The Ruminant Livestock Efficiency Program
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RUMINANT LIVESTOCK EFFICIENCY PROGRAM

Ruminant Livestock Efficiency Program
Atmospheric Pollution Prevention Division
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PREFACE

The purpose of this document is to describe the status of activities undertaken by the EPA and USDA through the Ruminant Livestock Efficiency Program (RLEP) in 1998. The RLEP was initiated in 1993 as Action Item 39 of the President's Climate Change Action Plan. RLEP is a voluntary program that works with beef and dairy cattle farmers to improve production efficiency and reduce emissions of greenhouse gases in the US. In the fall of each year, a conference is held where program participants meet to share information on their accomplishments and present plans and ideas for future activities. The two main components of the program are research and education.

When the RLEP began in 1993, Washington State University had just published the methodology for the SF_6 tracer–based livestock methane measurement technique in the scientific literature. Today, in addition to Washington State University, four other research institutes in the US are using the technique. These include Utah State University, the University of Tennessee, the University of Georgia and the University of Southwest Louisiana. Elsewhere, it is being used in Canada, New Zealand, Australia, the United Kingdom, India, Zimbabwe and Ukraine. Also, scientists from Uruguay, Costa Rica and Mexico have been trained and are planning to start up measurement programs in their countries. In each country including the U.S., the technique is being used to improve livestock emission inventories and to quantify the effects of improved management practices on the environment, specifically how improved management reduces methane emissions per unit of product. In the US, methane measurement studies mainly focus on improving beef cow diets through better forage and grazing management practices. Studies have also been implemented to examine effects of production enhancing technologies such as growth promotants and ionophores. In developing countries, researchers are studying the effects of dietary supplements such as molasses urea blocks and oilseed cakes.

The educational activities initiated by RLEP are numerous. In eleven southeastern states, USDA NRCS technicians work closely with 48 farmers who have agreed to use their farms to demonstrate improved grazing management techniques. In Virginia, special efforts are being made through a pilot project to address total greenhouse gas emissions from livestock production. Through this RLEP sponsored project, USDA NRCS works closely with Virginia Tech Extension on a variety of projects: improved grazing management education, beef production efficiency and retained ownership education, financial and business planning for beef operations, monitoring carbon content in pasture soils that have been converted to improved management, and a new pastureland management software program.

In the intermountain west, Utah State is incorporating research results into ongoing extension programs. Three major sets of activities include an NRCS-USU video production on plant-herbivore interactions, Western Integrated Resources Education program (*WIRE*), and the Utah Grazing Lands Conservation Initiative (*GLCI*).

The National Council for Agricultural Education and the Future Farmers of America developed classroom educational materials on climate change and livestock production systems. Materials include a student reference text, a teacher's guide, a poster and a video. The plans are to introduce the materials to teachers, and to provide training to teachers at workshops next summer.

Because improved pasture management has been identified as a potential means for sequestering substantial amounts of atmospheric carbon, RLEP is sponsoring a new project to quantify carbon sequestration in pastures of the Southeastern United States. Colorado State University recently began this work, which includes setting up long-term microsites to allow accurate collection and analysis of soil samples, compilations of state-wide pasture land use data, and simulation modeling of soil C dynamics. Their work is an integral part of the Virginia Pilot Project and will eventually become part of the larger regional program.

Colorado State University is also developing a livestock production systems simulation model for RLEP to evaluate the net impact of changes in livestock production practices on total greenhouse gas emissions at the farm level. Many practices directed at improving efficiency and decreasing emissions of a particular greenhouse gas might simultaneously produce multiple or ripple effects on the system which could suppress or enhance net greenhouse gas emissions from the production system. This project will enable us to identify practices that provide the greatest overall benefits to the environment considering emissions of all major greenhouse gases including methane, nitrous oxide and carbon dioxide. It will incorporate the effects of agricultural soil as a sink for atmospheric carbon plus the effects on economic returns resulting from implementing these practices.

The data contained in this document is presented as a status report and is not in all cases, in its final form. All data should therefore be considered preliminary. For information on a specific study, please contact the author directly. Contact information is provided in the last section of the document.

