time period.

"I can't throw a document on your desk and say we're making x more dollars, but I'm confident we'll find any loss of production has been more than offset by (reduced) health and grain costs," one farmer said.

Most farmers felt the only other viable alternative was to get bigger, more capital-intensive, and more high-tech. To most, this alternative was financially riskier and less satisfying.

"Before I started grazing I was 3X milking," one farmer said. "I was going a different direction. I feel much better about this choice."

"This is a way for what I think of as the family farm to make it."

"I've always believed there were two ways: high-input-high-output, or low-input-low-output. But what has interested me about this is that even though it's low-input, I don't think it's low output," said one particularly enthusiastic participant.

Several farmers are considering going seasonal--a logical extension of the grazing philosophy. "At first I thought seasonal was crazy," one participant explained. "But once you get into it, you really get into it.

Serving as a Model

Certainly, the project serves as a model to show how rational grazing can work. In addition, the program serves as a model of grass-roots diffusion of technology rather than the more traditional top-down approach.

Farmers seem to appreciate the fact that this research is being conducted on real farms and that it is not some product or scheme dreamed up in an office, researched on a university herd, and pushed on the farmer. One person contrasted the project to "Isoplus and other wonders" which resulted from university research, received glowing reviews, and failed on real farms.

Participating grass farmers feel they are being watched by others. They see themselves as innovators, and they seem to enjoy it.

"My brother's gone total confinement," said one farmer. We talk a lot. You can imagine. But who knows, I think he may change."

Several farmers talked about how they were leading the nutritionists rather than the nutritionists leading them. "For years he (the nutritionist) has been back and forth," a farmer said. He was very nervous when we started. We overgrained. But now he's come around."

Support

Everyone interviewed felt the visits from Lisa and Joshua as well as the support group meetings were very useful.

Some people mentioned they had tried grazing or thought about it before but had not been able to implement it successfully without the program. Several people explained that managing a pasture program is much more complicated than meets the eye and that the help of Lisa and Joshua has been crucial.

Most people asked about the support group meetings prefaced their remarks with something about how they don't like meetings, and then they warmed up a little and admitted that the meetings were good.

"I'm not for meetings," one participant said. "But I try to go to these...I always learn something...There's not one I regretted going to...They're always pretty good."

Some farmers even mentioned that the groups were opportunities to break the isolation of the farm.

The project has also offered meetings on topics which other organizations may shy away from, such as homeopathy or holistic resource management.

If there was a complaint from the farmers about the EPIC project support, it was that some of the statements tended to gloss over the complications. "This is complicated. They shouldn't try to make it sound too simple," one farmer said.

Record Keeping

The project requires record keeping, both to help the participating farmers figure out what they are doing that's right and what they are doing that's wrong, but also to help in compiling the results from many farms for the collective learning process. Several of the participating farmers have trouble with record keeping.

This problem is not unique to the pasture management program, and Bill, Joshua and Lisa are sensitive to the farmers' gripes. It might be worthwhile to revisit the record keeping requirements line by line to see if all the information is necessary, if there is any way they could be simplified, or if there is a more automatic way of gathering any of the information.

Influence

Although the program is innovative and approached through farmers rather than through a government-based top-down process, it is gaining acceptance and influencing the thinking of agricultural government leaders.

The (now former) Commissioner of Agriculture from Massachusetts said: "There's no question it's got validity. It's where IPM was ten years ago--and now that's mainstream."

The Commissioner of Agriculture from Vermont said: "I have nothing by positive comments about the program. I certainly think given the milk crisis and feed costs toady, the approach is positive. It is a viable management tool and the knowledge needs to be afforded to everyone."

The mailings go to interested people in many states and several countries. The grazing conference attracted over 200 people. It is clear that getting people's attention is not a problem with this EPIC component.

Next Steps

The program is incredibly successful and deserves to be continued and expanded.

The popularity of the program may indicate the following:

Continued funding is crucial.

Overall administration and coordination of the program may need more explicit attention so that Bill, Lisa, and Joshua can most effective.

It may be an appropriate time to work more consistently and directly with some of the people who influence farmers, including veterinarians, feed representatives, nutritionists and extension agents. They certainly take the program seriously by now and their cooperation could be helpful to farmers who may want to try grazing in the future.

A comparison of quadrat, capacitance meter, sward stick, and a rising plate for estimating forage mass in a complex Kentucky bluegrass dominant-white clover sward

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Abstract

Very little information exists about estimating forage mass in North American complex grass-legume swards grazed under controlled rotational management with paddocks, recovery periods that vary according to plant regrowth, high stocking densities, and short grazing periods. This experiment was done to improve understanding of techniques to measure forage mass under such management with cattle and/or sheep grazing of a low-input (no N fertilizer), complex natural sward dominated by Kentucky bluegrass (smooth-stalked meadowgrass, *Poa pratensis*) and based on white clover, to develop objective management guidelines.

A single-probe capacitance meter (Pasture Probe), the Hill Farm Research Organization sward stick, a rising-plate meter, and cut quadrats were used to estimate forage mass of the sward that was rotationally grazed by cattle, cattle followed by clipping, cattle followed by sheep, or sheep alone during 1989 and 1990 grazing seasons. Mean target pre- and postgrazing forage masses were 2200 and 1100 kg DM ha^{-1}, respectively. Linear regressions and correlations were calculated relating meter and sward stick readings to forage ash-free organic matter mass measured by cutting quadrats of forage at ground level.

Mean coefficients of variation for quadrat, capacitance meter, sward stick, and rising plate were 28.8, 15.5, 27.2, and 27.9%, respectively, for pregrazing forage mass measurements, and 20.2, 10.1, 21.4, and 18.4%, respectively, for postgrazing measurements. These coefficients indicate that the capacitance meter was a more precise way for estimating pre- and postgrazing forage mass than the other three methods. Correlation coefficients relating cut quadrats to capacitance meter, sward stick, and rising plate readings were 0.65, 0.70, and 0.72 for pregrazing, and 0.36, 0.31, and 0.05 for postgrazing forage mass measurements, respectively. Correlation coefficients relating capacitance meter to sward stick and rising plate were 0.79 and

0.80 for pregrazing, and 0.67 and 0.49 for postgrazing measurements, respectively.

The nondestructive methods, particularly the capacitance meter, provided quick forage mass estimates at a level of precision adequate for making day-to-day grazing management decisions on farms.

Introduction

One of the most difficult problems in managing livestock feeding on pasture lies in accurately estimating how much herbage mass is present before and after grazing. These amounts need to be measured so that forage allowance and dry matter intake (net forage production) can be estimated to achieve optimum use of pasture forage in rations balanced with in-barn fed supplements. This problem is especially serious when feeding high-producing lactating dairy cows on complex swards that provide opportunities for significant selective grazing and forage waste, both of which result in sward structure and composition deterioration and lower net forage production or utilization (Korte *et al.*, 1987).

Indirect nondestructive methods for quickly estimating standing herbage mass in grazed swards can be useful for farmers and pasture researchers to manage grazing well (Frame, 1981). Pasture meters, such as the single-probe capacitance meter (Vickery and Nicol, 1982) and weighted disc or rising plate meter (Bransby *et al.*, 1977; Michalk and Herbert, 1977; Michell, 1982; Michell and Large, 1983; Varth and Matches, 1977), and the Hill Farming Research Organization (HFRO) sward stick (Hutchings, 1991; Rhodes, 1981) have provided useful results with N-fertilized monocultures of perennial ryegrass (*Lolium perenne)* and tall fescue (*Festuca arundinacea)*, and with perennial ryegrass-white clover (*Trifolium repens)* swards. Very little information exists, however, about their use on North American complex grass-legume swards grazed under controlled rotational management with paddocks, recovery periods that vary according to plant regrowth, high stocking densities, and short grazing periods. This study was done to improve understanding of techniques for measuring forage mass under such management with cattle and/or sheep grazing of low-input (no N fertilizer), complex natural swards dominated by Kentucky bluegrass (smooth-stalked meadowgrass, *Poa pratensis*) and based on white clover, so that objective guidelines for management can be provided to farmers.

Materials and methods

Details of sward culture

This study was done during 1989 and 1990 on a complex natural sward that had been grazed rotationally only by sheep during the latter half of 1987 and all of 1988. A uniform sward resulted that was composed of 81% grass, 9% white clover, and 10% forbs. Kentucky bluegrass comprised 70% of the grass. Other grasses present were orchardgrass (*Dactylis glomerata*, 20% of the grass), timothy (*Phleum pratensis* , 5%), and quackgrass (*Agropyron repens* , 5%). The forbs were dandelion (*Taraxacum officinale*, 5%) and chicory (*Cichorium intybus*, 5%). Inoculated white clover seed cv. 'Grasslands Huia' was surface-broadcast at the rate of 5 kg ha^{-1} in all treatments on 5 April 1989.

Experimental design

Treatments were: cattle (18-month-old Holstein heifers) grazing alone, cattle followed by clipping with a rotary mower to 2.5 cm from the soil surface, cattle followed by sheep, and sheep grazing alone. When paddocks accumulated a mean target forage mass of 2200 kg DM ha^{-1}, animals were allowed to graze. Animals were removed from paddocks at a target forage mass residual of 1000 to 1100 kg DM ha^{-1}.

The experimental site was on a Winooski very fine sandy loam (coarse-silty, mixed, mesic, Aquic Fluventic Dystrochrept) near Colchester, Vermont. The design was a randomized complete block, replicated three times.

Treatments were grazed simultaneously within each replicate, which were grazed in succession. Thirteen 2-year-old Holstein heifers and 120 sheep consisting of ewes, lambs, and yearlings of various breeds were used to graze treatments. Paddock sizes were 0.16 ha for cattle-grazed areas, 0.05 ha for sheep following cattle, and 0.08 ha for sheep grazing alone. Stocking densities were approximately 80 animal units (AU) ha^{-1} each for cattle and sheep, and 130 AU ha^{-1} for sheep following cattle. A higher stocking density of sheep following cattle was used so that sheep would eat forage that had been rejected by cattle quickly without having time to select for white clover. These stocking densities were chosen to represent average stocking densities currently being applied by dairy farmers. Grazing periods were 24 hours per paddock, except for sheep following cattle, when sheep grazed for 1 hour. Grazing began on 15 May and ended on 21 September in 1989, and began on 20 May and ended on 25 September in 1990.

Pre- and postgrazing forage mass was estimated with a single-probe electronic capacitance meter (Design Electronics Pasture Probe; Vickery and Nicol, 1982), the HFRO sward stick (Bircham, 1981), a weighted disc or rising plate meter developed by Rayburn (1991), and forage quadrats cut at ground level.

At least thirty capacitance meter measurements were made of the sward in actively grazed areas of each treatment before and after grazing (Boswell, 1986). Measurements also were made with the capacitance meter near the end of grazing each treatment to determine when to remove animals from paddocks. Then one (1989) or two (1990) sites containing the mean amount of forage dry matter (DM) ha^{-1} (as determined by the thirty capacitance readings) were located in each treatment paddock with the capacitance meter. At each site, ten capacitance meter, ten sward stick, and one rising plate measurements were made before clipping a quadrat of forage to ground level. Pregrazing quadrats were 0.1- x 1.0-m, cut with rechargeable 10-cm wide trimmers. Because of the difficulty of retrieving short plant pieces, postgrazing quadrats were cut with a knife within a 10-cm square quadrat in 1989, and with a 10.5-cm inside-diameter golf hole cutter in 1990. The turves were removed, tipped sideways over a receptacle, and cut at ground level with a scissors. Quadrat samples were dried at 55 C, weighed, and ashed at 600 C for 2 hours (Jones, 1984) to remove soil contamination.

The rising plate used was constructed of inexpensive readily available materials. It was a 45.7-cm square of 0.6-cm thick acrylic plastic, which exerted a downward pressure of 7.0 kg m^{-2}. The plate had a 3.8-cm diameter hole in the center to allow the insertion of a ruler for measuring compressed sward surface height, by reading across the top of the plate. The plate was carried by the ruler, which had a 0.6- x 5-cm bolt attached through a hole in the end of the ruler below the plate. At each site the plate was lowered slowly into position so that speed of movement would not add to downward pressure.

Correlations and linear regressions (y=a+bx) were calculated relating meter and sward stick readings to quadrat measurements and to each other, across all treatments and sampling dates of the five rotations in both years.

Results

Mean coefficients of variation for quadrat, capacitance meter, sward stick, and rising plate were 28.8, 15.5, 27.2, and 27.9%, respectively, for pregrazing measurements of forage mass, and 20.2, 10.1, 21.4, and 18.4%, respectively, for postgrazing measurements. These coefficients indicate that the capacitance meter was a more precise way for estimating pre- and postgrazing forage mass than the other three methods. This agrees with Geenty and Rattray (1987), who reported that the large pasture forage sampling errors due to inherent sward variations can be minimized by using a capacitance meter instead of cutting quadrats to estimate forage mass.

Correlation coefficients relating pre- and postgrazing forage mass measurements of cut quadrats to capacitance meter, sward stick, and rising plate readings were lower than coefficients relating capacitance meter measurements to sward stick and rising plate readings (Table 1).

Discussion

Available techniques for estimating forage mass all have varying degrees of problems, especially with complex grass-legume swards such as those that are common on pastureland in the northcentral and northeastern United States. The more well developed (a result of adequate time under appropriate grazing management), closely grazed, and uniform the sward is, the better all of the techniques estimate forage mass. Because of a problem of estimating postgrazing trampled forage mass, Stockdale and Kelly (1984) concluded that cutting quadrats was the best alternative for estimating forage mass in dairy research. In practice on the farm, however, it is very unlikely that farmers will cut quadrats to estimate forage mass. The method is too time consuming, and does not provide the timely results needed for day-to-day management decisions. In contrast, the nondestructive methods, particularly the capacitance meter, provided quick forage mass estimates at a level of precision that was adequate for making grazing management decisions on farms.

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Table 1. Regressions (y=a+bx) and correlations (r) relating pre- and postgrazing 1) quadrat-measured forage mass y (kg DM ha^{-1}) with a single-probe capacitance meter, rising plate, and sward stick readings; and 2) capacitance meter-measured forage mass y with rising plate and sward stick readings of a complex grass-white clover sward grazed by cattle and/or sheep in Vermont, USA during. 1989-1990 (N = 120).

Relationship	y=a+bx	r	Range of x
Pregrazing			
Quadrat and capacitance meter	-313.6 +0.9x	0.65	1575-3401kg DM ha^{-1}
Quadrat and sward stick	398.1 + 71.6x	0.70	7.6-27.6 cm
Quadrat and rising plate	392.9 + 317.8x	0.72	3.3-18.8 cm
Capacitance meter and sward stick	1285.4 + 65.9x	0.79	7.6-27.6 cm
Capacitance meter and rising plate	1302.6 + 286.3x	0.80	3.3-18.8 cm
Postgrazing			
Quadrat and capacitance meter	369.1 + 0.89x	0.36	855-1410 kg DM ha^{-1}
Quadrat and sward stick	931.8 + 79.9x	0.31	2.4-7.4 cm
Quadrat and rising plate	1237.6 + 53.4x	0.05	2.5-5.3 cm
Capacitance meter and sward stick	812.3 + 78.1x	0.67	2.4-7.4 cm
Capacitance meter and rising plate	869.0 + 221.8x	0.49	2.5-5.3 cm

Vermont Grazing Conference
July 14 &15, 1993

Are you tired of cash flows that leave little money in your pocket? If you're feeding livestock in confinement rather than on pasture, you're working too hard and spending too much money. You can improve your farm's profit margin and reduce your work load now, by making full use of pasture to cut feeding costs. Your pasture is a valuable resource that until now has been wasted. Forget about how pastures are! Think of how they could be if they were managed with the same level of technical know-how that you apply to other crops. This Vermont Grazing Conference will give you the answers you need.

Conference sponsored by American Farmland Trust, Shelburne Farms, Stockman Grass Farmer, University of Vermont Department of Plant and Soil Science, University of Vermont/Kellogg Foundation Environmental Programs in Communities (EPIC) Project, and University of Vermont Sustainable Agriculture Initiative.

VERMONT GRAZING CONFERENCE

Grazing Conference Agenda

July 14, 1993
Coach Barn, Shelburne Farms, Shelburne, VT

9:00 - 9:30	Registration
9:30 - 10:00	Welcome, Jean Richardson, Director, *University of Vermont/Kellogg Foundation Environmental Programs in Communities (EPIC) Project.*
10:00 - 11:00	Introduction to Grass Farming, Allan Nation, Editor, *The Stockman Grass Farmer.*
11:00 - 11:45	Rational (Controlled) Grazing: Realizing the Potential, Bill Murphy, Professor/Farmer, *University of Vermont Plant & Soil Science Department.*
11:45 - 12:30	Meeting the Nutritional Needs of Dairy Cows Under Rational Grazing, Tom Noyes, Dairy Industry Extension Agent/Farmer, *Ohio State University.*
12:30 - 1:30	Lunch
1:30 - 2:30	Quick and Easy Milking with Proper Parlor or Tie-Stall Design, Alan Henning, *International Consultant to Graziers.*
2:30 - 3:15	Seasonal Dairying: Advantages/Disadvantages, David Zartman, Professor & Chairperson, *Ohio State University Dairy Science Department.*
3:15 - 4:00	Pasture User Discussion Groups: Together We Can Do It! Lisa McCrory and Joshua Silman, Grazing Consultants, *EPIC Pasture Management Outreach.*
4:00 - 6:00	Farm Walk: Shelburne Farms, Brown Swiss Farm Gordon Searles, Farm Manager, *Shelburne Farms*
6:00 - ?	Cookout and Champ Watch overlooking Lake Champlain at Shelburne Farms

July 15
Farm Walks

9:30 - 10:00	Bus from Burlington to Fairfax
10:00 - 12:30	Mike & Tammy Hanson Holstein Farm
12:30 - 2:00	Bus to East Montpelier (box lunch on bus)
2:00 - 4:30	Brian Stone Seasonal Milking Jersey Farm
4:30 - 5:30	Bus to Burlington

Jean Richardson has traveled the world over as a Kellogg Foundation Fellow and Consultant. She directs the University of Vermont/Kellogg Foundation Environmental Programs In Communities Project (EPIC). The EPIC Project is made up of several different programs that are working together to create positive change in Vermont, and to provide models and ideas for other parts of the United States. EPIC is providing Vermonters with resources, technical assistance, and grant money to help make a long-term difference in our communities. Jean will challenge us all to reach beyond what we think is possible.

Allan Nation is the Editor of the *Stockman Grass Farmer* a major driving and facilitating force for the Grass Farming Revolution that is occurring in America. He has traveled extensively to study grassland agriculture in North and South America, Europe, and New Zealand. Allan will share his wealth of experience in showing you how to make money and live a good life with grass farming.

Bill Murphy researches and teaches anything about rational grazing that might help farmers use pasture to their best advantage. He raises dairy heifers on pasture grains without grain supplements on a 25-acre farm, where his first use of Andre Voisin's ideas 12 years ago resulted in his book on pasture management for farmers, *Greener Pastures On Your Side Of The Fence*. Bill will talk about quality-of-life, social, and environmental reasons why we should use the pasture resource better and more on how to do it.

David Zartman did the first research in the United State that showed the potential profitability and quality-of-life benefits of seasonal dairying on pasture. He has developed an enterprise analysis computer program that enables dairy farmers to analyze their operations, profit effect of changes, and plan for the greatest profitability. David will outline the pros and cons of seasonal dairying and show how everyone can win with it.

Tom Noyes operates his own dairy farm and has worked for years as an Extension Agent helping farmers feed cows at least cost in Wayne County, Ohio's No. 1 dairying county. Tom will tell you how to complement high quality pasture forage with concentrates for greatest profitability.

Alan Henning has over 15 years experience developing and managing dairy farms in New Zealand. He has designed and built herringbone cowsheds, worked with all aspects of pasture development and management, invented a simple low-cost system of rearing hundreds of calves, and milked herds of 80 to 450 cows. Alan will tell you how one person can milk at least 100 cows per hour with the appropriate milking equipment and milking parlor or tie-stall design.

Lisa McCrory survived on-farm pasture management graduate student research under rational grazing with high-producing Jersey and Holstein cows! Joshua Silman has helped to do rational grazing on-farm research for 5 years! Lisa and Joshua are very successfully assisting farmers in the first Pasture Management Outreach Program in the United States that uses the new Zealand concept of Pasture User Support Groups. They will talk about how the program is organized, what it involves, and its importance to farmers.

Mike and Tammy Hanson have a 65-cow herd of Holsteins that they began feeding under rational grazing management in April 1992. The Hanson's farm profitability increased 32% from feeding cows on pasture during 6 months, and barn chore time decreased 45% during the grazing season. Farm machinery was used so little during the grazing season that grass died under a big tractor! Mike will talk about what switching to pasture feeding has meant for them, showing that increased farm profitability <u>and</u> reduced labor requirements are absolutely essential for sustainable, family dairy farming.

Brian Stone is now in his second year of seasonally milking his 45-cow Jersey herd on rationally managed pasture. With seasonal dairying on pasture, Brian is making milk as cheaply as he can, while reducing his work load. Brain will tell you how he changed spring-calving seasonal dairying, and how he makes it work. He'll also tell you why he won't go back to milking cows 12 months a year.

Gordon Searles has been rotationally grazing the Brown Swiss herd at Shelburne Farms for over 10 years. During this period the herd has been recognized as one of the highest producing Swiss herds in the country. Gordon has traveled to Europe and New Zealand studying grass based dairying and has recently decided to switch the Shelburne Farms' herd to all spring calving. He will take you on a walking tour of the farm's pastures and share his experiences with you.

RESERVATIONS

Space is limited: reserve early!

Conference attendance fee is $20 per person or per farm. Lunch is $7.00/person. Cookout is $11/person. Bus is $10/person. If lunch, cookout and/or bus travel is desired, reservation and payment must be made by July 7.

Name______________________________Phone____________________

Address____

City________________________State/Province____________ Zip___________

July 14: No. of reservations _______ @ $20/person (or per farm) ________

Lunch: No. of people ______ @ $7.00 __________

Cookout: No. of people _____ @ $11.00 ________

July 15: No. of bus travelers ______ @ $10/person

Box lunch: No. of people _____ @ $7.00 ________

Total enclosed ___________

(Check payable to the University of Vermont)

Mail to: EPIC Pasture Management Outreach • Department of Plant & Soil Science • University of Vermont • Burlington, VT 05405-0082

For more information call (802) 656-0641, fax (802) 656-4656.

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Agricultural Systems: forthcoming.

An Economic and Environmental Assessment of Alternative Forage-Resource Production Systems: A Goal-Programming Approach

by

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An Economic and Environmental Assessment of Alternative Forage-Resource Production Systems: A Goal-Programming Approach

ABSTRACT

Decision-making involves several criteria, something not always reflected in models. In this study, profitability, risk and environmental criteria are simultaneously used to rank alternative forage-resource production systems. Experimental data for West Virginia beef cow/calf production are used together with secondary price data within a binary goal-programming model. Utilizing the branch-and-bound algorithm, the optimal system under each of twenty-one goal and penalty weight scenarios is obtained. An interesting, although not unexpected, result is that while the optimal system is relatively "parameter-insensitive" it is "criteria-sensitive."

Key words: multiple criteria, sustainability, forage-resource systems, goal programming

INTRODUCTION

Studies comparing producer decision-making alternatives often rely exclusively on a single criterion such as profits or risk. Yet, it is increasingly clear that additional factors, in particular, potential environmental impacts associated with alternative courses of action, are becoming more important in public and private decision-making. Thus, not only is there a need to consider these factors together with traditional criteria such as profits and risk, but also to consider them simultaneously. Recognizing this, we undertook a study comparing alternative forage-resource production systems based on profitability, risk and environmental criteria, within a framework known as "multiple-criteria decision-making" (MCDM). MCDM is a form of mathematical programming that incorporates multiple objectives within an optimizational framework to allow for a more realistic approach to decision-making problems (Romero and Rehman, 1989).

Despite the intuitive appeal of modeling within an MCDM framework, applications have been limited. Wheeler and Russell (1977), for example, used "goal programming" (an MCDM procedure described below) to assess alternative agricultural planning processes. Brink and McCarl (1978), employed goal programming to evaluate the tradeoffs between expected returns and risk among U.S. Corn Belt farmers. Barnett et al. (1982), utilized goal programming to evaluate the "aspiration levels" of Senegalese farmers. Finally, Rehman and Romero (1987) employed MCDM to formulate least-cost livestock rations.

While previous MCDM studies have integrated diverse objectives (e.g., profits, risk, production, social) within models, applications involving environmental impacts within the MCDM framework have not been observed. By including environmental impacts, this study departs from traditional MCDM applications.

Our objectives are to determine the profitability, risk and environmental impacts of alternative forage-resource production systems for beef cow/calf production, and to identify the optimal system based on these criteria. Seven management systems, comprised of various pasture and meadow management combinations, are specified for beef cow/calf production (Table 1). The production data are from an experimental site in West Virginia (WV), and are documented in Baker, *et al.* (1988) and Flaherty (1992). WV is particularly suited to the analysis for the following reasons: (a) it is a state where producers are confronted with high feed costs (U.S. Department of Agriculture, 1990), a reason being the hilly terrain characteristic of much of the state; (b) a relatively high degree of risk-aversion exists on the part of producers with regard to adoption of alternative systems (Fox *et al.*, 1991); and (c) environmental impacts in the form of pasture soil erosion are among the highest in the U.S. (Iowa State University, 1989). While the production data used in this study are site-specific, the approach and results have implications for other regions.

METHODOLOGY

A goal programming (GP) model was constructed to evaluate the profitability, risk and environmental impacts (the "goals") of the production systems. In general, the solution to a GP problem is comprised of the optimal level of activities based on satisfying concurrent goals. To arrive at this solution, deviations from the desired goals need to be minimized. Two procedures can be used to accomplish this: weighted goal programming (WGP) and lexicographic goal programming (LGP). WGP is based on attaching weights to the deviations of the goals ("penalty weights") and simultaneously minimizing these deviations. On the other hand, the LGP procedure attaches weights directly to - or prioritizes - the goals. Then, the deviations from the goals are minimized according to the order of priorities. The WGP procedure is used in this study.

A WGP model is constructed based on the following formulation (Hillier and Lieberman, 1980):

$$Minimize\ Z=\sum_{k=1}^{K}(W_k^+ y_k^+ + W_k^- y_k^-), \tag{1}$$

subject to

$$\sum_{j=1}^{n} c_{j_k} x_j-(y_k^+ - y_k^-)=g_k, \quad for\ k=1,2,\ldots,K \tag{2}$$

and

$$y_k^+ \geq 0, y_k^- \geq 0, x_j \geq 0 \quad (j=1,2,\ldots,n) \tag{3}$$

where

Z = the weighted sum of deviations between the individual objective functions and their corresponding goals;

y_k^+ = the auxiliary variable for exceeding the goals;

y_k^- = the auxiliary variable for under achieving the goals;

W_k^+ = the penalty weight for exceeding the goals;

W_K^- = the penalty weight for under achieving the goals;

x_j = the activity (forage-resource system or technology), j = 1, 2, 3, ..., 7;

c_{jk} = the activity's contribution to each goal; and

g_k = the individual goals, k = 1, 2, 3, corresponding to the profit, risk, and environmental goals, respectively.

The decision variables, x_j, in the model are assumed to be mutually exclusive, i.e., the decision maker is limited to selecting only one of the seven management systems depicted in Table 1. Given the type of systems, this is a realistic assumption. Thus, the model now becomes an "integer" goal programming problem and the decision variables become binary, 0 or 1, with just one system being selected from among the seven that are specified. This can be established by adding two conditions to the model and using an integer algorithm to obtain the solution. The conditions are represented as:

x_j = 1, if decision j is yes, and 0 if decision j is no

and

$$\sum_{j=1}^{n} x_j = 1. \qquad (4)$$

The model can be represented in matrix form as:

$$\begin{array}{cccccccccccccc}
0 & 0 & 0 & 0 & 0 & 0 & 0 & W_1 & 0 & 0 & W_2 & W_3 & 0 & = Z \\
c_{11}x_1 & c_{21}x_2 & c_{31}x_3 & c_{41}x_4 & c_{51}x_5 & c_{61}x_6 & c_{71}x_7 & -y_1 & y_1 & 0 & 0 & 0 & 0 & = g_1 \\
c_{12}x_1 & c_{22}x_2 & c_{32}x_3 & c_{42}x_4 & c_{52}x_5 & c_{62}x_6 & c_{72}x_7 & 0 & 0 & -y_2 & y_2 & 0 & 0 & = g_2 \\
c_{13}x_1 & c_{23}x_2 & c_{33}x_3 & c_{43}x_4 & c_{53}x_5 & c_{63}x_6 & c_{73}x_7 & 0 & 0 & 0 & 0 & -y_3 & y_3 & = g_3 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & = 1
\end{array}$$

where the notation is as previously defined.

(Note: row 1 above represents the weighted goal programming model objective function. The latter is specified to minimize the weighted sum of deviations between the individual objective functions and their corresponding goals. Since the individual activities (management systems) themselves are not included in the objective function, their corresponding objective function coefficients equal zero).

Management systems, decision variables, and goals

Seven management systems were selected for evaluation. These systems, outlined in Table 1, range from conventional systems, such as continuously grazed pastures with legume-grass meadows, to innovative or more intensive production systems, comprising rotational grazing of pastures and extended fall grazing on meadows for example. A given system consists of producing cows (15% of which are two-year-old replacement heifers) and mature bulls (one per 25 producing cows), involves a 205-day weaning period for calves, and assumes that 40% of yearling heifers are kept for replacements. Animal nutrient requirements were based on National Research Council (1984) guidelines. Figure 1 shows the annual animal-forage distribution for each system. Summer grazing constitutes a 153-day period from May 6 to October 6. Winter feeding periods vary across systems due to variations in fall grazing capabilities.

The decision confronting a decision-maker is which of the seven management systems (the "decision variables") to select for beef cow/calf production. Three goals are assumed to influence this decision. They are profits, risk, and an environmental goal. Profits are measured as returns above all operating costs. Risk represents the variability of profits, and is measured as the coefficient of variation (CV) of profits. Soil loss, measured in tons per hectare per year, is used to represent the environmental impact of the management systems. Differences in profit, risk and soil loss among systems are caused by factors such as forage production, carrying capacity, calf prices, and length of slope. The optimal system is one that simultaneously maximizes profits, minimizes risk, and minimizes soil loss, and is determined by the GP model.

DATA AND ESTIMATION

The data representing the marginal contributions (c_{jk}) of the three goals specified in the model, namely profit, risk, and soil loss, are presented in Table 2. An examination of these values reveals that no system is optimal in terms of all three criteria. Therefore, the next step is to use the GP model to determine the optimal system.

Three goal scenarios are specified as part of the analysis: A, B, and C. A is the base scenario; B and C each represents a sensitivity analysis of the base scenario. The average revenue above operating cost per hectare for WV for 1990 (WV Department of Agriculture, 1991) was used to obtain the profit goal of $173/ha. for the base scenario. The median CV for profit was used to obtain the base scenario CV goal of 0.615. The average annual soil erosion rate for class I-III land for the period 1982 through 1987 as identified by the National Resources Inventory (NRI) was 3.26 tons/ha (Iowa State University, 1989). Since this land classification range emulates that found at the experimental plots from which the production data were obtained, a soil loss goal of 3.26 tons/ha was used in the base scenario. These base scenario goals are subsequently increased and decreased by 30% for the goal sensitivity analysis, with the corresponding numerical values summarized in Table 3.

Penalty weights are subjective measurements of value that the decision maker places on not reaching the targeted goals. Ideally, these rankings would be available in cardinal measurement to represent the preferences of decision makers. Since this information is not available, an ordinal measuring method was used to establish the penalty weights. Penalty weights of 1, 3, and 5 were arbitrarily selected, but used under all seven possible permutations or "penalty weight scenarios" (Table 3). The use of alternative penalty weights and goal scenarios should preclude any trade-off restrictions which might occur from the ordinal penalty weight structure of the model (Romero and Rehman, 1989).

Additional data required for the model included production data for each of the seven systems that were evaluated. Data pertaining to meadow dry-matter production, animal stocking rates, and calf production, were obtained from experimental plots in North Central WV. These data, together with price data from secondary sources (U.S. Department of Agriculture, 1990; WV Department of Agriculture, 1991; and Cattle Fax[1]), were used to compute the value of profit for each system. Soil loss for each system was estimated using the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). The monetary value of off-farm erosion damage was then estimated based on this value and a unit monetary value obtained from a previous study (Ribaudo, 1989).

The "branch-and-bound"algorithm (Greenberg, 1971) is used in estimation.[2] The computer software package, LINDO (version 4.0, Schrage, 1987) which utilizes this algorithm to solve integer problems such as this, was used.

A summary of the analytical procedure is presented in Figure 2.

RESULTS

The GP model results, consisting of the optimal choices under the alternative scenarios, are presented in Table 4. As indicated previously, these scenarios refer to alternative combinations of penalty weights and goals. For example, scenario 2A can be interpreted as a composite of penalty weight scenario 2 and goal scenario A (numerical values for which are contained in Table 3);

scenario 6B is likewise a composite of penalty weight scenario 6 and goal scenario B; and so on. System VI, based on rotational pasture grazing and extended fall-season meadow grazing with nitrogen, is the optimal forage- resource management system when profitability, risk and environmental criteria are considered simultaneously, under all but four of the scenarios. For these latter scenarios (1C, 2C, 3C, and 7C), system II, based on rotational pasture grazing and legume-grass meadow, is optimal. In general, the results show that system VI is optimal across all penalty weight and goal conditions other than when there is less penalty weight for risk and the goals are numerically low.

The results, in general, are different - or, at least not as unequivocal - if either only a single criterion or a set of any two criteria are represented in the model. For example, given differences in factors such as dry matter production, stocking rate and length of grazing season among different systems, systems VI and VII dominate in terms of profit; systems V and VI dominate in terms of risk; and systems II and IV dominate in terms of environmental characteristics. While system VI dominates if profit and risk are the only criteria used, systems II, IV and VI dominate if profit and soil loss are used as the only criteria. Such results are further justification for using the MCDM framework in modeling decision-making alternatives.

The weighted deviations presented in Table 4 represent the objective function value, which is the sum of the weighted deviations from the goals. Since penalty weight scenario #7 does not attach penalties for not achieving any of the goals, the value of the weighted deviation is zero.

An extension of this analysis was to extrapolate the results to quantify aggregate impacts within an appropriate Soil Conservation Service-defined "land resource area" (LRA) in WV (LRA-127) (U.S. Department of Agriculture, 1979). An LRA is defined by the Soil Conservation Service as an area of land reasonably alike in its relationship to agriculture, with emphasis on combinations and/or intensities of problems in soil and water conservation; thus, LRAs are useful in delineating land to enable comparisons of productivity and potential for soil erosion, for example. Assuming that most of the pasture land in LRA-127 is conventionally grazed, if an alternative forage-resource management system, i.e., the optimal system as identified earlier (system VI), is adopted instead, the aggregate impacts for this LRA are as follows: soil loss would be reduced by over 12,000 tons per year (for an area covering 49,000 ha.), and net benefits to producers and society (i.e., taking into consideration the reduction in soil loss as a result of the alternative system), would increase by almost $4 million per year. It should be noted that such results are for illustration only. Actual impacts would depend on factors such as the number of producers - and acres - that shifted to the "more sustainable" alternative system.

CONCLUSIONS

Studies comparing producer decision-making alternatives often rely exclusively on a single criterion such as profits or risk. Yet, it is increasingly clear that additional factors such as potential environmental impacts associated with alternative courses of action are becoming more important in public and private decision-making. The objective of this study was to use profitability, risk and environmental criteria simultaneously to evaluate alternative forage-resource production systems. This was accomplished within the "multiple-criteria decision- making" framework. Experimental production data for seven forage production systems for beef cow/calf production in West Virginia were combined with secondary price data within a goal programming model that was developed.

Results indicate that a system involving rotational pasture grazing and extended fall-season meadow grazing with nitrogen application is optimal in terms of profit, risk and environmental criteria. This result was relatively insensitive to changes in the parameters, which in this case are the magnitude of the goals (one goal each for profit, risk and soil loss) and penalty weights (penalties defined within the model for deviating from each of the goals). However, as one might expect, the results are "criteria-sensitive," which, of course, is further justification for using the

MCDM framework in modeling decision-making alternatives. Major factors influencing profit, risk and soil erosion of individual systems - and therefore causing differences in these values among systems - are dry matter production, carrying capacity, calf prices, length of grazing season, and length and steepness of slope.

Recognizing the existence of multiple objectives, as well as the underlying constraints, and modeling accordingly could benefit decision makers in selecting an alternative course of action - or on incentives for policy makers to offer - to ameliorate negative environmental externalities. Thus, an implication of this study is that by including multiple objectives - which in reality characterizes most decision-making processes - economic models can yield more robust results and improve the quality of decision-making.

Finally, it should be noted that even though an MCDM approach can produce superior results compared to a single-criterion approach, it also has limitations. One such limitation encountered in this study, and one that future similar studies can aim to overcome, is to find a more precise way to quantify the goals and penalty weights within the model.

Notes:

1. Cattle Fax is a non-profit organization located in Denver, CO, providing regional cattle marketing information for the U.S.

2. For larger problems, alternative algorithms such as the "Pivot and Compliment" method (demonstrated, for example, for the GAMS/ZOOM computer program by Brooke et al., 1988) would be needed.

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Table 1: Description of Individual Forage-Resource Production Systems (x_j) for Beef Cow/Calf Production.

System	Description[a]
I	continuously grazed pastures, legume-grass meadows
II	rotationally grazed pastures, legume-grass meadows
III	continuously grazed pastures, nitrogen application to meadows
IV	rotationally grazed pastures, nitrogen application to meadows
V	continuously grazed pastures, extended fall grazing on meadows, nitrogen application to meadows
VI	rotationally grazed pastures, extended fall grazing on meadows, nitrogen application to meadows
VII	continuously grazed pastures with buffer area, nitrogen application to meadows

[a]Further details on these systems can be found in Fiske (1992).

Table 2: Profitability, Risk, and Soil Loss for Each Production System.

System	Profit ($/ha.)	Profit CV	Soil Loss (tons/ha./yr.)
I	116	.76	3.71
II	126	.71	2.97
III	114	.85	3.71
IV	126	.78	2.97
V	193	.41	4.20
VI	217	.38	3.46
VII	163	.59	4.20

Data sources: Baker, et al. (1988) and Flaherty (1992) for production data; U.S. Department of Agriculture (1990) and WV Department of Agriculture (1991) for price data; and Iowa State University (1989) and WV Soil Conservation Service (1989) for soil loss data.

Table 3: Goals (g_k) and Penalty Weights (w_k) for the Goal Programming Model.

	Profit ($/ha.)	Profit CV	Soil Loss (tons/ha./yr.)
Goal Scenarios[a]			
A	173	.615	3.26
B	225	.8	4.20
C	121	.43	2.22
Penalty Weight Scenarios[b]	$W_2(y_2^-)$	$W_1(y_1^+)$	$W_3(y_3^+)$
1	3	1	5
2	5	1	3
3	1	3	5
4	5	3	1
5	1	5	3
6	3	5	1
7	0	0	0

[a]A is the base scenario. B and C represent a sensitivity analysis of the base scenario in which the base scenario goals are respectively increased and decreased by 30%.

[b]Represent alternative combinations of penalty weights.

Table 4: Optimal Production Systems Under Alternative Scenarios.

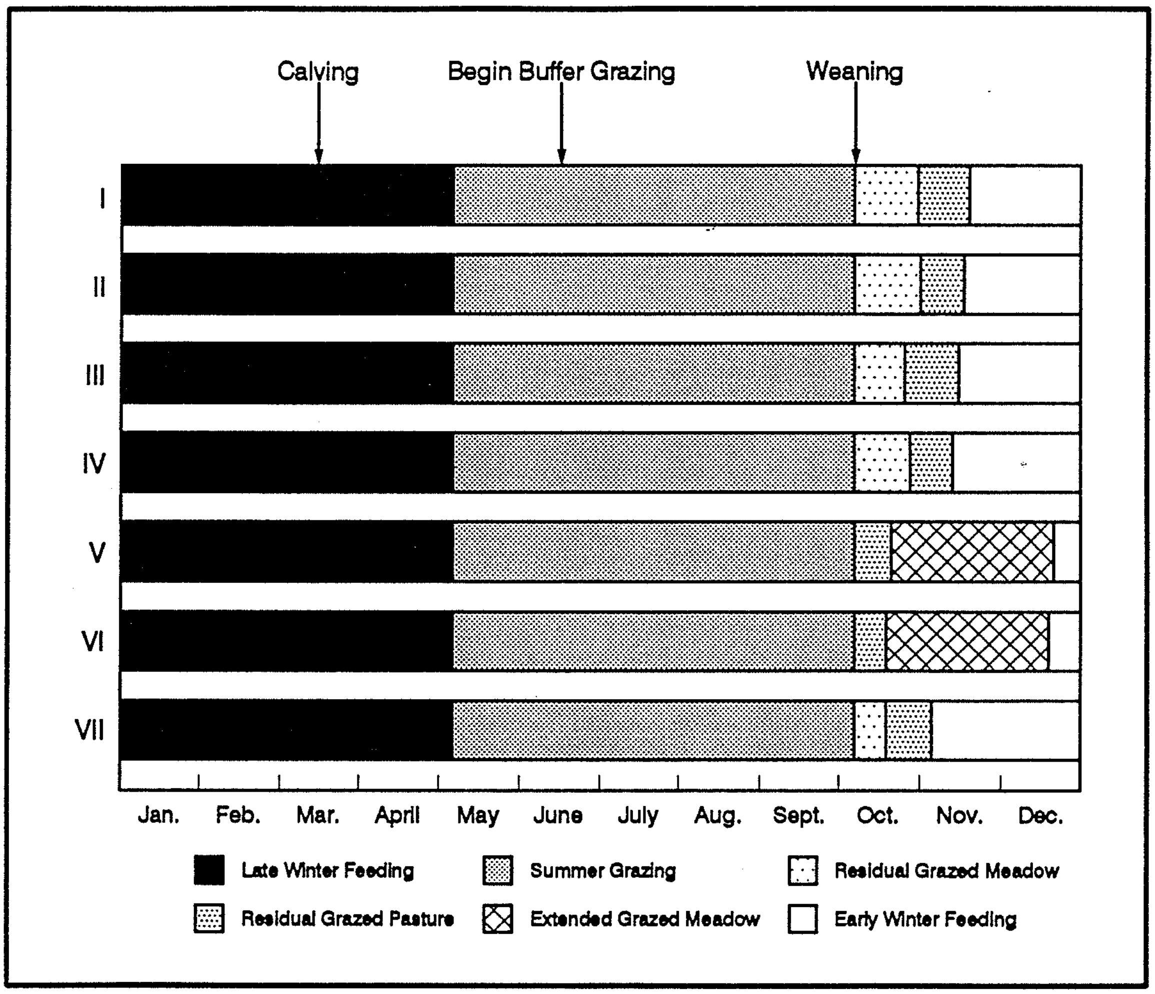
Scenarios[a]	Optimal System	Weighted Deviation
1A	VI	.4
2A	VI	.24
3A	VI	.4
4A	VI	.8
5A	VI	.24
6A	VI	.8
7A	VI	0
1B	VI	9
2B	VI	15
3B	VI	3
4B	VI	15
5B	VI	3
6B	VI	9
7B	VI	0
1C	II	1.8
2C	II	1.2
3C	II	2.3
4C	VI	.5
5C	VI	1.5
6C	VI	.5
7C	II	0