Mark Orlic
US EPA

WELCOMING REMARKS

Charles Adams, NRCS Regional Conservationist

Welcome to the state of Georgia and to the Southeast Region. As Regional Conservationist for NRCS in the Southeast, I am pleased to have the opportunity to attend to attend this year's conference in person and to provide you with this welcome. We want to thank the University of Georgia and Dr. Mark McCann for acting as the host for this year's conference and for the opportunity to enjoy these fine facilities.

This year's meeting is of particular significance as it marks the third and final year of the regional interagency agreement between NRCS and EPA for cooperation on the Ruminant Livestock Efficiency Program (RLEP). With the help and cooperation of private livestock producers, we have accomplished much through implementation of this effort.

Environmental Protection Agency funding of research efforts here in the Southeast and across the country have extended our knowledge and understanding of how ruminant diets affect the efficiency of production. Global climate change funding from NRCS has been used to establish approximately thirty livestock efficiency demonstration farms scattered across the southeast. These demonstration farms are serving as models for other producers to help them understand what improved efficiency of production can mean in terms of a healthier bottom line and a cleaner environment.

The timing of this effort has been especially opportune. It has coincided with an on-going effort, begun at the request of the nation's livestock producers in the early part of this decade, to expand NRCS's program of conservation technical assistance on our country's privately owned grazing lands. This Grazing Lands Conservation Initiative (GLCI) and the Ruminant Livestock Efficiency Program have common objectives in improving livestock production practices.

Here in the Southeast the level of livestock management is traditionally among the lowest in the nation and the availability of NRCS technical assistance for improved grazing management has been limited. We have been able to use these two programs, GLCI and RLEP, together to accelerate the development of our capacity to provide assistance on grazing lands in this region.

We have made much progress over the last three years. In addition to the establishment of the livestock production demonstration farms which have provided opportunities for public field days, accomplishments include:

- expanded NRCS staff qualified to provide grazing lands assistance

- creation of two regional grazing lands leadership positions in the NRCS Southeast Region to assist states with training and development of state grazing lands assistance programs

- dedicated staff at each NRCS state office to provide leadership for the grazing lands program

- expanded partnerships with other agencies, industry groups, and cooperative extension to assist and educate the public and to provide workshops and training to NRCS conservation professionals in grazing lands management.

Throughout the past three years, we have worked to incorporate concerns over the effect of agricultural activities on atmospheric carbon into the overall NRCS conservation assistance program and not to treat these concerns as a program unto themselves. Working together, we have helped to focus attention not just on the level of greenhouse gases produced by ruminant livestock, but on the overall benefits of well managed grazing systems. These positive impacts, especially carbon sequestration in grazing lands and other agricultural soils, have become a part of the international discussion about how to best control the earth's atmospheric carbon levels.

The work that has been done and which continues to be done under this effort is helping to create a holistic view of the impacts of the livestock industry on atmospheric carbon and to demonstrate that this important industry is a part of the solution to global climate change rather than a cause. The completion of the current agreement for NRCS cooperation with EPA on improving livestock production efficiency does not denote an end to our joint efforts. The excellent cooperative work, involving not just NRCS and EPA but the Forage and Grassland Council and Cooperative Extension as well as private producers, is ongoing

Where do we go from here with interagency coordination and public involvement? How do we continue to improve the level of livestock grazing management and production efficiency in this and other regions? As you discuss these issues here at this meeting, I wish you well and will be interested in the results of your deliberation and discussions.

PROGRAM INTRODUCTION

Tom Wirth, US EPA

Welcome to the Ruminant Livestock Efficiency Program's Annual Conference.

For the RLEP, 1998 was a classic roller coaster year. In spite of excellent progress on several fronts, recent developments such as budget cuts, congressional riders on EPA's budget, among other things, have forced us to narrow our focus and make some changes.

First of all, there have been a number of important accomplishments that should not be overlooked:

- The SF_6 measurement technique has been perfected for a variety of animal types and situations and is now being used across the US and around the world to measure emissions of methane from ruminant livestock.
- University research, that we will hear more about in this meeting, has established a firm basis for evaluating measures to reduce methane emissions from livestock on a per unit of product basis.
- Through EPA's cooperative agreement with USDA-NRCS, RLEP has developed a very promising model forage and grazing management program in Virginia. The next step is to use it as a case example and apply it in other states.
- Forty-eight demonstration farms have been established across the Southeast to show how improved management can lead to lower methane emissions per unit of product as well as increased profitability for the producer. Numerous producers have visited these farms and benefited by participating in field day activities.