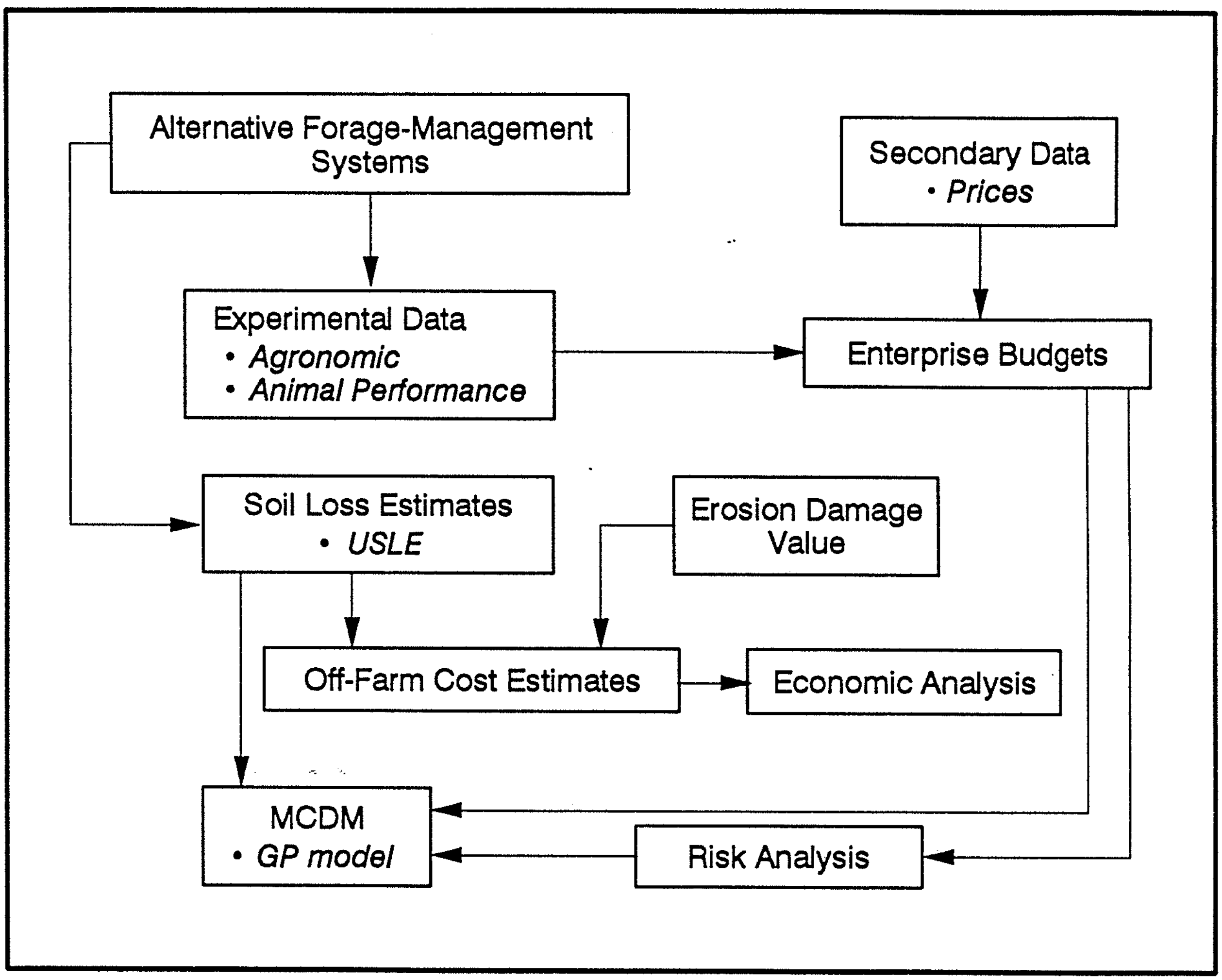
[a]Represent alternative combinations of penalty weight scenarios (#1 to #7 in Table 3) and goal scenarios (A, B, and C in Table 3).

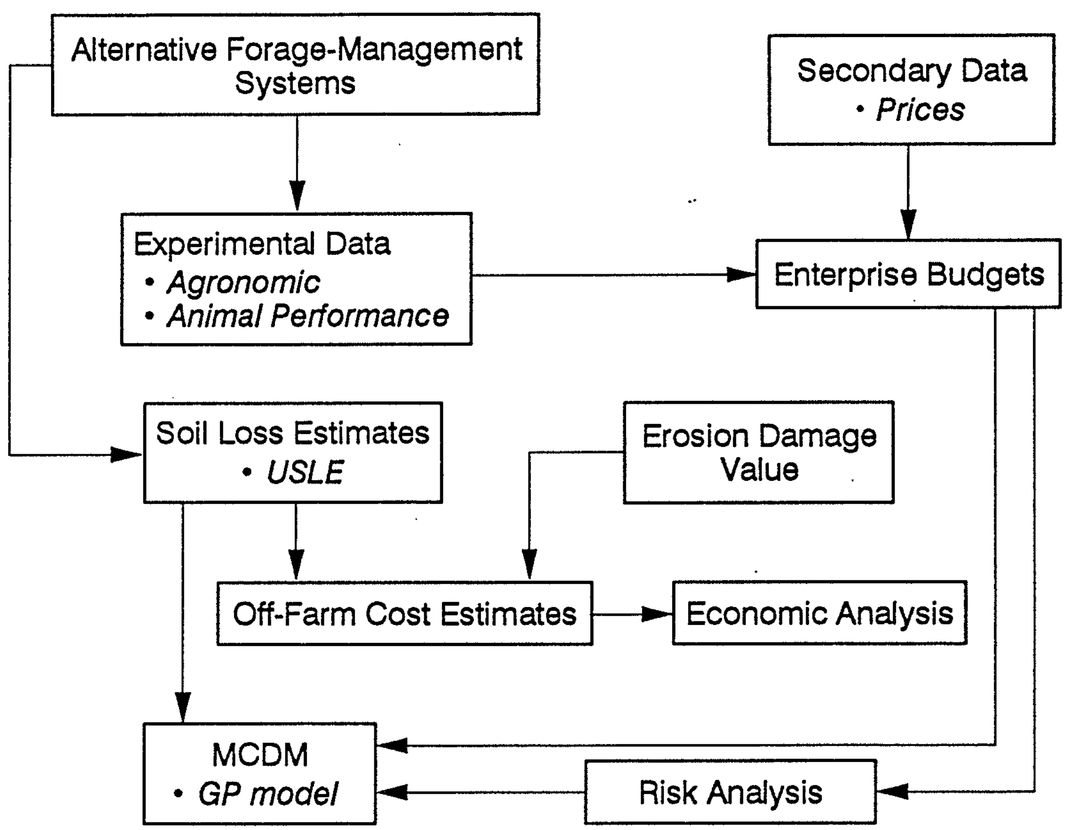
Figure Captions

Figure 1. Annual Forage Distribution for the Alternative Beef Cow/Calf Production Systems.

Figure 2. Flow-Chart of the Beef Cow/Calf Production System Analysis.


Calving
Begin Buffer Grazing
Weaning
I
II
III
IV
V
VI
VII
Jan.
Feb.
Mar.
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Late Winter Feeding
Summer Grazing
Residual Grazed Meadow
Residual Grazed Pasture
Extended Grazed Meadow
Early Winter Feeding


Alternative Forage-Management Systems
Secondary Data
• Prices
Experimental Data
• Agronomic
• Animal Performance
Enterprise Budgets
Soil Loss Estimates
• USLE
Erosion Damage Value
Off-Farm Cost Estimates
Economic Analysis
MCDM
• GP model
Risk Analysis



Alternative Forage-Management Systems
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West Virginia Ag. + For. Exp Stn Ann. Report - 1992

tribute to statewide economic development. Using previously estimated input-output multipliers for the West Virginia economy, we estimate that each $100,000 increase in fish production could, by virtue of its linkages with other sectors of the state economy, increase overall state output and income by as much as $190,000 and $160,000, respectively. We also estimate that each additional job created in the aquaculture production sector could create an additional two jobs in related sectors.

Additional research in progress, in cooperation with individuals from the WVU Extension Service, the W.Va. Department of Agriculture and the University of Delaware, is aimed at achieving a better understanding of the entire aquaculture spectrum in West Virginia, comprising fish production, processing, marketing and consumption. This is being accomplished through a series of mail surveys. Preliminary results from the first of these surveys—a restaurant survey—reveal that on average, approximately 25% of total restaurant food sales is obtained from fresh fish and seafood. The size distribution of restaurants was fairly uniform, with most restaurants reporting annual sales from all items for 1991 of between $500,000 and $1 million per restaurant. Health and taste were consistently ranked as among the most important reasons customers were perceived to select fresh fish and seafood. Price, on the other hand, did not seem to be an important determinant of the purchase decision, indicating the relative insensitivity of fish demand by consumers to price changes (a result borne out by previous research in this area). An implication of our findings is that a marketing or promotional strategy for fish should stress health, nutritional and other qualitative attributes rather than price attributes.

G.E. D'Souza, A. McCauley and A. Vanderpool

An Economic and Environmental Assessment of Alternative Forage-Resource Management Systems

Studies comparing producer decision-making alternatives often rely exclusively on a single criterion such as profit or risk. Yet, it is increasingly clear that additional factors such as potential environmental impacts associated with alternative courses of action are becoming more important in public and private decision-making. Thus, not only is there a need to consider these factors together with traditional criteria such as profitability and risk, but also to consider them simultaneously within a framework referred to as "multiple-criteria decision-making" (MCDM). Recognizing this, researchers at WVU undertook a study comparing alternative forage-resource management systems based on profitability, risk and environmental criteria. Soil loss was used in this study to represent the environmental impact. Experimental data were obtained for seven forage-resource management systems for beef cow/calf production in West Virginia. These data, together with price data from secondary sources, comprised the input into a goal programming model developed for the study.

Results indicate that, of the seven resource management systems evaluated, a system involving rotational, summer grazing of pasture and extended, fall grazing of meadow is optimal in terms of profit, risk and environmental criteria. This result was relatively insensitive to changes in the parameters, which in this case are the values of the individual objectives (profit, risk and soil loss) and the penalty weights (penalties defined within the model for deviating from each of the objectives). However, the results *are* criteria-sensitive, i.e., the results are different if either only a single criterion or a set of any two criteria are represented in the model. This is further justification for using the MCDM framework in modeling decision-making alternatives.

An extension of this analysis was to extrapolate the results to quantify aggregate impacts within an appropriate Soil Conservation Service–defined "land resource area" in West Virginia (LRA 127). Assuming that most of the pasture in this LRA is conventionally grazed, if an alternative forage-resource management system, i.e., the optimal system as identified earlier, is used instead, the aggregate impacts are as follows: soil loss would be reduced by over 12,000 tons per year (for an area covering 122,000 acres) and net benefits to producers and society (i.e., taking into consideration the reduction in soil loss as a result of the alternative system) would increase by almost $4 million per year. It should be noted that such results are for illustration only. Actual impacts would depend on factors such as the number of producers and acres that shifted to the more sustainable, alternative system.

This framework can be used to evaluate other systems in other areas. Ultimately, Extension agents can use the information obtained to help producers meet environmental standards while at the same time maximizing their profits subject to risk or other constraints.

G.E. D'Souza, W.A. Fiske, J.J. Fletcher, T.T. Phipps, W.B. Bryan and E.C. Prigge

Factors Affecting Farmland Values in West Virginia

The market for farmland in West Virginia is heterogeneous, with only 22% of the state's land in farms, but with about 75% in large forested areas and affected by mineral developments, as well as by out-of-state urban impacts on land use and values for residences, second homes and recreational activities. An economic model was developed to investigate the impacts of various factors in determining farmland prices. A combination of cross-sectional and time-series data using county data from the 1950 to 1987 Census of Agriculture reports was used. The model variables included net farm returns per acre, capital gains per acre, distance from and size of nearest major population areas, interest rate, agricultural productivity and the farm wage rate. The dependent variable was average per acre value of land and buildings. A series of dummy variables was used to account for county effects. Boone, McDowell and Mingo counties were not included in the analysis because the Census of Agriculture did not report information on those counties in some years due to a low number of farms and census disclosure regulations.

Approximately 90% of the variation in land prices was explained by the independent variables in the model. The six variables each had statistically significant regression coefficients and the set of dummy variables was jointly statistically significant. The results indicate that a $1 increase in annual net returns per acre is associated with a $1.21 increase in the per acre price of farmland while a $1 increase in expected capital gains will cause a $0.53 increase in land prices. The expected capital gains was based on the average annual increase in land prices during the previous census period. Similarly a one-percentage-

Grazing for Lower Costs, Higher Profit

Robin Jackman, center, points out pasture highlights during a group meeting at his Vergennes farm. *Photos/Susan Harlow*

Larry and Donna Holmes, Essex Junction dairy farmers, look at their pastureland with a different eye now. "I used to think that pasture was just a way to use up land you didn't want to harvest crops on," Larry Holmes said. "But if you do it right, you get just as good a return as if you're harvesting it."

The Holmeses use rational grazing, also called rotational grazing, Voisin or intensive grazing, on the farm where they milk 45 Holsteins. Pastures are divided into small paddocks and animals rotated through them for short periods of time. The small size of the paddocks encourages the animals to graze the pasture uniformly and without waste; the paddocks get a rest period during which they can regrow and improve.

"By dividing up the pasture and putting cows on 12 hours in each plot, they milked better with no additional roughage. We maintained the same level of production and the cost was the same and lower," Larry Holmes said.

Holmes had always divided his pastures, but last year he joined the Pasture Outreach Management Program, a project of the University of Vermont's Environmental Programs in Communities. Farmers in the program are visited every few weeks during the grazing season by pasture management consultants Lisa McCrory or Joshua Silman. They help farmers to not only manage pastures but also to plan feed programs and balance rations, and with herd management. They walk the pastures with the farmers, note such things as where animals are grazing inadequately or whether paddock size should be changed, and discuss possible improvements. They take several soil tests during the season, and a forage analysis during each visit. Before and after grazing, they measure forage mass with a pasture probe, estimate dry matter intake per cow and determine the rate of plant growth for each month.

For their part, farmers keep data sheets on milk production, milk quality, feed, manure and fertilizer applied, production costs, income and other data. The information from this "enterprise analysis" should help the farmer assess his or her farm, the economics of rotational grazing and where changes should be made.

The program started last year with 27 farmers in Addison, Franklin, Grand Isle and Chittenden counties. This year, another two dozen farmers in Lamoille and Washington counties joined the program.

Most of the farmers are in dairy. But some also raise beef or plan to soon. And although the program is geared to dairy farms, beef, sheep and other livestock operations can also benefit from rotational grazing, and from integrated management of their farms.

"Rational grazing is a way of producing high quality feed at the lowest cost, and stocker calves, to raise to the weight you want, require dairy-quality feed. That can be done cheapest on grass," said Dr. Bill Murphy of the University of Vermont, the coordinator of the program who has been researching grational grazing for almost 10 years.

"We're learning how to be grass farmers, raising energy from the sun and marketing it. It doesn't matter what you're growing as long as you can market that sun energy," McCrory said. "It's important for everyone to be familiar with fencing, paddock size, the number of animal units for a given area, how high the grass should be when harvested by the animals, the quality of feed and of the land, and animal health."

Another important part of the program is monthly meetings of program farmers from each county and anyone else who's interested. These are discussion groups, in which farmers learn from each other, ask questions and share experiences. "It's never some guy giving a monologue," McCrory said. "One thing that works against farmers is they're independent, competitive and isolated, so they miss out on one of their best resources. The program creates a good network. People know they're not alone. If someone is trying something new alone, it's tough—the negative feedback is often stronger than the support."

Lisa McCrory, pasture consultant.

Dan Rowe of Cornwall has been rotationally grazing his dairy herd for eight years. This year, he'll rotate them through 20 permanent paddocks and three "super" paddocks. On an adjacent 250-acre piece that had grown up to scrub, he's raised beef for two years, rotating them through four lots. He plans to do that again this year with a cow/calf operation.

With half his farm too steep for a tractor, rotational grazing works well. Better than well, Rowe said. "The pasture is just more than 100 percent better use of the land," he said. "It's much easier making milk on pasture than in the barn; when they're on pasture they're just a whole different herd."

His 90-cow milking herd thrives on the pasture, maintaining a 20,000-lb. herd average, and his production costs drop "dramatically" during the grazing season, Rowe said. The cows are much healthier as well. The incidence of mastitis drops, teats aren't stepped on, and Rowe said he's never had a case of DA during the summer.

For him, the forage analysis is one of the most important parts of the program. Another is recordkeeping. "It forces you to manage even better," he said. "But you can't go into it half-heartedly."

The practice of rational grazing has been growing steadily throughout the Northeast, where two-thirds of a pasture's growth occurs during just one-third of the year. Rotational grazing takes advantage of pasture as the primary crop, not just a place where you shuffle your heifers off.

Many farmers who rationally graze have found their production costs reduced through lower feed and labor expenses, so that profits are often increased. An analysis of the 27 farms that participated in the program last year and who reported data shows they increased their farm profitability an average of 34 percent, Murphy said.

In Vermont, Mike and Tammy Hanson of Fairfax, members of the Pasture Management Program, saved $12,800 in feed costs last year through rotational grazing, with a small drop in milk production. They more than doubled their net income in 1992 over the previous year.

And a study of 20 dairy farms in Wisconsin, comparing grazing herds to confinement herds on stored feeds, found that grazing cows netted $1.16/cwt. more for milk than the confined herd. The confined herd produced twice as much milk but expenses were also higher.

The project is funded by the Kellogg Foundation, and the USDA Sustainable Agriculture Research and Education Program (SARE). The project is free to farmers at present.

Anyone who is interested is welcome to attend the monthly meetings in Franklin, Addison, Lamoille and Washington counties, usually on Wednesdays, from May through October. For information about where and when, or just to get more information on the program, contact the Pasture Management Group, c/o Joshua Silman or Lisa McCrory, Plant and Soil Science Department, Hills Building, Burlington, Vt. 05405, tel: 656-0641.

Susan Harlow

Willie Gibson, UVM Extension System specialist, during a group meeting of the Pasture Management Outreach Program.

Events continued

UVM Pasture Management Specialist Chet Parsons "Practical Research"
Bill Tracy, Auburn, NY "Intensive Stocking on 1000 Acres"
Skip Bevins, USDA Livestock Marketing "Evaluating and Grading Cattle"
Hume, MacKillop & Clapp "Vt. Beef '93: Hails, Scales and Sales.
Registration: $10 including lunch, $5/additional family member.
Contact: Allen Hitchcock, 1329 Furnace Rd., Pittsford, VT 05763, (802) 483-2319.

August 1	Consignments for Vermont Statewide Feeder Sale open to VBPA members. Non-members not considered until September.
August 14	N.E. Angus Foundation Female Sale–Cloudland Farm, Woodstock, Vt.-Bill Emmons, 802-457-1520
August 31-Sept. 2	Great Vermont Dinners, Champlain Valley Fair, Essex Jct.
Sept. 17	Deadline for Feeder Sale consignments.
Sept. 25	N.Y. Angus Field Day, Leatherstocking Farm, Greenwich, N.Y. Wayne Ripstein, 518-692-9773
Oct. 2	Last day for weaning and pre-conditioning for VBPA Sale.

Vermont Horse Council News

A Needed Bill In Senate Judicial Committee

By Jane Brown

The Vermont equine industry is on the threshold of getting legislation passed to limit the liability of persons involved in equine activities. This bill, H.43, if passed will end frivolous lawsuits and reduce insurance costs. The horse industry in Vermont greatly needs to have this bill passed.

For those of you unfamiliar with H.43, and for those wanting a review, the bill was introduced in January 1993 by Rep. David K. Brown. The first draft was made from an existing Massachusetts law.

The equine bill provides important definitions to ensure every facet of 'equine activities', 'participant' and 'inherent risks' are clarified. The text is very extensive and too long to state here. But, all aspects of the horse industry are included and there is no room for misinterpretation by the courts.

The general provisions, in a nutshell, state that a sponsor, professional or any other person will not be held liable, if said persons were prudent in assessing riding skills, provided safe tack or equipment and posted known dangerous conditions existing on owned, leased or rented land/facilities.

Unfortunately, H.43 did undergo some extreme changes. The House Judicial Committee proposed a strike-all after the enacting clause. This strike-all affords less protection to sponsors and organizers, and leaves many questions unanswered. The courts are left to determine what classifies as an 'equine activity' and what 'inherent risks' are. This revised bill is what has passed the Vermont House this spring.

The Senate Agricultural Committee has since amended to return the bill to its original form, plus a few helpful provisions in determining riding skills.

H.43 is presently in the Judicial Committee of the Senate. Senator John H. Bloomer is the Chairman. He is also a lawyer. Needless to say, he does not favor H.43. Influencing Senator Bloomer is the key. Rep. Brown and others in favor, strongly suggest supporters to write or phone Sen. Bloomer this summer and again in January. Persistence and numbers will help move this bill into law.

If additional information is needed, contact Rep. Brown at 765-4525 or myself, Jane Brown at 765-4232.
Write or phone your support of bill H.43 to:
Senator John H. Bloomer
Boardman Hill
W. Rutland, VT 05777
438-5500
The Vermont Horse Council Endorses Bill H.43 and Encourages All Members To Contact Their Senator and Senator Bloomer.

Cows Graze on Green Pastures, Instead of Concrete Floors

University of Vermont (UVM) researcher Bill Murphy is trying to get farmers to rethink how they feed their cows, getting them to move away from confinement feeding to rational grazing -- controlled, intensive rotational grazing for short durations -- for six months of the year. And many dairy farmers, thanks to a new pasture management program that takes the research to the farm are stopping to listen and learn.

Murphy and research filed technicians Lisa McCrory and Joshua Silman are working with 48 farms in four counties to assist farmers to more efficiently manage and use pastures to feed lactating cows. The end result can be a savings on milk production costs, time, and labor as well as a better quality of life for the farmer.

The pasture management outreach program, which provides individual consultations, forage and soil sampling, and monthly meetings for program participants to compare notes, is funded by the Kellogg Foundation-supported Environmental Programs in Communities (EPIC), a project of the UVM Environmental Studies Program, with additional support from the Northeast Sustainable Agriculture Research and Education (SARE) Program.

It's an outgrowth of Murphy's on-going, on-farm research on intensive pasture management. It was begun last year to help spread the word about the benefits of well-managed rotational grazing versus confinement feeding.

"Although putting cows on summer pasture is not a new concept for most Vermont farmers, rational grazing, which makes use of smaller paddocks and frequent moving or rotation of cows, is," Murphy says. "This system allows pastures to be grazed more evenly and efficiently.