Like all Climate Change Action Plan programs, RLEP must be evaluated in terms of how well it is reducing emissions, at what cost, and with what level of industry participation. The family of government sponsored climate change programs has grown rapidly over the past few years with several programs achieving high levels of success. In most cases the successful programs are the ones with good industry participation at the national level. Although RLEP enjoys excellent relations with demonstration farmers and a number of state level organizations, the national organizations that represent the industry still have not chosen to participate in climate change programs. This situation has hindered broad scale implementation of the program.

For decades, managers of conservation programs have wrestled with difficulties of quantifying the benefits of environmental improvement. While the RLEP may be having positive impacts in the short term, and certainly will in the future, it will always be difficult to measure success using the same standards that are applied to many of the other climate programs. The specific actions that RLEP promotes will always result in increased efficiency of livestock production, but livestock respiratory gases never flow through pipelines and are not metered. In most cases, efficiency improvements can lead to net emissions reductions but the results are determined in an indirect manner. Because direct and immediate reductions of methane from livestock digestive systems do not occur, the program can not produce the short-term results that are needed for Climate Change Action Plan programs. So what this all means for the future of RLEP is that we will continue to operate but on a reduced budget from EPA. Fortunately, NRCS has not been affected by these changes so RLEP will continue to advance and while EPA funding has been reduced, it has not been eliminated so support will continue for most of the current commitments.

The Virginia activities are a high priority and will not be affected. This includes support for the beef production efficiency and retained ownership project, the formation of the Forage and Grassland Council grazing clubs and the development of the Pasture Land Management Software. It also includes support for classroom educational activities with the Future Farmers of America. Unfortunately, the most serious cutbacks will be to the research part of the program as a result of congressional riders on EPA's appropriation bill.

The other projects that were recently started up with Colorado State University will also continue as planned. These include a comprehensive systems analysis of livestock production related greenhouse gas emissions and their economic implications, plus a project to quantify the carbon sequestration potential on pastureland in the Southeastern US from improved grazing management.

In the future, RLEP will be incorporating a more holistic systems approach to reducing greenhouse gases from livestock production systems, both domestically and internationally. This is being done to ensure that our efforts to reduce emissions of one gas do not result in increased emissions of another to the extent that net emissions are increased. This analysis will take all greenhouse gases into account including methane, nitrous oxide and carbon dioxide, to ensure that the mitigation options we are promoting are the most "greenhouse friendly" options available. Only with a truly holistic approach to reducing greenhouse gas emissions, can we be sure that the environment will benefit as much as the producer when production efficiency is improved.

VIRGINIA PILOT PROJECT

Glenn Johnson, USDA NRCS, Bill Wayson, Virginia Forage and Grassland Council

A project was initiated in Virginia in late 1997 to develop a model for assisting ruminant livestock producers that would:

- improve the environment which includes reducing greenhouse gas emissions and sequestering carbon in the soil;
- improve ruminant livestock production efficiency;
- improve technology transfer;
- promote cooperation among agencies and with producers;
- actively and meaningfully involve producers;
- provide consistency and continuity to all of the above.

A major project strategy is to involve producers, not only as recipients of information, but as partners in determining how and what information should be delivered and shared. Consequently, where appropriate, many projects are "close to the producer". Another major strategy was to consider as many factors in grazing management as possible, including plants, soils, animals, economics, and environment. To accomplish these goals, program flexibility has been maintained so that lessons learned during the project can be incorporated for improvement. In this sense, the project is dynamic and evolving.

Producer Involvement

The Virginia Forage and Grassland Council (VFGC) has begun a project to improve technology transfer by beginning at the "ground level". A key focus throughout the project has been the solicitation of input from the producer, looking for suggestions for development and execution of the project. Towards that end, two information gathering efforts were made across Virginia; a phone survey of approximately 300 ruminant livestock producers was done and eight focus group discussion sessions were held.

The focus groups contained both beef and dairy producers from 35 counties. Participants were of all ages and most beef producers were not considered full time producers. Other crops (tobacco, grains, and cotton) as well as off farm employment often commanded priority.

The broad based questions for the focus groups were:

- Why do you raise livestock?
- What is "good" pasture management?
- What sources of information on pasture management have you used in the past?
- What kind of information do you need?
- How is the best way for information to be presented to you?