"Pasture that is continuously grazed does not have time to recover and may eventually die. In rational grazing, cows are not moved back into an area until there is a pregrazing forage mass of 2,200 to 2,400 pounds of dry matter per acre, or in other words, the grass has reached a height of about six inches."

The beauty of this system is that the farmer doesn't have to cut the grass to feed to cows in the barn. Instead, the animals "feed themselves' on the pasture, allowing the farmer time for other activities including recreation.

Grazing also eliminates the need to grow as much corn and hay, which in turn reduces use of farm equipment and fertilizer costs. In addition, grain bills, which can account for up to 60 percent of farm expense, are substantially reduced.

Researchers have estimated that it can cost up to six times more to feed cows indoors than it does on pasture under rational grazing. Murphy adds that, depending on the quality of the pasture, a farmer's potential savings can range from $12,000 to $24,000 during the six-month grazing season.

Peter Young and Nancy Everheart of Plainfield are believers. The husband-wife team run Hill Farm, a small operation producing premium, certified organic milk for Vermont markets. Although these grass farmers understood the fundamentals of rational grazing, their biggest concern was that they might not be doing it right.

"I think we were following all the rules," Young admits, "but I needed someone to walk around with me and reassure me that I was doing it correctly. You can just go so far in a vacuum." That's why he was eager to sign up when the program expanded into Washington County this year.

He notes that rational grazing fits with their philosophy of organic farming. "It helps us work with the resources that are available to us, such as manure for fertilizer instead of 10-10-10."

The couple currently keep their cows out night and day from May 1 through mid-October, moving the animals to fresh pasture every 24 hours. They's like to keep the herd outside year-round, feeding big bales in the winter months, though efficient pasture management, they hope to stretch the grazing season out a few months on either end.

The outreach program is funded through March 1995 although Murphy hopes it can be continued and expanded into other counties. Eventually, he would like to see all of Vermont covered with 120 farms enrolled in the program.

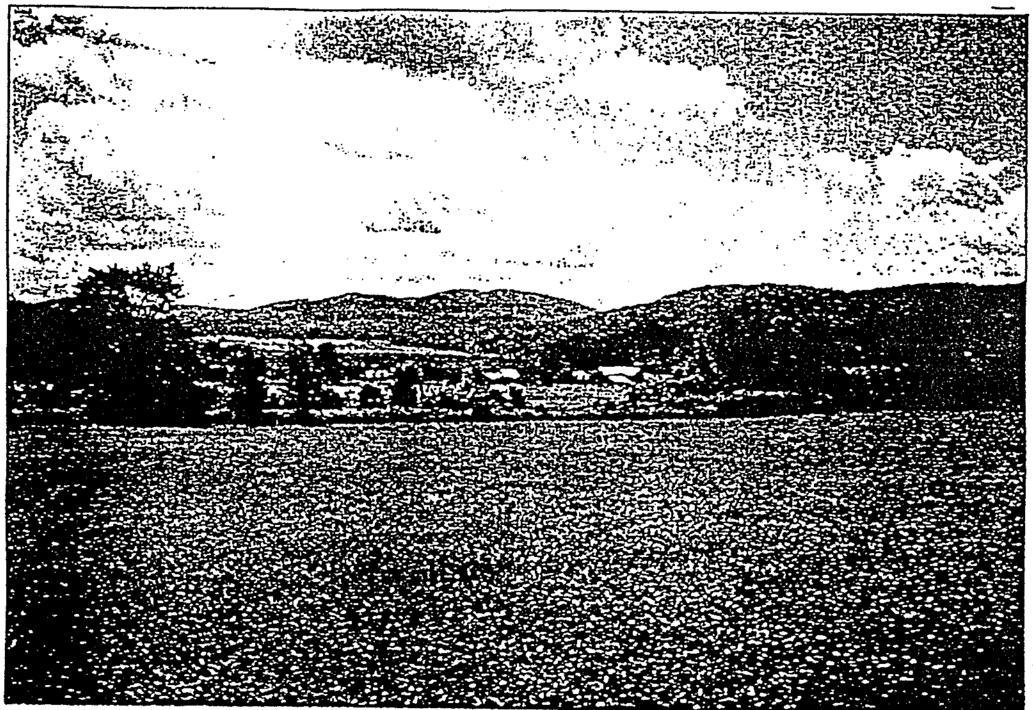
"I think many farmers are skeptical that rational grazing will work in Vermont," the pasture management specialist says. "But we are proving that it can, and does, work. Farmers who follow sound pasture management practices are seeing both economic and personal benefits."

To learn more about this, call (802) 656-0641.

Grass Farmer

September, 1993 — THE GRASS PROFIT PAPER — Volume 50, Number 9

SERVING NORTH AMERICAN GRASS FARMERS SINCE 1947. BEEF/DAIRY/SHEEP/GOATS/PIGS/POULTRY



Vermont graziers are finding that management intensive grazing techniques not only offer a major improvement in their lifestyle but also help preserve the vanishing pastoral landscapre. For more on how MIG pays off in Vermont, read the article below.

Grass Dairying: A Way Out of the Woods in Vermont

by Jim Bauer

BURLINGTON, Vermont: Probably in no other state is the concern over the "look" of the land felt as deeply as in Vermont. The pastoral landscape that made Vermont a favorite vacation spot for urban Northeasterners has been slowly reverting to scrub forest for two generations as farmers have left the land. Today a tourist can drive for miles and miles without a glimpse of a pasture and the postcard pretty homestead that most people think of as Vermont.

"If I wanted to look at woods all day, I would have gone to New Hampshire," a tourist at a roadside rest stop grumbled to me. With the urban New England economy in a continuing depression due to the shakeout in the computer and defense industries, a similar depression in tourism would drive the already hard pressed Vermont economy to the wall.

"The rural landscape has become just a background to highly specialized, scientifically trained urban technicians," explained Vermont rural activist Jean Richards. "We have lost the sense of interconnectiveness of all the segments of our economy. The computer designer at IBM in Burlington feels no sense of being in the same economic boat as the Vermont dairy farmer, but he is and the boat is sinking."

The shift to "modern" dairy production techniques based upon stored forages and grain has been particularly devastating in a region with thin, rocky soils, a short growing season and high grain and feed prices. In this, the most rural state in the U.S., the former milk shed for Boston and New York, there are only about 3000 dairy farmers left and the rate of decline has been around ten percent a year. (Same rate as U.S. as a whole.) At this rate there will be no dairymen left in a decade.

However, the news is not all bad. The good news in Vermont is that management intensive grazing pays.

In mid July over 200 graziers from all over New England and Quebec gathered at historic Shelburne Farms to hear and share the good news about grass. The conference was sponsored by the American Farmland Trust, University of Vermont, EPIC, and The Stockman Grass Farmer. Conference coordinator was Dr. Bill Murphy, University of Vermont professor, grazier, and author of the popular book "Greener Pastures on Your Side of the Fence."

Mike and Tammy Hanson of Fairfax, Vermont, opened their farm to the group and told of their experiences with shifting their herd to grass.

The Hansons said grazing had brought a major improvement in their quality of life. "I spent the whole month of August last year just goofing off," Mike said. "This is a form of farming the whole family can participate in and enjoy. My 11 year old can move the fences and set the water tanks. Even your youngest children can get out and walk the land with you. You aren't out there all day on a tractor constantly separated by technology from your children."

Mike said that this was his last year for corn and that he planned to sell all of his field equipment and buy in his stored feeds and forages in the future. "I'm convinced you can buy it cheaper than you can grow it."

The Hansons currently graze 70 Holstein cows on 51 acres of bluegrass and white clover pasture. During the spring lush the cows graze on only 15 acres and the remainder is cut for stored winter feed. Mike said he has seen his herd average drop from 19,200 lbs. to 18,300 lbs. since switching to grazing.

"We weren't making any money at 19,200 in confinement and we are at 18,300 on grass, so it is not a great sacrifice. We found out it costs rather than pays to try to maintain these very high herd averages," he said.

University of Ohio extension agent, Tom Noye, agreed. He said Ohio

Continued on p. 6

See related story, Page 4

Mitch Posin and Clarissa Allen are converting their Martha's Vineyard acres to a management intensive grass farm.

Forage Reports
Addison

Month	% DM	% CP	% ADF	% NDF	NEl	% NSC	% TDN	Ca	P	K	Mg	RFV	%SP
May	21.84	24.35	23.66	49.62	0.73	15.99	73.56	0.83	0.46	3.21	0.24	133.81	49.76
June	17.89	21.63	26.19	51.68	0.69	16.36	70.98	0.84	0.43	3.29	0.21	124.42	51.20
July	22.36	21.49	27.43	50.11	0.68	18.14	70.12	0.87	0.41	3.12	0.23	127.42	52.10
August	24.89	24.19	23.95	42.74	0.69	23.08	73.45	1.14	0.42	2.64	0.31	156.57	49.89
September	23.61	26.64	25.06	47.00	0.69	16.36	72.57	0.83	0.49	2.88	0.29	138.46	44.20

Forage Reports
Franklin

Month	% DM	% CP	% ADF	% NDF	NEl	% NSC	% TDN	Ca	P	K	Mg	RFV	%SP
May	18.76	23.23	23.39	43.59	0.70	23.17	73.89	0.98	0.42	2.64	0.28	153.30	47.85
June	18.92	24.52	22.56	49.59	0.74	15.85	74.39	0.84	0.47	3.39	0.23	134.57	46.75
July	20.07	22.28	24.43	48.06	0.71	19.45	72.63	0.89	0.42	2.89	0.26	136.94	42.20
August	20.14	24.11	22.74	42.79	0.70	23.11	74.40	0.93	0.44	2.47	0.29	158.16	48.14

Forage Reports
Lamoille

lonth	% DM	% CP	% ADF	% NDF	NEl	% NSC	% TDN	Ca	P	K	Mg	RFV	%
lay	19.36	23.87	23.13	46.65	0.72	19.49	74.09	0.83	0.44	3.05	0.26	144.17	54
une	19.88	22.95	22.39	49.37	0.75	17.61	74.45	0.83	0.45	3.26	0.24	137.58	48.
uly	19.06	22.31	23.90	48.34	0.72	19.34	73.50	0.85	0.43	3.17	0.24	137.60	46.
ugust	19.82	25.16	23.20	45.12	0.69	19.70	74.07	0.74	0.46	2.72	0.27	148.78	45.
eptember													

Forage Reports
Washington

Month	% DM	% CP	% ADF	% NDF	NEl	% NSC	% TDN	Ca	P	K	Mg	RFV	%SP
May	21.69	20.84	25.35	50.43	0.70	18.74	72.34	0.78	0.41	2.81	0.21	130.41	50.16
June	18.36	22.63	23.86	50.15	0.73	17.08	73.13	0.86	0.44	3.25	0.22	131.53	46.40
July	19.76	20.78	27.72	51.88	0.67	17.15	70.09	0.87	0.40	2.91	0.25	122.60	48.94
August	17.39	24.28	23.89	45.47	0.69	20.29	73.49	0.91	0.45	2.64	0.31	147.51	44.50
September													
Oct													

Grazing 'Disadvantages' Noted

To the Editor:

I'd like to respond to the person who asked about the negatives, or disadvantages, to grazing (Milk Pail *Agri-View*, Dec. 17-18 editions). Here's a few I've encountered; these are all things I don't get to do much of anymore.

I don't get to ride a big powerful tractor, and listen to the roar of exhaust. I don't see the fuel delivery man much anymore, either. In fact, I only used 1,000 gallons this year for a 60-cow herd, or less than 20 gallons per cow. Before, I was using 50 gallons per cow. I don't get to visit with the vet much anymore. An $800 vet bill doesn't bring them out too often.

I don't get to green chop every day like before, or play ring-around the green feed rack, slippin' and sliding in the you-know-what. Speaking of "what," I don't get to haul much during the grazing season; the cows deposit it in the paddocks. That, in turn, makes it so I don't get to buy fertilizer because they poop and pee 50 pounds a day. Two hundred days of grazing makes 10,000 pounds of the stuff. It takes about one acre per cow, so 5 tons ends up being a lot of fertilizer per acre. It isn't feasible to use a large diesel tractor, so I "have to have" a small gas tractor (the only luxury it's been necessary to buy). A John Deere B doesn't get many "wows," so I have to do without an inflated ego. But I have admit it's enjoyable to putt around dragging and clipping paddocks on it.

I can only graze the 199 days from Apr. 15 to Nov. 1, so I only get to feed out of storage for 150 days. Also I don't get to formulate fancy rations with a feed consultant (they used to be called salesmen). You see, the only feed the cows receive is about 8 pounds of ground corn a day for the 200 days, do much recreational tillage, as I don't grow very much corn now.

Since I started grazing, I haven't been able to claim a loss on my income tax. I think another reason is, I haven't entered the "bragging contest" of high herd averages. And I don't get to buy any protein supplements anymore. I don't raise a lot of youngstock. The cows seem to last forever, consequently I don't get to break in many new heifers to milking. Also, I don't get to throw a switch to feed my cows. I have to walk to the pasture and observe, and think, how much to give them today, and tomorrow. And answer 1,000 questions like, "Grandpa what kind of bird is that?" and "Wow, look at this bug!" Keep those articles on grazing coming. They're appreciated by someone who's grazing, and doing without.

Jim Brown
RR 3 Box 174

FUN READING! ←

Vermont (continued from p. 1)

research showed cows on good pasture should not be fed more than 14 to 15 lbs. of grain per day. "The return of milk per pound of grain fed is very marginal in a pasture system with a return of approximately one-half pound of milk per pound of grain. You must monitor your milk/grain ratio very carefully for maximum profitability."

While on pasture, Mike said his cows receive 14 lbs. of corn a day and no protein. He said he likes a stock density of 60 cows per 3/4 acre per 12 hours. "We have found it is very important to always give your cows at least a little fresh pasture after each milking even if they have left a too high residual. Fresh pasture is their reward for going through the hassle of milking," he said.

Grazing consultant, Alan Henning, a speaker at the conference agreed with Mike's observation. "What makes the cows want to go to the milking parlor is the knowledge that there will be fresh pasture as a reward on the other side. You do not need feed in the parlor to make the cows want to go there."

University of Vermont researcher, Abdon Schmitt, said in his studies of cows' grazing behavior that the morning graze is the most important. "82 percent of the cows grazing time is done before 11 AM," he said. "Only 12 percent occurs after 3 PM."

Abdon said he recommended that paddocks not be divided in half between the morning and evening graze but on an 80/20 split basis with 80 percent of the paddock being made available for the morning graze and the remaining 20 percent opened after the evening milking or after 3 PM with beef and sheep.

Bill Murphy said that there was a definite difference in the regrowth and stability of paddocks on the Hanson farm that had never been plowed and those that were plowed 20 to 30 years ago. "Voisin said it took a pasture 100 years to recover from a plowing. It appears that all of our pasture renovation should be done primarily by overseeding and plowing should be avoided."

Murphy said the best weed control was a regimen of pasture clipping following grazing. "The only real weed we have in pasturing is the thistle. All the other so-called weeds are readily grazed as long as they are kept immature. Pasture clipping thistles before seedset will eventually reduce them as well."

He said the primary fertilizer most Vermont farms needed was lime. "By buying in our grain and spreading the manure we are bringing in a lot of fertility as a byproduct."

He said they have found no benefit from either breaking up the manure piles with a drag harrow or from using a pasture aerator. "If a treatment doesn't make at least a half a ton more dry matter per acre, it isn't worth it. We've seen absolutely no response from either."

Alan Henning said the major difference between New Zealand high throughput milking parlors and American milking barns was that the New Zealand parlors were designed by people who understood how a cow thinks and sees the world.

"A cow does not like to enter a building that she cannot see the way out the other side," he said. "New Zealand milking parlors are built with open sides and ends so the cow can see the way out the other side. If you make the milking parlor dark the cows are going to slow down and be very slow to enter. If you are going to milk 100 to 150 cows an hour by yourself, you can't afford such slowdowns."

He said the open sides also let sunlight into the parlor and that sunlight was the best sanitizer there was.

Continued on p. 7

An Emotional Support Service for New Grass Dairymen

BURLINGTON, Vermont: Dairymen in Vermont have a unique service available to them, an extension and support group dedicated to helping them make the often emotionally disturbing transition from traditional to pasture based dairying. The service is called Pasture Management Outreach Program and its consultants are Joshua Stillman and Lisa McCrory of the University of Vermont. The program is funded by a grant from the Kellogg (Cereal) Foundation.

"Dairymen trying to make the transition get so much negative flack from their feed dealers and other input sellers that we felt they needed a little hand holding," explained Dr. Bill Murphy of the University of Vermont.

Dr. Bill Murphy explains part of Vermont's Grazier Outreach Program is training dairy producers' "grass eye" with the help of an electronic pasture probe.

Currently there are 48 cooperating dairy farmers in the program. A major part of the program is teaching dairymen to gauge the dry matter content of their pastures. The dairymen guess how much dry matter is in a particular paddock and then Josh or Lisa uses an electronic "Pasture Probe" to show them how far on or off the mark they were.

Another valuable service is a monthly pasture forage analysis to build the dairymen's confidence in the feed value of pasture. This is necessary due to misinformation about the value of pasture from input salesmen.

Each month there is a pasture walk and discussion on one of the cooperating farms. These pasture walks are open to any and approximately 300 graziers from all over the state have participated in these programs.

Lisa McCrory said the average increase in net profitability seen by her dairymen in their first year of switching to pasture was $15,000 based upon an average 48 cow herd.

Murphy said the Vermont effort was a pilot program that he hoped other states would copy. "The outreach program is primarily important for the social and emotional support it gives. We want the transition to pasture to be a positive experience for the dairyman." ■

Mike Hanson says grass dairying allowed him to get off the tractor and back in touch with his family.

Henning was questioned about the effect of cold with open sided milking parlors. He said this was seldom a problem with seasonal dairying. He said as the weather turned colder near the end of the milking season, a dairyman could go to once a day milking in the middle of the day. He said some dairymen were using removable, clear plastic, freezer flaps as cool season windbreaks.

Henning said the major point in fast milking was to let the cow go as soon as she was milked. "Don't make the first cow in wait for all the others to be milked to get out. Get that machine off of her as fast as possible and let her go and graze."

He said to have everything ready before the cows arrive and to start milking before all the cows were at the parlor. "Don't make the early cows wait until all the cows are at the parlor before you start milking them. Seeing those early cows getting the first choice of fresh pasture will pull the laggard cows through the milking parlor like a magnet."

Going seasonal was a controversial topic. Mike Hanson said he didn't think his debt service payments would allow him to do it and several others questioned the wisdom of going without any cash flow for three or four months. However, East Montpelier Jersey grazier Brian Stone said he is glad to have made the switch and would never go back to milking 12 months a year.

"I am in the second year of seasonal production and have absolutely no regrets," Brian said. "Being seasonal has allowed me to save $8000 to $10,000 a year in grain costs."

He said he has dropped grain feeding to just six pounds of grain a day and has seen production actually increase as his pastures and management got better. "The fastest way to a better bottom line is to concentrate on cutting costs," he said. "My purchased feed cost per cwt. of milk is only a dollar. We're at the point now where we don't really care what the price of milk is."

Lawrence Shearer, a seasonal dairyman from Colrain, Mass., agreed that grain bill savings was a major advantage to going to pasture but having all the cows dry at the same time was also a major advantage to going seasonal. "It is during the dry period where you have the biggest advantage over the conventional dairyman. It is very easy to manage a whole herd of dry cows."

Brian agreed saying that his cows now wintered outside on hay stacks with no supplemental feed at all.

Shearer also said dairymen should not let their debts defer them from going seasonal. "We now pay all our bills six months in advance," he said. "Last year my son and I split $100,000 in net income from just 48 cows. Seasonal dairying is the only way to have both a low labor input and a high income."

Brian recommended that once the decision to go seasonal has been made to change over as fast as possible. "If I had it to do all over again, I would sell everything that didn't fit and replace them." He said that because of the good success of early seasonal converts subsequent dairymen would find their lenders much more cooperative.

Brian Stone says he has absolutely no regrets about going to a seasonal grass dairy. He says his success will make it easier for others who want to follow.

He said he currently starts calving on May 1 and has a goal of having all of his calves born in a 45 day period. This year he calved on pasture and has been rearing the calves on pasture with a Paul McCarville whole milk tank. He said he had found no disappointments with either. He said he plans to cut his lactation period back to only eight months a year as his cow numbers rise. "Seasonal dairying emphasizes the economic marginality of the late lactation period."

Brian said his pastures were a mix of white clover, timothy, orchardgrass and Reed canarygrass. All of these had been established through overseeding. "The only thing I plow now is the garden." ■

Comparative Economics of Intensive Pasture Rotation and Conventional Management Practices on Northeast Dairy Farms: A Case Study Approach

By

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ABSTRACT

This paper looks at the farm level economic impact of Intensive Pasture Rotation on twenty five farms in Northern New England. Case study data indicate that IPR management has some economic advantages in medium sized dairy farms in the areas of labor use, equipment costs, net revenues, and debt burden.

Comparative Economics of Intensive Pasture Rotation and Conventional Management Practices on Northeast Dairy Farms: A Case Study Approach

I. INTRODUCTION - PROBLEM STATEMENT

Census data indicate the trend of disappearing numbers of dairy farms in the Northeast and Vermont has progressed unabated since we have recorded such figures. The reasons for this trend can be traced to productivity enhancing advances in technology and management which have permitted fewer farms to produce more milk using fewer of society's resources. In addition, we see increasing alternative demands on the land and labor resources of the region. For the most part this development has been positive for society, in that we have enjoyed a reliable and relatively inexpensive supply of a wholesome food source, while at the same time, those left in business of producing milk stood a better chance of earning a good living.

More recently, many have become concerned with the pace of this trend and its apparent consequences. Technology driven economies of scale are most often pointed to as the source of the small and medium sized dairy farm's inability to compete with the regional and national trend towards larger production units. If the pace of disappearance of farm numbers continues past some vaguely defined threshold level, the structure of our rural economy may be irreversibly changed from one of a productive agriculture and tourism based economy to something very different, and to many, less desirable.

In addition to the shrinkage in farm numbers in our rural communities, there is also a rise in concern for the environmental impact of dairy farming systems that rely on cropping and confinement feeding as key components to the management system. These concerns focus on the long-term environmental sustainability of farming systems that rely on regular applications of pesticides and fertilizers as well as the potential for ground and surface water nitrate contamination resulting from concentrated applications of cow manure to the soil

(Young,1985,1986).

Recently, there has been increased interest in farm management systems that incorporate pasture as a major component of the dairy management system (Murphy, 1986 Burns, 1988; Pillsbury, 1989;). Under the title of Intensive Pasture Rotation (hereafter IPR) there exists a family of dairy management approaches that seek to:

1. Lower the demand for cropped and purchased feeds by supplementing or supplanting traditional sources of animal nutrition with pasture.

2. Lower the cash input expenses of the farm by substituting management for capital without sacrificing profitability.

3. Lower the adverse environmental impact of dairy management systems by reducing the demand for pesticide and fertilizer inputs as well as concentrated applications of manure to the soil.

The purpose of this paper is to report the early process of identifying the set and value of economic parameters under which IPR management makes sense in Northeast dairy farming. Specifically, we begin the process by examining the state and economic implications of IPR management as it has been employed to date. We seek answers to how IPR management affects dairy farms in the areas of labor use, equipment use, cash flow, and overall profitability.

II. RESEARCH METHODS.

This paper reports the results of a case study analysis undertaken in the Summer and Fall of 1991 as an intermediate step in the design of a Operations Research Simulation model designed to look at the interactions of the full range of economic variables impacted by IPR at the farm level. A case study approach was undertaken to generate data appropriate for a representative farm model of a pasture based management system. These data are reported in this study to profile the current state of IPR management as practiced. In particular, answers were sought as to how

IPR management impacts the following economic aspects of farm level dairy production:

- The overall cost structure of dairy farms.
- The use and distribution of labor on the farm.
- The use and cost of equipment.
- The short and medium - term cash flow and debt service.
- Overall dairy farm profitability.

The potential ambiguities of causality in a case study approach are well recognized. Caution must be exercised in the interpretation of the data because there is no perfect mechanism to control for quality of management, genetics, and changes in environmental conditions and their subsequent impact on production. Nor are there sufficient observations to make use of appropriate statistical distributions in the interpretation of results. On the other hand, a case study approach permits a depth and quality of information collection not generally possible by survey of larger populations. The data represent what is the current use of resources and management practices on the studied farms, not necessarily an optimal mix. The standard of argument here must be preponderance of evidence and consistency of results as opposed to a rejected null hypothesis at some level of probability.

Using extension agents, other local experts and the producers themselves as sources of information, a total of 25 farms were identified, including 14 Jersey based herds and 11 Holstein based and mixed breed herds. These are all the farms known to practice IPR as a dominant component of their management system in the Vermont study area. To minimize performance and productivity differences due to economies of scale, breed type, technology and particular form of pasture rotation practiced, farms were grouped and analyzed so as to isolate the following characteristics.

- Medium herd size (40 - 79 milking head).
- Large herd size (80 or more milking head)
- Predominately Jersey herds.
- Predominately Holstein herds.
- IPR and primarily purchased feed (i.e. little or no cropping)
- IPR and cropping activities.

The size categories were selected to conform with ELFAC and AGRIFAX record keeping service reporting classes. The size classes will also help to isolate some of the impact of economies of size on the results. The category "Medium Jersey, IPR, and Cropping Activity" was problematical because only one of the three surveyed farms exactly fit the criteria (42 milking head). The other two farms had fewer than 40 milking head (25 and 34) but both farms had an unusually high proportion of dry cows relative to other observations at the time of interview. The three farms had similar total adult cow numbers (45, 40 and 49). Ultimately, the farms were included in the category because their technology and practices were similar, the data collected was representative of the entire year, and the dangers of drawing conclusions from a single observation were considered grave. No large Jersey herds practicing IPR were found. The category "Medium Holstein, IPR, and Purchased Feed" was dropped from the analysis because only one observation was found.

In each size category, a "conventionally" managed, i.e. confinement managed, farm was identified and interviewed for comparison purposes. These benchmark farms were selected because they were thought to represent examples of "best management practices" for their category.

Each farm was subjected to detailed personal interviews, over the period July-September 1991, seeking to identify and enumerate all labor practices, equipment use, and cost categories which might be expected to change as a result of an IPR management focus. Milk production and revenue data were also collected.

Practices and cost categories not expected to change as a result of management approach were either standardized or eliminated from the budget to minimize the impact of management quality on the results. Data were not collected on real estate or building capital expenses because such data would vary greatly from farm to farm, confusing interpretation of budgets. In addition, real estate differences are not believed to be systematically affected by the management systems under study. All labor on the farm, including family labor, was charged at a constant hourly wage rate. Similarly, economic equipment costs were handled by treating all equipment as new and depreciating the item over its expected lifetime. Annual cash equipment costs were established by assuming all equipment was 100% debt financed over five years, (the term established as common by local equipment dealers) at an identical rate of interest. Cost and revenue data are reported on a per cow rather than per cwt. of milk basis to minimize the impact of herd genetics, as evidenced in production, on interpretation of the results.

It should be noted that costs were computed in two ways: total economic costs and on a cash flow basis. The first method, which accounts for the hourly cost of a durable item as a function of its entire economic life is more important in understanding long-run profitability and sustainability of the management practice. Cash flow is based on annual cash inflows and outflows, i.e. what the producer might see in his or her checkbook. The cash basis is important in understanding short-run profitability and sustainability because it is on this basis that many producers will make their short-run decisions.

III. RESEARCH RESULTS

Overall Economic Cost Structure . The results summarized in Table 1 under total economic costs reveal a mixed picture for medium sized Jersey farms practicing IPR management. On a unit cost basis, IPR - Purchased Feed farms and Conventional farms were approximately equivalent. Medium IPR & Crop Jersey farms exhibited considerably higher unit costs though it should be noted that this category had the smallest average herd size of the groups.

The results are more clear for Holstein herds (see Table 4). IPR managed farms generated lower costs per cow than did conventionally managed farms by a large margin. For large Holstein farms, unit costs were almost identical. This could tentatively indicate diseconomies of scale for IPR management at larger herd sizes.

Labor Use. Analysis of labor use on pasture managed farms indicates that farms which employ IPR techniques tend to use less labor on both total and per production unit basis (see Tables 2 and 5). In addition, these farms use labor with less daily and seasonal variation than do conventionally managed dairy farms. This is particularly true of purchased feed operations which do no cropping. The single exception was observed in the Medium Jersey IPR & Crops category where per unit labor costs were very high. As mentioned, this category is characterized by smaller herd sizes, but some of the labor savings is lost on farms which practice both IPR management and cropping activities. Presumably these farms crop less as more feed demands are met by pasture sources.

The pattern of labor use on IPR managed farms is very important if a farm finds itself facing a relative labor shortage, as is often true in the Northeast. Farm managers practicing IPR techniques may be able to reduce labor demands to what are deemed more personally acceptable levels given family labor availability and desires for alternative uses of time. Some producers

TABLE 1. Total "Economic" and Cash Costs and Returns from Jersey Case Study Farms.

Farm Category	Total and Per Cow Economic Cost	Total and Per Cow Net Return	Total and Per Cow Cash Cost	Total and Per Cow Net Cash Return
Med. Jersey, IPR & Purch. Feed n=5	48084 1075	28420 635	55832 1248	20672 462
Med. Jersey, IPR & Crops n=3	48753 1448	21030 624	63878 1897	5905 175
Med. Jersey, Conventional 2x n=3	67304 1057	48534 762	95697 1503	20141 316
Lg. Jersey, Conventional 2x n=1	96204 875	50013 455	121556 1105	24660 224
Lg. Jersey, Conventional 3x n=1	493762 1496	151312 459	514498 1559	130576 396

Table 2. Labor Costs on IPR and Conventionally Managed Jersey Farms. (Includes Contract Labor)

Farm Category	Total and Per Cow Labor Cost ($)
Med. Jersey, IPR & Purch. Feed n=5	18195 407
Med. Jersey, IPR & Crops n=3	21708 645
Med. Jersey, Conventional 2x n=3	29540 464
Lg. Jersey, Conventional 2x n=1	29311 266
Lg. Jersey, Conventional 3x n=1	96679 293

Table 3. Equipment Costs on Jersey Case Study Farms.

Farm Category	Total and Per Cow Cost ($) Economic Costs	Total and Per Cow Cost ($ Cash Basis
Med. Jersey, IPR & Purch. Feed n=5	2217 50	9966 223
Med. Jersey, IPR & Crops n=3	6970 207	22094 656
Med. Jersey, Conventional 2x n=3	10868 171	39262 617
Lg. Jersey, Conventional 2x n=1	10293 94	35645 324
Lg. Jersey, Conventional 3x n=1	13993 42	34730 105

Table 4. Total "Economic" and Cash Costs and Returns from Holstein Case Study Farms.

Farm Category	Total and Per Cow Economic Costs	Total and Per Cow Net Return	Total and Per Cow Cash Cost	Total and Per Cow Net Cash Return
Med. Holstein, IPR & Crops n=3	60033 1012	69036 1164	74313 1253	54755 923
Med. Holstein, Conventional 2x n=3	79834 1565	32643 640	109985 2157	2492 49
Lg. Holstein, IPR & Crops n=2	110397 1240	83180 935	142575 1602	51002 573
Lg. Holstein, Conventional 2x n=3	179884 1273	140463 994	222000 1571	98347 696

Table 5. Labor Costs on IPR and Conventionally Managed Holstein Farms

	Total and Per Cow Labor Costs (Including Contract)
Med. Holstein, IPR & Crops n=3	22893 386
Med. Holstein Conventional 2x n=3	22847 448
Lg. Holstein, IPR & Crops n=2	30506 343
Lg. Holstein, Conventional n=3	36166 256

Table 6. Equipment Costs on Holstein Case Study Farms.

	Total and Per Cow Costs ($) Economic Costs	Total and Per Cow Cost ($) Cash Basis
Med. Holstein, IPR & Crops n=3	12430 210	26711 450
Lg. Holstein, IPR & Crops n=2	14827 167	47004 528
Med. Holstein, Conventional n=3	12254 240	42405 831
Lg. Holstein, Conventional n=3	16910 120	59026 418

practicing IPR management were observed to hold off farm jobs and still keep total hours worked at acceptable levels. The additional sources of income permitted some families to continue operating medium sized farms which could not have otherwise generated an acceptable standard of living though farm remained profitable.

Equipment Use. As is shown in Table 3, farms which practice both IPR and purchased feed management incur substantially less equipment expense than do conventionally managed farms or IPR farms which also crop. Some of the advantage of IPR management appears to be lost if the farm continues to crop, and does not plan carefully in using its equipment efficiently. The reason for this is clear.

If a farm has cropping activities, equipment should be used to its economic capacity. Equipment such as tractors, balers, etc. come in "lumpy" units. The reduced demand on equipment resulting from animals getting more of their nutrition needs from pasture does not reduce equipment ownership costs. Much of the difference in cash costs observed between medium Jersey IPR, Purchased Feed Farms and Medium Jersey IPR, Crop Farms is due to this phenomenon. The relationship repeats between Large Holstein IPR and conventionally managed farms (see Table 6). In both cases the IPR farms are on the lower end of the cow number side of the category, it is possible larger farms in the medium category would use cropping equipment more efficiently. However, no such farms were found in the study area. Comparisons between unit equipment costs of medium and large size categories indicate economies of scale in equipment use regardless of management system.

Short versus Long - Run Profitability and Debt Costs. Tables 1 and 4 compare total "economic" costs and returns and annual cash flows for Jersey and Holstein herds. The difference lies in how durable expense items are handled. For example, a tractor which costs $50,000 today may have 5,000 hours of expected life. Today's hourly economic cost would be 50,000/5,000 = $10.00 per hour using a straight line assumption. The producer may use this tractor over a decade so the economic cost can be spread over ten years. However, most producers will have financed some or all of the capital to purchase the machine at a locally standard loan period of 5 years. Cash cost reflects the fact that the producer must make periodic payments of principal and interest over a shorter period than the economic life of the equipment. The potentially reduced equipment needs of IPR management due to the increased use of pasture as a feed source may significantly reduce the cash demands and therefore the intermediate term debt loads of those who practice IPR.

Table 1 contrasts total economic to cash costs and net returns[1] for Jersey herds. As described earlier, medium IPR & purchased feed farms and conventionally managed farms generated almost identical economic costs on a unit basis. However, due to the lower equipment needs of a purchased feed operation, unit cash costs are substantially lower on a cash basis. This phenomenon is reenforced in the net revenue figures which show the IPR & purchased feed category out performing conventionally managed medium sized herds on a both a total and unit cash basis despite the contrary result in terms of economic costs and net returns. Such results would tend to make IPR technology more attractive to producers in the short-run. Caution must be used in interpreting revenue results. Because of the case study nature of the data, it is not possible to unambiguously relate production differences to the management system employed.

The medium Jersey IPR % Crops category performed relatively poorly on both an economic and cash basis. Clearly, when employing pasture rotation and cropping activities, management

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[1] Net figures are computed as a return to management, land, buildings, and risk

attention must be paid to using all available resources efficiently. Discussions with producers indicated that many were consciously experimenting with appropriate operation size after having adopted IPR management techniques.

The results in Table 4 indicate that medium Holstein herds employing IPR management out performed the selected conventionally managed farms in all cost and net return categories. The same cannot be said in the comparison of large sized Holstein herds. As currently practiced, IPR management in large holstein herds would appear to suffer from diseconomies of scale.

IV. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FUTURE RESEARCH

This paper was intended to report the initial progress towards determining the appropriate economic role(s) of Intensive Pasture Management in Northeast dairy agriculture. Data from a series of 25 case studies conducted between July and September 1991 are summarized. Included in the analysis were examples of "best practice" conventionally managed farms for comparison purposes. The variables examined with respect to the impact of pasture management included, herd size, breed type, labor use, equipment use, economic costs and revenues as well as cash flow.

The study begins to support a positive role for IPR management in Northeast dairy production, but suggests that systems primarily based on pasture feeding during the growing season will not be a panacea for all. Results indicate that as practiced, IPR management is a better alternative for medium sized herds than for large herds. Diseconomies of scale were observed in the larger size categories.

The results also indicate that careful planning is required in the case of IPR management systems that continue to incorporate crop enterprises. Herd sizes must be managed so that both pasture and capital resources are used efficiently.

The reduced demand for nutrients from on farm crop enterprises means the input demand for labor on farms is reduced and distributed more uniformly across the day, season, and year. In the extreme case of 100% purchased feed, IPR operations, enough labor was released from the farms to permit off-farm employment of the operators. Looking at the family operation as a whole, we observe a unit consisting of a moderately profitable and thriving medium sized dairy operation, combined with off farm employment to provide both sufficient family income and a sustainable standard of living.

Excessive debt loads and interest rate risk are often cited as a major source of financial difficulty on Northeast dairy farms. The case study results tend to support the hypothesis that short term net cash flows can be improved by substituting management for capital in terms of supplying a higher percentage of animal nutrition needs from pasture sources rather than from crop enterprises reducing the need for costly equipment.

Case studies such as this can provide valuable insights into the economics of current IPR practices in current conditions, but have limited application in examining the impact of IPR management under the full range of resource constraints and relative price changes that might be expected to occur in both inputs and output. These questions can only be answered though the use of simulation models which permit the isolation and interaction of these key variables.

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The Economics of Intensive Pasture Rotation in Northern New England: A Mathematical Programming Approach

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I. INTRODUCTION TO ECONOMIC ANALYSIS

Census data indicate the trend of disappearing numbers of dairy farms in the Northeast and Vermont has progressed unabated since we have recorded such figures. The reasons for this trend can be traced to productivity enhancing advances in technology and management which have permitted fewer farms to produce more milk using fewer of society's resources. In addition, we see increasing alternative demands on the land and labor resources of the region. On the consumer side, the recent growth in the demand for dairy products has been flat or non existent while the demand for milk has been typically inelastic.

For the most part this development has been positive for consumers, in that we have enjoyed a reliable and relatively inexpensive supply of a wholesome food source, while at the same time, those left in business of producing milk stood a better chance of earning a good living.

More recently, many have become concerned with the pace of this trend and its apparent consequences. Technology driven economies of scale are most often pointed to as the source of the small and medium sized dairy farm's inability to compete with the regional and national trend towards larger production units. If the pace of disappearance of farm numbers continues past some vaguely defined threshold level, the structure of our rural economy may be irreversibly changed from one of a productive agriculture and tourism based economy to something very different, and to many, less desirable.

In addition to the shrinkage in farm numbers in our rural communities, there is also a rise in concern for the environmental impact of dairy farming systems that rely on cropping and confinement feeding as key components to the management system. These concerns focus on the long-term environmental "sustainability" of farming systems that rely on regular applications of pesticides and fertilizers as well as the potential for ground and surface water nitrate and phosphorous contamination resulting from excessive and concentrated applications of cow manure to the soil (Young,1985,1986).

Focus on the management variable in dairy farming makes sense with respect to addressing both the profitability and environmental problems mentioned above. If there exist levels and types of management which can be substituted for scarce and expensive capital, land, and labor resources on the farm, profitability may be improved, while lowering cash expenses. Similarly, there may be management techniques which can be applied to the dairy farm which reduce environmental impacts without adversely affecting profits.

Recently, there has been increased interest in farm management systems that incorporate pasture as a major component of the dairy management system (Murphy, 1986 Burns, 1988; Pillsbury, 1989). Under the names of Intensive Pasture Rotation or Controlled Grazing (hereafter IPR) there exists a family of dairy management approaches that seek to:

1. Lower the demand for cropped and purchased feeds by supplementing or supplanting traditional sources of animal nutrition with pasture.

2. Lower the cash input expenses of the farm by substituting operator management for labor and capital without sacrificing profitability.

3. Lower the adverse environmental impact of dairy management systems by reducing the demand for pesticide and fertilizer inputs as well as concentrated applications of manure to the soil.

The purpose of this research is to examine how IPR management impacts the use of land labor and capital resources on medium sized dairy farms. Specifically, we seek answers to how IPR management affects dairy farms in the areas of labor use, equipment use, cash flow, and overall profitability. We hope to demonstrate the set of economic circumstances where IPR management makes sense in contrast to conventional confinement management practices on medium sized dairy farms.

II. DESCRIPTION OF INTENSIVE PASTURE ROTATION MANAGEMENT

IPR management is comprised of a set of practices designed to exploit maximum advantage of an under-utilized resource on farms in the Northeast; the pasture. Most dairy farms in the northeast practice some form of confinement management where cows are kept in the barn most of the time and feed is brought to the animals. Such a system typically employs little or no use of pasture as a feed source except for young and dry stock.

What pasture is used in the Northeast is subject to continuous grazing which means animals are confined in large spaces and they choose when and where to take grass. Such a system retards pasture regrowth and therefore the amount of potential feed value to the animal (Murphy, 1992).

In an IPR system, pasture forage becomes a principle feed source during the late spring, summer and early fall months. Additional feed sources are used as supplements to maintain production levels. Animals are confined to relatively small paddock sizes, usually by temporary fences, which are designed to permit the optimal amount of nutrient value to be removed in twelve hours. By "optimal" is meant to balance the amount of nutrient value removed by animals against pasture regrowth rates. The objective is to maximize the total nutrient value available to the animal over the season. Animals are then moved to a new paddock and the old paddock is allowed to regrow. The number of paddocks in the rotation is lowered when pasture regrowth is rapid and increased when regrowth slows as the season progresses. If regrowth exceeds the animal's capacity to consume, as is quite likely in the late spring and early summer, the excess can be baled or chopped as feed or mowed and removed.

If implemented successfully, the IPR system has a number of potential economic, agronomic and environmental advantages both at the farm level and to the dairy production industry at large. At the economic level, an IPR system can reduce cash expenses on the farm by substituting owner management for capital inputs while at least maintaining production. IPR systems reduce the need for cropped feed sources and therefore some or all of the equipment necessary to support crop activities. In addition, as crop activities are reduced, the demand for labor overall and particularly at peak times such as planting and harvest is reduced. IPR management tends to use labor in a more uniform fashion throughout the growing season, lessening the demand for hired labor.

The demand for labor on the farm is also lessened during the pasture season due to the fact that the animals spend relatively little time in the barn. Labor savings may be offset to some degree by the increased demand for time in moving paddocks, water supplies, etc.

Because, the animals are not confined indoors during the pasture season, but rather are regularly rotated through the available pasture land, the need for investment in manure containment and disposal system capacity is reduced.

From the agronomic point of view, IPR management tends to promote faster pasture regrowth, increasing the amount of usable nutritional value available to animals. In addition, IPR management in Northeast pastures tends to promote higher densities of legume type plant species such as clover. This phenomenon, increases available nutrient value to dairy animals and reduces the need for added soil fertility inputs.

From the environmental perspective, the regular rotation of animals through pasture paddocks during the growing season means that nitrogen and phosphorous run-off and leeching is reduced in comparison with systems that rely on concentrated applications of manure on top of or into the soil. Non point source pollution of surface and ground water supplies an issue of growing concern in many parts of the country where dairy farming is concentrated. IPR as a management practice represents a potential though partial solution to this problem. In addition, by reducing the demand for crops on the farm, fertilizer and chemical applications to the soil will be reduced.

III. EXAMINING THE ECONOMICS OF INTENSIVE PASTURE ROTATION: THE MATHEMATICAL PROGRAMMING MODEL

The General Model

Math programming models, sometimes called Operations Research models, are the logical conceptual approach to examining the economics of IPR management. The profitability of IPR management in dairy farming is affected by a variety of farm level and economic and policy influences such as milk prices and pricing policies, feed prices, labor costs and availability, fertilizer and chemical inputs, nutritional quality and quantity of pasture sources. In turn, significant adoption of IPR management practices in the region, will affect the demand for inputs, and seasonal availability of milk supplies. Only a mathematical programming model can simultaneously account for and examine all these influences.

In addition, math programming models generate results that are easily transformed into budget presentation format. This is of particular advantage for extension and technology adoption purposes. Farm decision makers, who may be unfamiliar with the programming research method, can readily interpret results and recommendations in the form of budgets. These budgets can be compared and adapted to their own local circumstances.

The specific approach used to examine IPR management on dairy farms was the development of a Linear Programming (LP) simulation model of a "representative" dairy farm. LP models farm operations under the assumption of maximization of the value of an explicit objective function constrained by the resource limitations, prices, and technology available to the farm.

The representative farm concept is designed to incorporate the typical attributes associated with the type of farm to be studied; in this case medium sized Jersey and Holstein herds representative of dairy farming in Vermont. The representative farm is not meant to replicate any particular farm exactly, but rather an average of farms observed in the category.

LP is considered a normative economic approach because it generates results that indicate what could be possible given efficient use of the resources at hand and a stated objective or goal for operation of the farm. LP models are capable of handling a variety of operational goals, including the possibility of multiple objectives. For this application, we chose profit maximization as the operating goal for a number of reasons. First, the actual operating goals of farm operators are probably as complex and variable as people are individuals. Adopting any particular set of multi-objective goals as the operating criteria for the farm is arbitrary to the extent that excludes other possibilities. Using maximum profit as the operating objective may be simplistic, but it consistent with the efficient allocation of resources to their most valuable uses, thus speaking to the economic sustainability of IPR management. In addition, profit maximization is probably an important component of most operators criteria. The LP model used to model the impact of IPR management on dairy farms can be formally stated in general form as follows:

$$\begin{aligned} & Max \sum_{j=1}^{n} c_j\, x_j \\ & subject\ to \sum_{j=1}^{n} a_{ij}\, x_j \le b_i \quad for\ i = 1,2,\ldots,m \\ & and \quad x_j \ge 0 \quad for\ j = 1,2,\ldots,n \end{aligned} \tag{1}$$

where:
- c_j = costs and revenues associated with the activities represented in the model,
- x_j = the farm activities explicitly represented in the model,
- a_{ij} = technical coefficients which measure the resource requirements of the jth activity in the ith constraint.
- b_i = constraint values which limit the use of available resources in the model.

The major activities represented in the model simulation are presented in Table 1.

Table 1 Major Activities included in LP Model.

1. Crop Production for Hay, Haylige, Corn Silage.
2. Feed Purchase for Hay, Haylige, Corn Silage, Low - Medium - High Protein Concentrates, High Energy-Protein Supplements.
3. Pasture Production-Rotation.
4. Seasonal Milk Production.
5. Hired Labor.
6. Storage
7. Nutrient Ration Balancing.

The representative farm was modeled on a monthly activity basis in order to capture differences in crop seasons as well as winter versus summer activities. Separate models were run based on Herd type (Jersey versus Holstein), and production level (annual herd averages of 12 and 14 thousand pounds/milking cow for Jersey's and 13, 18, 22 thousand pounds for Holstein's). In each model run the herd was broken into four evenly spaced seasonal herds. The division was uniform because little or no seasonality in production was noted in the surveyed farms. Milk production in each group was distributed across a 305 day lactation curve so that peak production and nutrient demand periods would be represented. The maximum herd size; 40 milking head for Jerseys and 60 head for Holsteins was determined based on "medium" size average milking herd observed in the farm survey.

Note that no other revenue producing activities are included in the model except the sale of milk. This simplification was employed for a number of reasons. There was no commonality of revenue activities observed in the farms surveyed to generate input budget data. In addition, the inclusion of activities such as sugaring, calf sales, meat sales, etc. would tend to detract focus on the issue of study, (i.e. IPR management). Finally, the inclusion or exclusion of these activities was not expected to change or be changed by IPR management except insofar as IPR management frees up additional family labor to be directed at other activities. This conclusion can be made without direct incorporation of alternative revenue activities in the model.

A total of 1776 individual activities were incorporated into each model. A unique aspect of this model is the inclusion of an internal ration balancer which permits direct consideration of the interaction between feed quantity, quality, cost, and source on all the other economic and technical variables in the model.

Constraint categories used in the model are summarized in Table 2.

Table 2 Major Constraint Categories Included in the LP Model.

1. Limits on Total Land and Land Devoted to Particular Crops.
2. Pasture Land Limits.
3. Pasture Rotation Requirements by Season.
4. Allowed Mixes of Crop versus Purchase versus Pasture Activities.
5. Maximum Herd Size Limits.
6. Monthly Labor Demands.
7. Unpaid Labor Limits.
8. Storage Limitations.
9. Equipment Demands and Use Limits.
10. Conversion of Feed Sources to Nutrient Values.
11. Limits on Certain Nutrients and Nutrient Sources.
12. Milk Production Demand for Nutrients.

Approximately 1700 constraints were required to describe the representative farm for a given herd type and production level. The structure of specific constraint categories will be discussed in the following section.

Data Sources

On the revenue side of the objective function, monthly milk prices were calculated based on 1991 blend price averages from Federal Order #1. Prices were adjusted based on the assumed butter fat content for Jersey and Holstein cows and published fat differentials for the Federal Order.

Variable input prices for feeds, fertilizers, chemicals, etc. are based on observed prices from local dealers. Non traditional input prices purchased silage were based on interviews with surveyed farms. Equipment expenses were based on variable costs of gas, oil, and maintenance, as reported by local dealers. Fixed costs (not directly incorporated into model) were estimated based on survey reported actual use and dealer supplied information on purchase prices and expected lifetimes. For fixed cost purposes, all equipment was considered to be the same age across farms.

Technical coefficients and constraints were developed based on personal interview farm surveys conducted during the summer-fall of 1991. Using extension agents, other local experts and the producers themselves as sources of information, a total of 25 farms were identified, including 14 predominantly Jersey based herds and 11 predominantly Holstein based herds. These were all the farms known to practice IPR as a dominant component of their management system in the northern Vermont study area. To minimize performance and productivity differences due to economies of scale, breed type, technology and particular form of pasture rotation practiced, farms were grouped and analyzed so as to isolate the following characteristics.

- Herd Size
- Herd Type
- IPR Management and Primarily Purchased Feed (i.e. little or no cropping).
- IPR and Cropping Activities.

In each size category, a "conventionally" managed, i.e. confinement managed, farm was identified and interviewed for comparison purposes. These benchmark farms were selected because they were thought to represent examples of "best management practices" for their category.

Each farm was subjected to detailed personal interviews, over the period July-September 1991, seeking to identify and enumerate all labor practices, equipment use, cropping patterns, pasture rotation practices and cost categories which might be expected to change as a result of an IPR management focus. Milk production and revenue data were also collected. It should be noted that the labor practices and times included in the model were based on the recollections of the operator at the time of interview and not on observation. This may have adversely influenced the results of the labor cost part of the model and will be discussed later.

Practices and cost categories not expected to change as a result of management approach were either standardized or eliminated from the budget to minimize the impact of management quality on the results. Data were not collected on real estate or building capital expenses because such data would vary greatly from farm to farm, confusing interpretation of budgets. In addition, real estate differences are not believed to be systematically affected by the management systems under study.

Yields of forage crops (Hay, Haylige, and Corn Silage) and were based on available budget data and confirmed as reasonable by local extension agents and state extension specialists.

The nutritional content of cropped and purchased forages was based on recognized text values for feeds of the type employed. These values were adjusted based on the recommendations of local Extension Nutrition Specialists and University forage lab personnel. The nutritional content of purchased feeds and supplements was based on analyses provided by the grain dealers.

Pasture data reflecting quantity, quality and regrowth was devised using experimental data from Murphy (1992). The data were confirmed based on research done by Welch (1992) which back-calculated the nutrient value of pasture intake based on measurement of all other feed components and observed milk production. The above information permitted the calculation of the amount pasture land required assuming 12 hour rotation periods, observed regrowth, and maximum of two percent of body weight intake of pasture (on a dry matter basis).

The model was designed to determine the profit maximizing ration given milk prices, the sources and costs of available feeds, costs and availability of other physical inputs, and the nutritional requirements of the animal. Rations were balanced internally on Energy (Mcals.), Protein, Calcium, Phosphorous, and NDF.

IV. RESULTS

A total of fifteen models were examined so that the impacts breed type, (Jersey and Holstein) production level, and each of three management systems could be analyzed separately and compared. Optimal LP solutions were generated for each model. Results of these model simulations are summarized in Tables 3-8. Discussion of the model results is organized into four categories where IPR management seems to have the greatest potential impact at the farm level; feed costs, land use, labor use, and returns.

A word of caution is advisable with respect to interpretation of the results of these simulations. An LP model generate perfectly efficient results given costs, returns, technology and resource constraints specified in the model. The solutions represent what could be if managers made flawless decisions with perfect information. For example, the efficiency of feed use (and therefore the efficiency of cost) may seem excessive to knowledgeable readers. The results of these simulation models have their greatest value in relative comparisons (e.g. IPR management versus Confinement Management).

Feed Costs

As demonstrated in Table 3, the clearest result stemming from the model simulations is that IPR management save significant can save considerable cash resources over traditional confinement management systems. The reduced demand for on farm and purchased feeds results from using the pasture as a significant source of growing season nutrition. This result holds up across breeds and milk production levels. At the high herd production averages, efficient seasonal use of the pasture

Table 3 Variable Feed Costs (in dollars) by Management System

Model Type	Confinement	Pasture-Crops	Pasture-Purchase
Hol. 22K	52,156	36,710 (-30%)	33,769 (-35%)
Hol. 18K	43,482	29,603 (-32%)	27,199 (-37%)
Hol. 13K	36,549	24,138 (-34%)	23,000 (-37%)
Jer. 14K	31,107	22,029 (-29%)	18,583 (-40%)
Jer. 12K	28,934	19,127 (-33%)	15,335 (-47%)

Table 4 Total Land Use (acres) by Management System.

Model Type	Confinement	Pasture-Crops	Pasture-Purchase
Hol. 22K	108	76 (-30%)	59 (-45%)
Hol. 18K	92	67 (-26%)	59 (-41%)
Hol. 13K	71	63 (-11%)	59 (-17%)
Jer. 14K	41	40 (00%)	23 (-44%)
Jer. 12K	34	29 (-12%)	22 (-35%)

Table 5 Total Labor Use (hours) by Management System

Model Type	Confinement	Pasture-Crops	Pasture-Purchase
Hol. 22K	2,349	2,271 (-03%)	3,948 (+54%)
Hol. 18K	2,271	2,103 (-07%)	3,661 (+61%)
Hol. 13K	2,388	2,158 (-09%)	3,749 (+57%)
Jer. 14K	2,161	2,148 (-01%)	1,742 (-19%)
Jer. 12K	2,159	2,072 (-04%)	1,747 (-19%)

the pasture resource is able to provide sufficient nutrition to enable lower demand for cropped forages and purchased concentrates. Savings in feed costs range from 29% for the 14K annual average Jersey herd to 47% for the low producing Jersey herd. Holstein results are similar in magnitude while generating higher milk production.

Another measure of the impact of IPR management on feed costs is a feed cost ratio or feed cost of production per hundred weight of milk. Table 6. compares breeds, production level and management system with respect to the feed cost of producing milk. For all production categories, IPR management produces milk at a lower per unit cost.

Table 6 Feed Cost per Hundred-weight of Milk.

Category	Confinement	Pasture-Crops	Pasture-Purchase
Holstein 22K:	3.95	2.78	2.55
Holstein 18K:	4.02	2.74	2.51
Holstein 13K:	4.68	3.09	2.95
Jersey 14K:	4.93	3.50	2.95
Jersey 12K:	5.36	3.54	2.83

A strictly purchase feed IPR management model was included in the analysis, because it was felt that such an operation could take maximum advantage of the lower demand for cropping equipment that is one of the principle advantages of an IPR system. Operators adopting an IPR system have a given equipment complement which, to serve as an effective investment, must be used efficiently. Lowering the demand for crop equipment without planning for using the equipment profitably or changing equipment complements will result in increased loses. The purchase feed model consistently results in lower feed cost per unit milk.

Land Use

As indicated in Tables 4, IPR managed farms will tend to use land more efficiently to feed cows than confinement managed farms. The disparity in land use is positively correlated with production levels. As the production per animal raises, relatively more, and higher quality feed is required to produce the additional pounds of milk. This tends to decrease the demand for cropped forages on confinement managed farms, in favor of high quality concentrates with pasture feed sources making up the difference. In addition, some of the demand for hay or haylige based feeds can be meet on land used in the pasture rotation. This is most true during the early months (Late May and June) of the pasture rotation when pasture regrowth rates outstrip the animal demand for pasture. Excess forage must be removed to maintain pasture quality. This material can be used as feed. The Pasture & Crops model assumed all excess regrowth was taken as hay or haylige.

Another factor at work in the demand for pasture land on IPR managed farms is partly a function of the model design. The model assumed that the cows could consume up to two percent of body weight per day from pasture sources. According to results generated by Welch (1992), exceeding this limit might result in nutritional problems and lower milk performance though perhaps not profitability. Allowing a higher consumption rate of pasture was not allowed because of the lack of data on animal health at levels over 2% of body weight. As long as the model found pasture to be the cost effective source of nutrition, the model would choose this source up to the two percent limit. In the early and late season, pasture regrowth rates are sufficiently slow so as to greatly expand the acreage necessary to meet nutritional needs.

Pasture limits could have been set in the early and late seasons which would have greatly reduced the overall demand for land, but this would only have been accomplished by shifting to higher cost feed sources. While fixed land charges were not included in the model, LP analysis facilitates determining the value of a resource through the concept of "dual" or "shadow" prices which represent the value of an additional unit of resource unit (like an acre of pasture) to the objective function. In all IPR simulations the value additional acres of pasture in the early and late seasons far exceeded any current rental rates for pasture acreage.

The implications of these land use results with respect to recommending a pasture based management system cannot be ignored. Under the conditions studied, Pasture management results in more efficient use of land, which may be of particular value to farms which are relatively land poor or located on land which is not well suited to crops (eg. hillside farms).

Labor Use

The results of the analysis with respect to labor use on IPR managed farms was in many ways inconclusive. The prior expectation was that IPR managed farms would use significantly less labor than a similar size confinement managed farm due to reduced cropping demands. In addition, to lower overall demand for labor, it was expected that with reduced crop needs, IPR managed farms would use less hired labor. Labor use on pasture managed farms should be more uniformly distributed throughout the year, with less "peak" seasonal demands generated by cropping activities. The LP model was not well suited for examining the peak labor demand issue because it was organized in monthly production periods by logistical necessity. Any peak demand times which would necessitate hired labor were averaged across the month and only partially captured by the model.

As shown in the Table 5 the LP model simulations failed to show any consistent savings of labor use on IPR managed farms relative to confinement management except in the case of Jersey IPR-Purchase Feed management. In Holstein IPR-Purchase Feed operations, the simulation showed considerable increases in labor use. In all other cases labor use was relatively unchanged as a result of management system. There were a number factors which contributed to these unexpected results.

For each management and breed category, labor demands for the various activities identified on the farm were derived by personal interview with the operators. We have found, through experience that precise recollection of times spent in specific activities is difficult and variable. Such information needs to be developed through Time and Motion studies, but this approach is costly and time consuming.

In addition, several of the IPR farms interviewed had only recently adopted the management approach and may have been early in the learning curve. Examination of the labor time coefficients for the IPR farms involved in the study show many relative inefficiencies in tasks that are not related to pasture management, e.g milking, winter manure handling, etc. (see Condon & Ashley, 1992). Clearly, a definitive answer to the issue of labor use is a topic which will require further research.

Net Returns

The relative profitability of IPR management systems is examined in Tables 7. IPR management systems clearly have the potential to enhance net revenues on medium sized dairy farms where the system faces no technological or logistical barriers. Measured over variable costs only, IPR management generates income largely through savings in purchased feed and cultivation costs. The improved returns hold up even in high producing herds where expensive supplements must be used to maintain production levels.

The impact of IPR management on profitability is seen even more strongly when fixed costs are added back into the picture. For each management system, the ownership costs of a "typical" complement of cropping equipment were estimated based on the results of the farm surveys. To minimize differences across farms in age or quality of equipment, all machinery was valued as if new. Purchase prices and rated useful life spans for cropping equipment were obtained from local dealers. The variable costs associated with operating

Table 7 Net Returns ($) by Management System

Model Type	Confinement	Pasture-Crops	Pasture-Purchase
Returns Over Variable and Selected Fixed Costs *			
Hol. 22K	81,786	101,890 (+25%)	109,950 (+34%)
Hol. 18K	66,707	88,698 (+33%)	94,462 (+42%)
Hol. 13K	43,231	59,155 (+37%)	64,410 (+48%)
Jer. 14K	33,024	46,709 (+41%)	50,521 (+52%)
Jer. 12K	31,211	42,040 (+35%)	45,318 (+45%)
Returns Over Variable and Selected Fixed Costs (Cash Flow Basis) **			
Hol. 22K	63,480	84,320 (+33%)	109,540 (+72%)
Hol. 18K	36,321	72,840 (+101%)	94,320 (159%)
Hol. 13K	13,472	45,201 (+236%)	64,306 (+379%)
Jer. 14K	1,900	27,745 (+1360%)	37,654 (+145%)
Jer. 12K	-584	21,710	34,053

this equipment is already represented in the crop budgets used to construct the LP models.

Fixed costs associated with other sources on the farm such as milking equipment, buildings, land, etc were not considered here because they were not expected to change as a function of the management systems under study.

Equipment ownership costs were computed in two ways. First, the annual ownership costs were computed, depreciated, and charged an opportunity cost over the anticipated working life of the equipment. Net returns including equipment ownership costs calculated in this way appear in Table 7. as "Returns over Variable and Selected Fixed Costs." These values are best interpreted in the context of the long run sustainability of IPR management systems.

Equipment Costs were also estimated on a cash flow basis where all equipment was assumed to be financed at current competitive rates and terms. While this is an extreme assumption, it does emphsis more of the short term decision problems faced by managers. The net income values from this calculation should only be evalusated on a relative basis between management styles.

In either circumstance, it is clear that the addition of equipment ownership costs to the net returns equation favors the profitability of IPR management systems at all levels of production.

V. SENSITIVITY OF OPTIMAL SOLUTIONS

Linear Programming permits analysis of the sensitivity or stability of the maximum profit solutions identified by the representative farm simulations. In this case, the appropriate variable to monitor is the relationship between pasture costs the profitability of the intensively rotated pasture activity in the model. The sensitivity analysis will examine the allowable increase in the costs of employing intensive pasture rotation before the model would choose to reduce the use of this activity.

In this simulation the pasture rotation activity is unusually stable with respect to increases in the variable costs of pasture in most cases, small changes in the cost of an activity will induce changes in the optimal mix of activities as the model seeks to generate the maximum possible profit. The results of this simulation indicate that a minimum of a twenty-fold increase in the variable costs of maintaining pasture would be tolerated before the model would choose to use less of this activity. The most sensitive month with respect to intensive pasture use is September, where grass regrowth is at its slowest and more acres are required to complete rotations. In other months pasture costs could increase even higher before the model would opt to reduce this activity. Intensive pasture management appears to make sense under a wide range of relative cost situations.

VI. SUMMARY

Based on this study's results, Intensive Pasture Rotation as a management alternative must be given serious consideration by any medium sized dairy farm with the pasture resources at hand. IPR management can significantly enhance the profitability of the dairy operation through reductions in the variable and fixed costs associated with feeding dairy cows at all levels of production.

Specifically the study has shown that variable feeding costs are significantly reduced as a result of reduced demand for forage crops and purchased feeds. Forty percent reductions in variable feed costs over conventional techniques appear possible in well managed IPR systems. Further, simulation results indicate that the modle is very stable with respect to increases in the costs of maintaining pastures.

The agronomic and animal science research associated with this project has demonstrated that a well managed pasture can become the foundation of an effective feeding program for dairy cows. This economic analysis has showed that the pasture resource is financially productive as well.

Excessive debt loads and interest rate risk are often cited as a major source of financial difficulty on Northeast dairy farms. This study tends to support the hypothesis that short term net cash flows can be improved by substituting management for capital in terms of supplying a higher percentage of animal nutrition needs from pasture sources rather than from crop enterprises thus reducing the need for costly equipment.

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Contract Grazing of Beef Cattle: A Decision Theory/Portfolio Comparison

by

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Contract Grazing of Beef Cattle: A Decision Theory/Portfolio Comparison

Abstract

Contract grazing, a pasture-based beef cattle production option that is gaining in popularity, is compared to traditional pasture-based resource alternatives such as cow/calf and summer stocker in terms of profit and risk characteristics. Two conceptual frameworks are used: decision theory and portfolio theory. Models were developed for each and estimated using primary and secondary data with West Virginia as the study area. Contract grazing is found to be an optimal alternative under a wide range of scenarios. In addition, the solution is relatively insensitive to model specification. A benefit of using two frameworks is that the results are potentially more robust.

Key words: contract grazing, pasture resources, beef cattle, decision theory, portfolio analysis

A contract is a tool by which individuals (sometimes assisted by an attorney) establish a private set of rules to govern a particular business or personal relationship (Dunfee et al.). Contracts have been used in production agriculture for many years (a summary of the different types of contracts used in agriculture is contained in Heifner, Wright, and Plato). For example, the poultry industry is almost totally vertically integrated and utilizes contracts for over 90% of total production and marketing (Osborne, 1992). In contrast, only 10% of the cattle on feed are under contract (USDA, 1992). Among other things, contracts provide a mechanism for producers and buyers alike to potentially reduce business risk. The contractual arrangement depicted in this study is the contract grazing of feeder cattle, an arrangement whereby cattle owned by one party (the cattle owner) utilize the pasture resources of another party (the land owner) in exchange for a previously negotiated price. This study examines contracts from the land owner's perspective.

Despite the fact that contract grazing as a beef cattle production option is fairly widespread, only one known study has focused on analyzing the underlying economics. Johnson, Spreen, and Hewitt (JSH) use a stochastic dominance approach to evaluate contract grazing. They find that the optimal alternative depends on the negotiated price per pound of gain, the higher the price, other things equal, the more desirable the contract grazing option.

Although this study resembles the JSH study, the results from these two studies can not be directly compared given differences in the approach, time period, study area, and production options considered. The key difference is that in this study the results are compared under two different analytical frameworks: decision theory and portfolio theory. Such a "horizontally-integrated" approach provides a mechanism to determine whether or not the results are sensitive to model specification. In the process, it increases the robustness of results, and therefore their reliability for decision-making or policy formulation purposes. An example of a study using two models/frameworks is where Gebremeskel and Shumway use a decision theoretic approach together with linear programming to identify optimal calf marketing strategies. Besides the fact that they evaluate a different product, another difference between this study and that one is that this study uses a decision theoretic approach in conjunction with quadratic programming.

The objective is to determine the profitability and risk attributes of contract grazing as a production option by itself or in conjunction with existing cattle production alternatives. Contract grazing is compared to two traditional alternatives, cow/calf and summer stocker production. Models were developed under each conceptual framework (decision theory and portfolio theory) and estimated using a combination of primary and secondary data. The application is to West Virginia (WV), where beef cattle traditionally have dominated receipts from production agriculture ($123 million or 36% of the total in 1990), and where contract grazing potentially fits in well with pasture and other resource endowments. Further, it should be noted that the number of cattle shipped into the state has increased from 3,000 head in 1980 to 30,000 head in 1991 (WV Department of Agriculture).

A brief review of the theoretical framework underlying the economic analysis is presented next, followed by a description of the methodology including the models. The data requirements are then outlined, followed by a discussion of the results and their implications. For ease of exposition, the decision theory analysis and portfolio analysis are generally covered under separate headings in most sections.

Theoretical Framework

<u>Decision Theory</u>

Decision theory has been used extensively in agricultural production analysis. Knight classified the degrees of knowledge as: (a) perfect knowledge, (b) risk, a priori or statistical, and (c) uncertainty. Knight's three categories, although they have been elaborated upon and redefined by others since 1921, are still applicable to all forms of business (Castle, Becker and Smith).

Prior to Knight, Bayes and Bernoulli established the theories and principles upon which decision theory is modeled. Bayes' theorem is shown in discrete form as:

$$P(\Theta_i|z_k) = \frac{P(\Theta_i)P(z_k|\Theta_i)}{\sum_{iP}(\Theta_i)P(z_k|\Theta_i)} = \frac{P(\Theta_i,z_k)}{P(z_k)} \qquad (1)$$

where $P(\Theta_i \mid z_k)$ is the conditional posterior probability, $P(\Theta_i)$ is the probability of states Θ_i, and $P(z_k \mid \Theta_i)$ is the conditional likelihood of the state (Anderson, Dillon, and Hardaker, 1977). Bernoulli's principle provides the means for ranking risky prospects in order of preference, the most preferred being the one with the highest (expected) utility. It thus brings together in an explicit way the decision maker's degree of belief and degree of preference. The latter, of course, is an important subjective input in a decision analysis (Anderson, Dillon and Hardaker). The combination of the Bayes, Bernoulli, Knight, and von Neumann and Morgenstern work provides the foundation for the models currently used.

<u>Portfolio Theory</u>

The portfolio approach allows one to analyze how risk to an investor or a producer is affected by product diversification, with the potential for risk reduction determined by the number of alternatives in the portfolio, and the correlation among the expected returns of the individual alternatives.

A quadratic programming model, based on portfolio theory, was used by Hazell in the determination of optimal farm plans under uncertainty. Gebremeskel and Shumway state that quadratic programming permits tracing out efficient sets of solutions (called "portfolios") that minimize the variance in profit at alternative expected profit levels along the mean-variance (E-V) frontier. Hazell modified the quadratic programming model to include the total absolute deviations. The objective in this model was to minimize the total absolute deviations (MOTAD) the end results being approximately the same as those for the quadratic model but requiring less data. Gebremeskel and Shumway used Hazell's MOTAD model in their study of calf marketing strategies. Anderson, Dillon, and Hardaker further discuss the E-V and MOTAD approaches.

The literature contains numerous other applications based on either decision theory or portfolio theory for evaluating comparative production systems. As usually pointed out in these studies, each model has limitations depending upon the given situation. Using a combination of approaches can help overcome these limitations.

Methodology

Three beef cattle production alternatives are compared: cow/calf (C/C), summer stocker (S/S), and contract grazing (C/G). Enterprise budgets were developed for each of these alternatives as one of the inputs into the decision theoretic and portfolio analyses. The optimal alternative was first determined under various price and weather scenarios and using different criteria within the decision theoretic framework. Next, the mean-variance frontier for various portfolios comprising combinations of cow/calf, summer stocker and contract grazing alternatives was derived through a sensitivity analysis of a quadratic programming model within the Markowitz portfolio framework (Figure 1 contains a summary of the analytical procedure). Each of these analyses is described next.

<u>The Decision Theoretic Analysis</u>

Decision theory analysis involves determining the optimal alternative under five different criteria: 1) **maximin (or minimax)**, 2) **maximax (or minimin)**, 3) **minimax regret**, 4) **expected monetary value**, and 5) **expected opportunity loss.**

These are defined by Anderson, Sweeney and Williams as follows. According to the maximin criterion, the decision maker selects the alternative that **maxi**mizes the **mini**mum possible payoff. Using the maximax criterion the decision maker selects the alternative that **maxi**mizes the **maxi**mum payoff.

Using the minimax regret criterion, the decision maker selects the **minimum** of the **maximum regret**; where the regret or opportunity loss is the difference between the optimal payoff and the experienced payoff, calculated as follows:

$$R(d_i,s_j)-V^*(s_j)-V(d_i,s_j) \qquad (2)$$

where

$R(d_i,s_j)$ = regret associated with decision alternative d_i and state of nature s_j.

$V^*(s_j)$ = best payoff value under state of nature s_j.

$V(d_i,s_j)$ = experienced payoff.

The expected monetary value (EMV) criterion requires the calculation of the expected value for each decision alternative, with the alternative yielding the highest expected value to be selected. EMV is calculated in the following manner:

$$EMV(d_i)=\sum_{j=1}^{N} P(s_j)V(d_i,s_j) \tag{3}$$

where EMV(d_i) denotes the expected monetary value for alternative d_i and state of nature s_j, P(s_j) is the probability of occurrence for state of nature s_j, N is the number of possible states of nature, and V(d_i,s_j) is as previously defined.

Since one and only one of the N states of nature can occur, the associated probabilities must satisfy the following two conditions:

$$P(s_j) \geq 0 \text{ for all states of nature } j \tag{3.1}$$

and

$$\sum_{j=1}^{N} P(s_j)=P(s_1)+P(s_2)+.....+P(s_n)=1 \tag{3.2}$$

The expected opportunity loss (EOL) uses the probabilities of the states of nature as weights for the opportunity loss values and computes the expected value of the opportunity loss as follows:

$$EOL(d_i)=\sum_{j=1}^{N} P(s_j)R(d_i,s_j) \tag{4}$$

where P(S_j) is as previously defined and R(d_i,s_j) denotes the regret or opportunity loss for decision alternative d_i and state of nature s_j.

Payoffs are calculated for each pasture utilization alternative under the nine different scenarios shown in Table 1. The "high" and "low" prices, and "good" and "bad" weather in the Table represent deviations from normal.

The Portfolio Analysis

Portfolio analysis provides a framework within which the interaction and trade offs in risk and returns among the three pasture use alternatives can be considered. In this case, it addresses the issue of whether or not adding a C/G option to an existing C/C operation is an efficient strategy to increase efficiency of pasture resource use and reduce risk while maintaining or increasing returns. A quadratic programming model was developed to quantify the interactions and tradeoffs. Anderson, Dillon and Hardaker characterize the Markowitz portfolio model in the following manner:

If borrowing and lending are excluded, we must have $q_i \geq 0$ and $\Sigma q_i \leq Z$; and any specified mixture of the n risky prospects will have an expected net return of:

$$E=\sum_{i=1}^{n} q_i e_i \tag{5}$$

and variance of net return of

$$V=\sum_{i=1}^{n}\sum_{j=1}^{n} \sigma_{ij} q_i q_j=\sum_{i=1}^{n}\sum_{j=1}^{n} \rho_{ij}\sigma_i \sigma_j q_i q_j \tag{6}$$

where e_i = expected net return per unit of investment in prospect i, j = 1, 2,....,n.

σ_i = standard deviation of the per unit net returns from prospect i.

$\sigma_{ii} = \sigma^2_i$,i,e., the variance of the per unit net returns from prospect i.

σ_{ij} = covariance of the per unit net returns from prospects i and j.

ρ_{ij} = correlation coefficient of the per unit net returns from prospects i and j.

Z = total units of investment funds available.

q_i = units of investment allocated to prospect i.

After the equations were defined, they were converted to a linear form using the Kuhn-Tucker first-order conditions before estimation. The LINDO microcomputer package (Schrage) was used. A sensitivity analysis of the portfolio model was conducted to derive the efficiency frontier.

Data

Both primary and secondary data were used. A mail survey of all known contract grazers in WV was conducted with the help of the WV Cooperative Extension Service. The objective was to obtain historical data on production costs, revenues and live weight gains for C/G for the period 1989-92. A total of 32 contract grazers was contacted. The response rate was approximately 34 percent.

Secondary data needed included yearly average prices and weights of cull cows, calves, yearlings and replacement heifers for the years 1989 through 1992. Prices received were obtained from Cattle Fax (a non-profit organization located in Denver, CO) and the WV Department of Agriculture. Variable production costs were also compiled for the specific alternatives, with data sources including the WV Department of Agriculture and U.S. Department of Agriculture (1991, 1992). Input-output coefficients for the C/C and S/S enterprise budgets were obtained from Eagan (1985).

Weather data with regard to the temperature and precipitation monthly departures from normal for WV from 1989 to 1992 were obtained from the National Oceanic and Atmospheric Administration. Means were calculated assuming that the yearly seasonal average consisted of the months April through October. The reasoning behind this is that these months are considered the critical growing season for forage production, and this period includes the months during which most animal weight gain occurs (Osborne, 1991).

Results

The findings are presented in two parts. The first part consists of the findings from the decision theoretic analysis and the second one consists of the findings from the portfolio analysis.

(a) Decision Theory Results

Using the nine scenarios presented in Table 1, payoffs were calculated for each of the three alternatives under each scenario. Table 2 contains the payoffs. The C/C alternative shows the greatest variability in payoffs with a coefficient of variation (CV) of -6.82. Incidentally, the C/C alternative shows a profit in only four out of the nine scenarios (Table 2), which is consistent with a study by Cattle Fax showing that the average C/C alternative is profitable in only six years out of a twelve year period. The S/S alternative has a CV of 4.27, while the C/G alternative has a CV of 0.49.

The five decision theory criteria previously stated were applied to the results in Table 2. According to the maximin criterion, C/G is the optimal alternative because it has the maximum of the minimum payoffs ($384). However, the maximax criterion indicates that C/C has the maximum payoff, $8,349. For the minimax regret criterion, equation (2) was applied to the payoffs in Table 2. The regret results are presented in Table 3. C/G is found to be the optimal alternative with a maximum regret of -$10,087.

The EMV and EOL results are presented in Table 4. The EMVs were calculated for each alternative using equation (3). According to the EMV criterion, C/G is the optimal alternative ($4,079), followed by S/S ($290) (Table 4). Equation (4) was used in the computation of the EOL values for each alternative. The optimal decision using the EOL criterion is again the C/G operation, followed by the S/S alternative.

In summary, under all but the maximax criterion, C/G is the preferred alternative.

(b) <u>Portfolio Analysis Results</u>

In the previous section the alternatives are considered independently of the others. Even though the results clearly indicate the preference of one alternative (C/G) under most criteria, it does not reveal the nature of the tradeoffs in risk and returns among the alternatives. Portfolio analysis enables us to do this.

Figure 2 shows the mean-variance (E-V) frontier, or the nature of the trade offs between risk and returns for various combinations of the alternatives. The portfolio with the highest return is a 100% C/C operation; however it also has the highest risk. By diversifying the portfolio to include 67% C/C and 33% C/G, for example, risk is reduced by 56% while expected returns decrease by only 21%. As the proportion of C/G increases in the portfolio, the expected returns and risk both decrease, even though risk decreases at a much higher rate than expected returns.

The S/S alternative does not play a role in the portfolio diversification until expected returns are down to $1,250 and risk is below the $100 (in terms of standard deviation) range. The reason for this is its strong positive correlation with C/G (0.99), its higher standard deviation compared to that for C/G ($439 vs $376) and the higher expected return of C/G ($1,360 vs $110).

In reality, S/S and C/G are similar. Both involve an approximately six-month cycle, with an objective of maximizing weight gain per animal subject to the producer's constraint. The main difference is that in the S/S alternative one must take ownership of the animals thereby adding exposure to cattle price risk.

Conclusions

The economics of contract grazing as a beef cattle production alternative is evaluated using two different frameworks: decision theory and portfolio theory. As part of the decision theoretic analysis, expected payoffs are calculated under nine scenarios with respect to prices and weather. The payoffs were then used in the determination of the optimal alternatives for five criteria: maximin, maximax, minimax regret, expected monetary value and expected opportunity losses. Under all but one criterion (maximax where the cow/calf option is preferred) contract grazing is the optimal alternative.

Next, the tradeoffs between risk and return among the three alternatives were estimated within a portfolio framework. The cow/calf alternative is the most profitable, but also the riskiest, reinforcing the results of the decision theoretic analysis. The inclusion of contract grazing in the portfolio has the expected reduction in risk. For example, a portfolio consisting of 67% cow calf and 33% contract grazing leads to a reduction in risk of 56%, with expected returns reduced by only 21%.

It is often presumed that cow/calf producers are risk averse; however, the findings from this study contradict this presumption. This study reveals that there are less risky beef cattle production alternatives for a landowner that are comparable in profitability to cow/calf production. Within the study area a majority of producers are predominantly cow/calf producers, which indicates that either they are unaware of the risk-return characteristics of comparable alternatives or that they are less risk-averse than generally assumed.

This results suggest that contract grazing is a feasible alternative for West Virginia cattle producers/land owners and perhaps elsewhere where conditions are similar. Contract grazing is feasible not only as a sole alternative, but also in conjunction with say, an existing cow/calf operation. Due to the almost perfect positive correlation between the contract grazing and summer stocker operations, including the two in the same portfolio would increase risk.

Given the large number of small and part-time cattle producers/land owners in West Virginia and the large amount of forage produced within the state, contract grazing can offer pasture producers/land owners a relatively low cost, low risk and potentially profitable alternative.

According to USDA (1991) estimates, in 1990 WV had 642,000 acres of pasture land in use, plus 99,000 acres of idle land suitable either for pasture or crops.

A possible avenue upon which to build from this study is to explore how contract grazing compares to other operations using various marketing strategies such as hedging. Another avenue for future work is to examine the impact of taxes on the various alternatives associated with beef cattle production. There may exist tax breaks or incentives which would influence the relative economics of contract grazing, and therefore beef cattle producers' decisions about which alternative to choose. In addition, data limitations led to the assumption of environmental neutrality for the three alternatives in terms of pasture, soil and water resources impacts. This assumption needs to be relaxed in future work.

The use of contract grazing requires locating and contracting with cattle owners which can tax the abilities and time of the many small and part time farmers who currently operate cow-calf systems. Thus, the development of a contract grazing cooperative may be worthy of investigation. A cooperative could also enable the use of idle pasture land - some thing that may not other wise be possible - to provide a relatively high income, low risk alternative for the land owner-members.

Finally, the benefits from using a "horizontally-integrated" analytical approach are reinforced by this study, namely, complementarity of results and increased reliability for decision- and policy-making.

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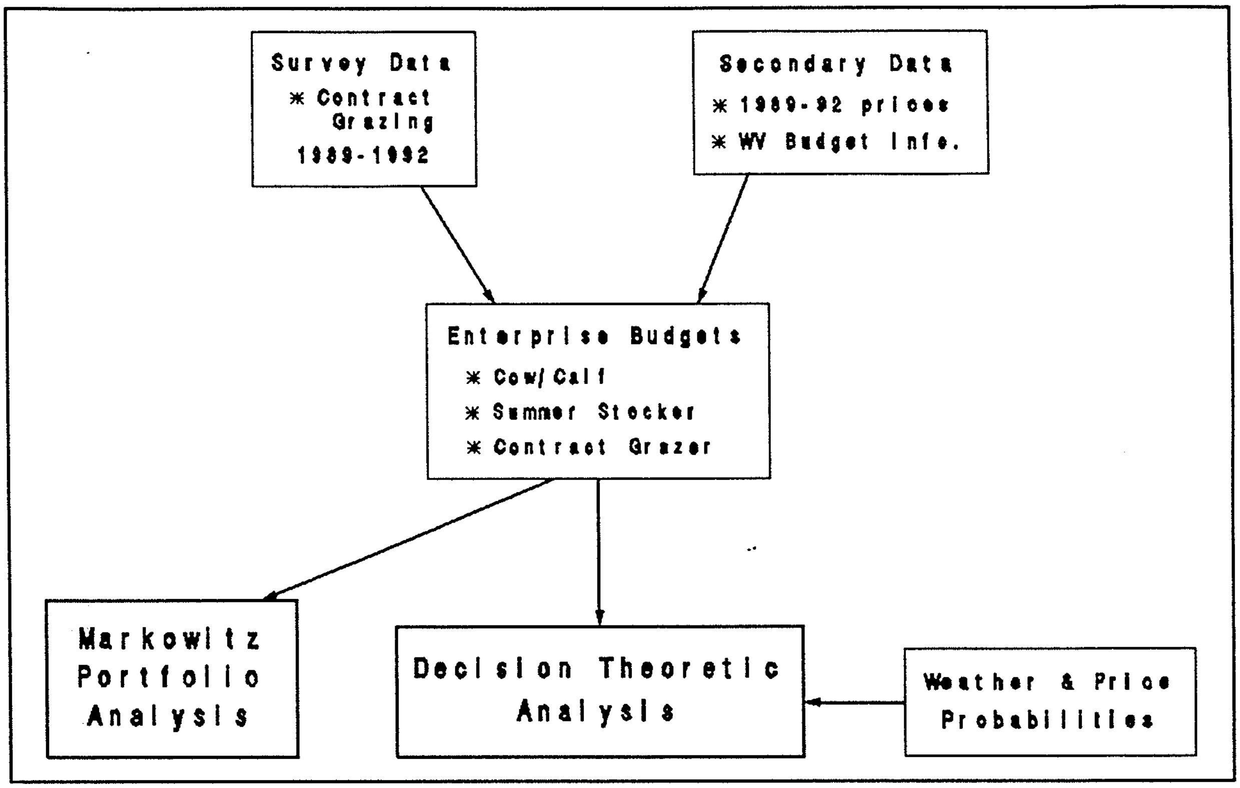

Figure 1. Flow Chart of the Analytical Procedure.

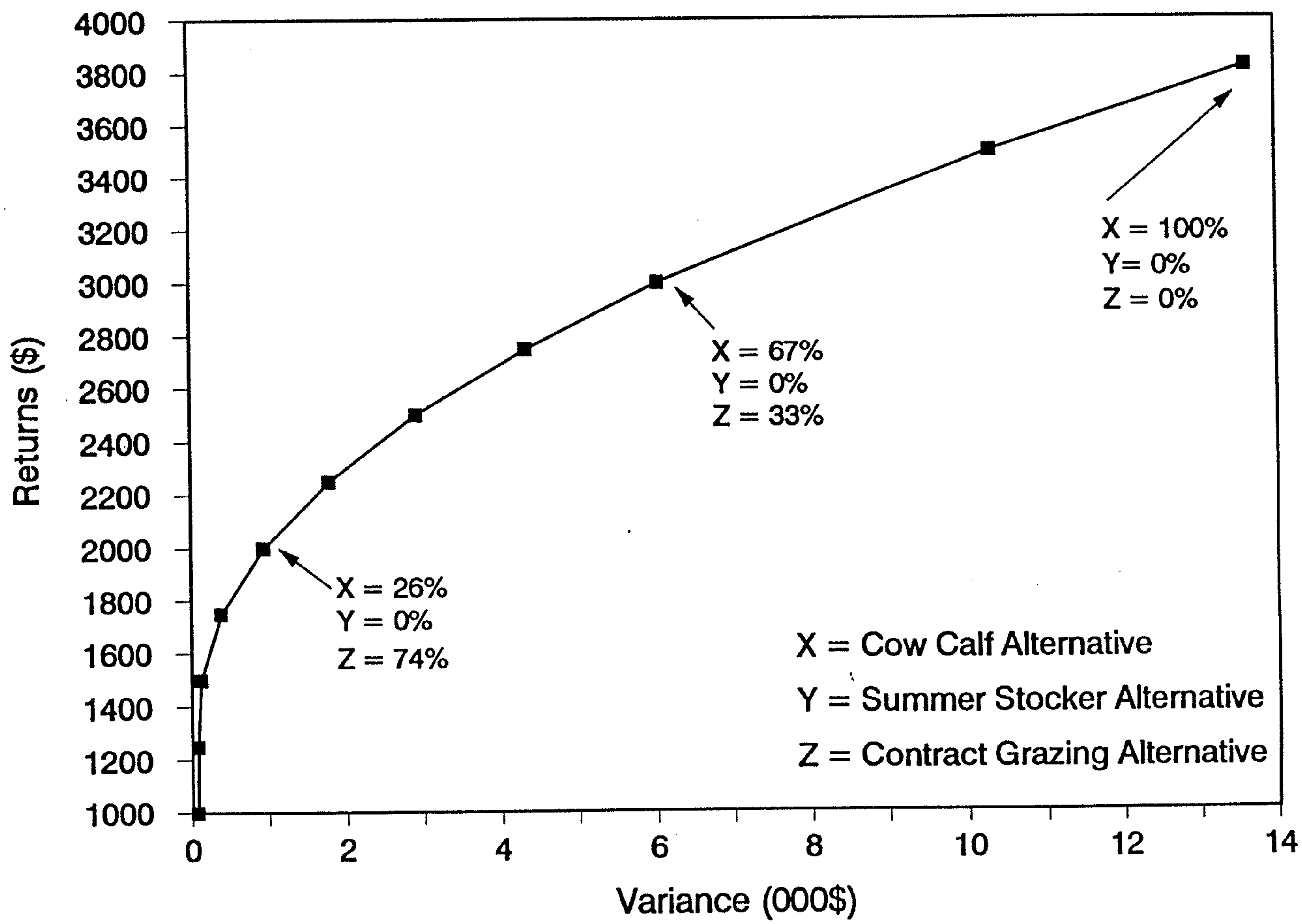

Figure 2. E-V Frontier for the Cow/Calf, Summer Stocker and Contract Grazing Alternatives

Table 1. Production and Price Scenarios for the Decision Theoretic Analysis

Scenario	Description
HP/GW	High prices and good weather
HP/AW	High prices and average weather
HP/BW	High prices and bad weather
AP/GW	Average prices and good weather
AP/AW	Average prices and average weather
AP/BW	Average prices and bad weather
LP/GW	Low prices and good weather
LP/AW	Low prices and average weather
LP/BW	Low prices and bad weather

Table 2. Payoffs for the Cow/Calf, Summer Stocker and Contract Grazing Alternatives Associated with Various Price and Production Scenarios[a]

Scenario	Cow/Calf	Summer Stocker	Contract Grazing
		-- $ --	
HP/GW	8,349	931	2,485.39
HP/AW	5,887	$654	1,735
HP/BW	3,173	($81)	985
AP/GW	487	$238	2,035
AP/AW	(1,319)[b]	$100	1,360
AP/BW	(3,303)	($164)	685
LP/GW	(5,578)	($165)	1,584
LP/AW	(6,984)	($553)	984
LP/BW	(8,390)	($297)	384

[a] All payoffs are in terms of total net returns above variable cost to the alternatives, assuming a given size operation, and are rounded to the nearest dollar. Scenarios are described in Table 1.

[b] Negative values are in parentheses.

Table 3. Minimax Regret Values for the Cow/Calf, Summer Stocker and Contract Grazing Alternatives Associated With Each Scenario

Scenario	Cow/Calf	Summer Stocker	Contract Grazing
		-- $ --	
HP/GW	0	(7,418)	(5,864)
AP/GW	0	(5,233)	(2,035)
LP/GW	0	(3,254)	(2,188)
HP/AW	(1,548)[a]	(1,797)	0
AP/AW	(2,697)	(1,260)	0
LP/AW	(3,988)	(849)	0
HP/BW	(7,162)	(1,419)	0
AP/BW	(7,968)	(1;537)	0
LP/BW	(8,774)	(681)	$0
REGRET	(32,137)	(23,448)	(10,087)

[a] Numbers in parentheses are negative values.

Table 4. EMV and EOL Values for the Cow/Calf, Summer Stocker and Contract Grazing Alternatives

	Cow/Calf	Summer Stocker	Contract Grazing
		-- $ --	
EMV	(2,515)[a]	290	4,079
EOL	(10,698)	(7,882)	(2,951)

[a] Numbers in parentheses are negative values.

Cattle and sheep grazing effects on net and rejected forage, and soil organisms, fertility, and compaction in a complex Kentucky bluegrass dominant-white clover sward

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Main

Abstract

Insufficient information exists about North American complex grass-legume swards grazed under controlled rotational management with paddocks, recovery periods that vary according to plant regrowth, high stocking densities, and short grazing periods. This experiment was done to improve understanding of sward and soil responses to such management with cattle and/or sheep grazing of low-input (no N fertilizer), complex natural swards dominated by Kentucky bluegrass (smooth-stalked meadowgrass, *Poa pratensis*) and based on white clover (*Trifolium repens)* , to develop objective management guidelines for farmers.

Treatments during two grazing seasons (1989-90) were cattle grazing alone (C), cattle followed by clipping (CC), cattle followed by sheep (CS), and sheep grazing alone (S). Since cattle (especially dairy cows) feeding on pasture is of most interest in these regions, clipping or sheep following cattle treatments were included to groom the pasture for subsequent grazings by cattle. Mean target pre- and postgrazing herbage masses were 2200 and 1100 kg DM ha^{-1}, estimated by single-probe capacitance meter (Pasture Probe) in actively grazed areas.

Plants in treatment S regrew quicker accumulating more forage (8282 compared to 5349 kg DM ha^{-1} for cattle-grazed paddocks, unadjusted for rejected area) than other treatments. This may have occurred because of grass growth being stimulated more by nutrients in sheep dung and urine, which were spread more uniformly (and probably the dung decomposed faster due to greater soil organism activity in treatment S) than cattle manure. After 2 years, S treatment soil contained 0.25% N, 5.7 kg available P ha^{-1}, and 379 kg K ha^{-1}, compared to an average of 0.19, 3.9, and 179 respectively for the same soil nutrients in cattle-grazed treatments.

By the end of the experiment the percent pasture area covered by rejected forage

was 39.7, 7.7, 16.0, and 0 for C, CC, CS, and S, respectively. When forage yields were adjusted for the average amounts of rejection, average annual net forage production was 3392, 4353, 4991, and 8282 kg DM ha^{-1} for C, CC, CS, and S, respectively.

Besides differences in manure distribution and forage rejection, differences in soil compaction among treatments also may have affected soil organisms and thereby plant growth. After 2 years, soil bulk density (g cc^{-1}) was 1.37, 1.37, 1.27, and 1.12; average soil penetrometer measurements (kg cm sec^{-1} sec^{-1}) to 20-cm soil depth were 9.8, 9.3, 9.5, and 6.7; soil nematode per 100 g of soil were: 5333, 8705, 2810, and 15208; soil rotifer numbers per 100 g soil were: 288, 242, 715, and 33; and earthworm numbers m^{-2} and their biomass (g m^{-2}) were 262 (205), 157 (162), 344 (409), and 294 (343) for C, CC, CS, and S treatments, respectively.

Close clipping or grazing by sheep following dairy cattle grazing decreased forage rejection by cattle. These treatments maintained more of the pasture in better condition for subsequent cattle grazing, resulting in more net forage production than no postcattle grazing treatment.

Introduction

Mixed animal species grazing practised elsewhere has improved net forage production, increasing animal growth rates by up to 8% and liveweight output per unit area by up to 13%. These benefits were due to complementary effects of different animal grazing patterns and habits, particularly preferential grazing by sheep of forage rejected by cattle around dung pats (Nolan and Connolly, 1977, Nolan *et al.*, 1988).

Most research on mixed animal species grazing, however, has been done on seeded monoculture swards of perennial ryegrass (*Lolium perenne*) receiving N fertilizer or combined with white clover. Insufficient information exists about mixed animal species grazing of complex swards, where variable rates of growth and maturity of different plant species provide more opportunities for livestock to graze selectively and waste forage. This study was done to improve understanding of sward, soil, and soil organism responses to manipulation of cattle and sheep grazing low-input (no N fertilizer), complex natural swards dominated by Kentucky bluegrass (smooth-stalked meadowgrass, *Poa pratensis*) and based on white clover, so that objective guidelines for managment can be provided to farmers.

In a succeeding paper of this series we will consider the use of four measurement techniques (cut quadrat, capacitance meter, HFRO sward stick, and a rising plate) when used for estimating forage mass of complex swards.

Materials and methods

ecov *Details of sward culture*

This study was conducted during 1989 and 1990 on a complex natural sward that had been grazed rotationally only by sheep during the latter half of 1987 and all of 1988. A uniform sward resulted that was composed of 81% grass, 9% white clover, and 10% forbs. Kentucky bluegrass comprised 70% of the grass. Other grasses present were orchardgrass (*Dactylis glomerata*, 20% of the grass), timothy (*Phleum pratensis*, 5%), and quackgrass (*Agropyron repens* , 5%). The forbs were dandelion (*Taraxacum officinale*, 5%) and chicory (*Cichorium intybus*, 5%). Inoculated white clover seed cv. 'Grasslands Huia' was surface-broadcast at the rate of 5 kg ha^{-1} in all treatments on 5 April 1989.

Experimental design

Treatments were: cattle (18-month-old Holstein heifers) grazing alone (C), cattle followed by clipping with a rotary mower to 2.5 cm from the soil surface (CC), cattle followed by sheep (CS), and sheep grazing alone (S). When all treatment paddocks accumulated a mean target forage mass of 2200 kg dry matter (DM) ha^{-1}, animals were allowed to graze. Animals were removed from paddocks at a target pasture mass residual of 1000 to 1100 kg DM ha^{-1}.

The experimental site was on a Winooski very fine sandy loam (coarse-silty, mixed, mesic, Aquic Fluventic Dystrochrept) near Colchester, Vermont. The design was a randomized complete block, replicated three times.

Treatments were grazed simultaneously within each replicate, which were grazed in succession. Thirteen 2-year-old Holstein heifers and 120 sheep consisting of ewes, lambs, and yearlings of various breeds were used to graze treatments. Paddock sizes were 0.16 ha for cattle-grazed areas, 0.05 ha for sheep following cattle, and 0.08 ha for sheep grazing alone. Stocking densities were approximately 80 animal units (AU) ha^{-1} each for cattle and sheep, and 130 AU ha^{-1} for sheep following cattle. A higher stocking density of sheep following cattle was used so that sheep would eat forage that had been rejected by cattle quickly without having time to select for white clover. These stocking densities were chosen to represent average stocking densities currently being applied by dairy farmers. Grazing periods were 24 hours per paddock, except for sheep following cattle, when sheep grazed for 1 hour. Grazing began on 15 May and ended on 21 September in 1989, and began on 20 May and ended on 25 September in 1990.

Soil fertility

Soil was sampled (7.5-cm deep cores) in the site area in October 1988, and in each treatment in November 1989 and 1990, to monitor changes in amounts of soil nutrients present during the study. Soil samples were analyzed by the University of Vermont Soil Testing Laboratory, using the modified Morgan's (ammonium acetate 1.25 molar at pH 4.8) extractant. Phosphorus was analyzed by colorimetric procedure (molybdenum blue). Al, Ca, K, and Mg were analyzed by ion-coupled plasma spectrophotometer. Total N was determined with the Kjeldahl procedure.

Forage accumulation and net forage production

Pasture mass was estimated with a single probe electronic capacitance meter (Design Electronics Pasture Probe). (Pasture mass also was estimated with clipped quadrats, HFRO sward stick, and a rising plate; the use and comparison of these methods will be considered in a succeeding paper.) At least 30 capacitance meter measurements were made of the sward in actively grazed areas of each treatment before and after grazing (Boswell, 1986). Measurements also were made near the end of grazing each treatment to determine when to remove animals from paddocks.

Rejected forage

Area of rejected forage was monitored by placing a 2- x 10-m quadrat at a randomly picked site in each paddock after each grazing in 1989, and after first and last grazings in 1990. Rejected forage areas around dund pats were counted within each quadrat, and three areas were picked at random for measurement of their circumferences and calculation of areas. The mean calculated area was multiplied by the number of rejected areas to obtain total area within the quadrats and percentage of overall pasture area that was covered by rejected forage (Bjarnason, 1984).

Soil compaction

Soil compaction was estimated by soil bulk density and penetration resistance measurements. Soil bulk density was determined (Blake and Hartge, 1986) on two 7.8 x 5.0-cm cores taken from each treatment in October 1990. Soil penetration resistance was measured to 30-cm depth with a DELMI penetrometer (Bradford, 1986) at five sites in each treatment in October 1990.

Soil organisms

In October each year paired soil samples (5 x 7.5 cm) were taken from each treatment to determine soil CO_2 respiration rates and organism numbers. At adjacent sites earthworms were extracted by pouring 4.5 liter of 0.8% formalin solution uniformly within a 27-cm diameter ring that had been embedded 1 to 2 cm into the pasture sod. All earthworms emerging in the ring within 10 minutes of pouring the formalin solution were collected, identified, counted, and weighed.

Results

Forage accumulation and net forage production

Forage accumulation (unadjusted for rejected area) and net forage production or utilization were greater during both years in S than in cattle-grazed treatments (Table 1a and c). Time of season influenced ($P<0.01$) forage accumulation and interacted with grazing treatment in both years ($P<0.01$, 1989; $P<0.07$, 1990).

Rejected forage

During the first rotation in 1989 no forage was rejected in any treatment. With each successive rotation, however, increasing amounts of forage around dung pats were rejected by cattle, especially in treatment C. In the first rotation of 1990 more forage area was rejected in C and CC treatments than during the last rotation of 1989. Apparently, cattle dung dropped at that time in those treatments overwintered with little decomposition, and adversely affected cattle grazing in spring 1990. By the end of the experiment cattle rejected nearly 40% of the pasture area in C, compared to 7.7, 16, and 0% rejected areas in CC, CS, and S respectively. (Table 1b, Figure 1.)

Soil compaction

Soil compaction tended to be greater under grazing by cattle as compared to sheep, and probably influenced soil organisms and plant growth (Table 1d).

Soil organisms

Carbon dioxide evoulution from soil microbial respiration was less in cattle-grazed treatments than in treatment S. Soil where only sheep grazed exhibited very high rates of CO_2 evolution (34-fold increases over cattle-grazed treatments). Soil under rejected forage around dung pats in cattle-grazed treatments evolved more CO_2 than in actively grazed areas (three times more in treatment C; five times more in treatment CS), possibly reflecting a greater amount of available nutrients and/or less soil compaction under dung pats. In general, CO_2 respiration levels were inversely related to the penetrometer estimates of soil compaction.

Soil nematode numbers were lower in cattle-grazed treatments than in treatment S (Table 1e). As with the microbial respiration, nematode numbers approximated an inverse pattern relative to soil compaction.

Soil rotifer numbers were higher in cattle-grazed treatments than in treatment S (Table 1e).

Average earthworm numbers tended to be greater in treatments where sheep grazed, than where only cattle grazed (Table 1e).

Soil fertility

Levels of N, P, K, Ca, and C tended to increase in treatment S during the experiment, compared to cattle-grazed treatments (Table 2). Sheep grazing for only 1 hour in each rotation tended to increase soil N and K levels in treatment CS.

Tables 1+2 }→
Figure 1 }

Discussion

Forage accumulation, rejected forage, and net forage production

One of the most difficult problems in doing pasture research and managing livestock feeding on pasture lies in accurately estimating how much forage mass is present before and after grazing. These amounts need to be measured so that forage allowance and dry matter intake (net forage production) can be estimated to make optimum use of pasture forage in balancing rations. This problem is especially serious when feeding lactating dairy cows on complex swards that provide opportunities for significant selective grazing and forage waste, both of which result in sward structure and composition deterioration and poor net forage production or utilization (Korte *et al.*, 1987).

The issues of where in a pasture to take measurements, and forage rejection must be confronted and resolved somehow. Taking measurements in actively grazed areas only, or randomly in grazed and ungrazed areas certainly results in different estimates of forage mass. During the first one or two spring rotations if grasses such as orchardgrass (*Dactylis glomerata*) and Kentucky bluegrass are not grazed because of initial repugnance around dung pats, they quickly mature, become increasingly rank, and tend not to be grazed at all during the rest of the season. Including forage mass measurements of such ungrazed areas during the season would provide erroneous estimates of forage accumulation and net forage production. In addition, cattle dung does not appear to be distributed randomly since, even under high stocking density of paddocks for short grazing periods, cattle select preferred areas where they ruminate and defecate. Even if rejected areas around dung pats were randomly distributed, farmers are unlikely to take measurements in a strictly random manner. It therefore seems preferable to take measurements in actively grazed areas only, estimate the amount of area covered by rejected forage, and adjust forage accumulation accordingly to obtain an estimate of net forage production. While clipping or grazing with another group of animals following cattle grazing decreases the amount of rejected forage, it does not eliminate it as a factor in estimating net forage production.

Soil fertility

The more vigorous plant growth observed under S probably was related to higher levels of nutrients in that treatment. Higher soil nutrient levels under S may reflect more uniform dung and urine distribution by sheep, compared to cattle. Cattle concentrate their dung and urine, resulting in patchy nutrient distribution. Because of its size, sheep dung probably decomposes more rapidly than cattle dung, resulting in nutrients becoming available more quickly from sheep dung. The greater number of nematodes and soil microorganism activity indicated by CO_2 evolution levels in soil of treatment S, probably increased nutrient availability .

Soil compaction

New Zealand researchers also have reported greater soil compaction under cattle grazing than under sheep (Frame & Newbould,1986). It is surprising that significant differences in soil compaction occurred here, however, given the relatively low stocking densities used and the limited time (total of 5 days year^{-1}) that animals actually grazed each paddock during the experiment. Depending on soil texture and moisture, soil compaction may be a problem on farms using low stocking densities and continuous grazing or long paddock occupations of several days. Davies *et al.* (1989) reported a doubling of net herbage accumulation and uptake of N, P and K from slitting (aerating) a soil that had been compacted by 26 years of dairy cow grazing. The compaction that may have limited soil organism activity and plant growth in this experiment, indicates that periodic soil aeration might benefit pasture plant production under cattle grazing.

Soil organisms

The number, variety, and biomass of biota encountered within the soil of the research site were all relatively abundant. Soil nutrient levels in Table 2 indicate that carbon/nitrogen (C/N) ratios ranged from 11.6/1 to 13.2/1. These were well within the optimal C/N range of 9/1 to 30/1 where soil biota can most efficiently carry out organic matter decomposition and nutrient recycling processes, so inappropriate C/N ratios did not limit effective functioning of the soil decomposer microcommunity in any grazing treatment.

Assessment of CO_2 production directly reflects the microorganism level of metabolic processes occurring in a soil. Measurement of this parameter provides a very sensitive means to assay intensity of management effects on soil microenvironments. It is one of the most important soil biotic indicators. Relatively higher levels of respiration indicate a healthier, more stable soil microcommunity. Lower soil bulk density in treatment S probably resulted in better aerobic conditions that stimulated higher metabolic rates; the more uniform deposition of sheep manure may have further promoted ideal environmental conditions for microbial functions.

Despite their poor media image, nematode populations in soil generally are extremely beneficial, with the dominant forms causing rapid decay and incorporation of organic matter within the soil and also nutrient cycling. Others of this diverse biotic group feed on bacteria, fungi, and soil protozoa, thereby assisting in the natural balance of other soil life forms. Destructive or pathogenic nematodes are absent or only present in very low numbers of $<1\%$ in nontilled soils; if present in sites of this kind, pathogenic nematodes normally are kept in check by predatory nematodes acting as natural biocontrol agents (Dindal, 1990). Greater soil compaction in treatments C, CC, and CS may have reduced the level of nematodes in the soil. This, along with decreased soil microbial activity, may have affected nutrient availability to plants and resulted in decreased herbage accumulation in those treatments.

The importance of earthworms is well documented (Dindal 1990). The general decrease of earthworm numbers and biomass during the second year in all experimental treatments reflects additive effects of disturbance caused by more intensive grazing practices through time. This kind of pattern is to be expected until this grazing practice is used for a number of years and an equilibrium is reached. The greater number of earthworm present on average where sheep grazed probably reflected the larger amount of forage accumulation in treatments CS and S, which resulted in more dead material returned to the soil and consequently more earthworms in those treatments (Curry, 1987).

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Table 1. Effects of cattle and/or sheep grazing and clipping after cattle on forage accumulation, rejected forage area, net forage production, soil compaction, and soil organisms of a complex Kentucky bluegrass dominant-white clover sward in Vermont, USA. 1989-1990.

Observation	Treatment: Cattle	Cattle/clip	Cattle/sheep	Sheep	SEM	P
a. Forage accumulation, kg DM ha^{-1}						
1989	5534	5465	6470	7346	57	<0.01
1990	4794	4569	5260	9218	105	<0.01
Mean	5164	5017	5865	8282	75	<0.01
b. Rejected forage, % of total pasture area						
1989	26.2	10.5	16.7	0	3.1	<0.30
1990	43.7	16.5	12.7	0	5.9	<0.06
Mean	35.0	13.5	14.7	0	4.5	<0.16
c. Net (adjusted for forage rejection) forage production, kg DM ha^{-1}						
1989	4084	4891	5390	7346	73	<0.01
1990	2699	3815	4592	9218	125	<0.01
Mean	3392	4353	4991	8282	72	<0.01
d. Soil compaction, October 1990						
Bulk density, g cc-1						
Soil depth 0-5 cm	1.37	1.37	1.27	1.12	0.09	0.04

Table 1 continued.

Penetrometer, kg cm sec-1 sec-1						
Soil depth, cm						
0-5	8.8	7.3	9.3	5.0	.57	<0.03
5-10	10.3	9.7	9.9	6.4	.29	<0.0005
10-15	10.2	10.5	9.7	7.5	.25	<0.0007
15-20	9.7	9.5	9.1	7.7	.36	<0.04
20-25	8.9	9.0	8.2	7.5	.42	<0.19
25-30	8.2	8.1	7.1	7.4	.61	<0.62
e. Soil organisms						
CO_2 evolution (October 1989; SEM in parentheses)						
mg CO_2/100 g soil	0.061 (.012)	0.053 (.004)	0.063 (.004)	1.70 (1.42)		
Nematodes (October 1990; SEM in parentheses)						
No. /100 g soil	5333 (2494)	8705 (2787)	2810 (765)	15208 (4607)		
Rotifers (October 1990; SEM in parentheses)						
No./100 g soil	288 (65)	242 (111)	715 (258)	33 (29)		
Earthworms m^{-2} (SEM in parentheses)						
1989	382 (49)	294 (75)	596 (216)	520 (149)		
1990	262 (29)	157 (28)	344 (19)	294 (17)		
Mean	322	226	470	407		
Earthworm biomass, g m^{-2} (SEM in parentheses)						
1989	437 (63)	235 (67)	474 (154)	322 (81)		
1990	205 (32)	162 (23)	409 (40)	343 (44)		
Mean	321	199	442	333		

Table 2. Analyses of soils sampled in November 1990 after 2 years of rotationally grazing a complex Kentucky bluegrass dominant-white clover sward with cattle and/or sheep, or clipping after cattle, Vermont, USA.

	Total		Avail.	Reserve					
Treatment	N	C	P	P	K	Mg	Ca	Al	pH
	------%------		----------------------kg ha $^{-1}$----------------------						
Cows	0.17	2.3	5.4	27	158	334	2511	56	5.4
Cows/clip	0.17	2.1	2.9	21	128	371	2713	37	5.4
Cows/sheep	0.23	2.7	3.4	19	252	307	2724	90	5.1
Sheep	0.25	3.1	5.6	43	379	352	3150	67	5.2
Control (October 1988):			2.0	21	187	372		65	5.6

Figure 1. Rejected forage areas in a complex Kentucky bluegrass-white clover sward during 2 years of rotational grazing with cattle and/or sheep and clipping after cattle in Vermont, USA.