- What are the limiting factors to implement improved grazing management on your operation?

Several conclusions from the focus groups were:

- Producers want information customized to their locality. State-wide information often does not address regional needs.
- Producers wanted to receive information through small, local group meetings so that they would have an opportunity for discussion and to learn from each other.
- Motives for raising livestock were primarily due to a sense of history, tradition, and lifestyle. Economic considerations, for the most part, did play a primary motivating role for raising livestock.
- Perceived barriers were increased time, labor, money (costs), and difficulty in water placement.

Consequently, the VFGC held a series of three conferences in separate locations across the state. The primary objective was to promote the formation of localized grazing clubs. As a result, twelve clubs were begun with nine being active. Many have met several times, somewhat organized themselves, arranged presentations from both agency specialists and producers, and conducted a number of pasture walks.

The VFGC is developing a support mechanism for the grazing clubs. Club projects may be financed upon application to VFGC. Requirements for such financial assistance are:

- the project must improve the quantity, quality and availability of forages;
- the project must have an outreach component;
- the club must provide a written report on results to VFGC as a feedback and documentation mechanism;

In addition, a graziers network is being developed across the state. A newsletter is being started to facilitate this effort.

Soils

As an excellent example of how different projects can work together for common goals, the Natural Resources Ecology Lab located at Colorado State University is conducting a study of five farms in Virginia to examine the effects of different pasture management systems on the soil's ability to sequester carbon. The project objectives include:

- provide baseline data on carbon sequestration potential of improved grasslands;
- verify soil carbon determination techniques;
- improve existing modeling efforts.

With the advent of international agreements to address climate change, many scientists and policy experts in the United States and Canada feel that agricultural soils may have some potential to sequester carbon. Improved sequestration with the use of conservation tillage in annual row crops has already been shown. This project is on the cutting edge of determining if well-managed pastures have the ability to improve sequestration.

In Virginia, five farms have been selected that represent different forage management systems and two areas of the state, mountain and valley and piedmont. Each of the farms will have multiple soil sampling sites identified with buried magnetic markers to allow accurate re-sampling in future years.

Plants

The combination of NRCS fecal sampling program and a Virginia Cooperative Extension forage sampling program on a climate change demonstration farm project has examined forage quality parameters over a grazing season.

At no time did either the fecal or forage samplings indicate a percent crude protein below 14.5% and %TDN (forage sampling) go below 61.9 and %DOM (fecal sampling) go below 62.4. This showed that a forage base of orchardgrass, fescue, bluegrass, alfalfa, red and white clovers could more than adequately meet the nutritional requirements of a cow-calf operation throughout the grazing season.

In addition, fecal sampling is being conducted on three other farms representing cow-calf, stocker and grazing dairy operations.

Animal

The Virginia Cattleman's Association has received EPA funding to conduct a project involving the improvement of cow-calf management. A series of "courses" are being held across the state to inform producers on the latest techniques for management. The project will also inform producers about the retained ownership of animals to feed lots so that they can receive valuable carcass information. Retained ownership will allow the producer to make informed management decisions on breeding and other aspects of cow-calf management. One of the most important environmental benefits of this program will be reduced emissions of methane because of the shortened time to slaughter.

Economics

Tom Hogan of ICF conducted an economic analysis of two demonstration farms in Virginia. This work included the development of business plans for each operation. The project is being conducted in order to understand the cost effectiveness of conservation and management improvements that are being promoted as a means of reducing greenhouse gas emissions. The results of the Graybeal farm are presented in the following section.

Summary

The Virginia Pilot Project covers a wide array of factors, including soils, environment, plants, animals and human. It is a "systems" type of approach to improving forage and livestock management in Virginia. Rarely has such an opportunity occurred. Enormous efforts are being taken to facilitate the successful execution of this program. One of the most important early benefits has been the improvement if interagency cooperation with the placement of the NRCS state agronomist at Virginia Tech to enhance technology transfer and development. Also, the Virginia cooperative extension service, soil and water conservation districts, Department of Conservation Resources and the Virginia Department of Game and Inland Fisheries have cooperated to take advantage of the opportunities this program offers. A key component is the active involvement of livestock producers in the formulation and execution of the program. Such involvement offers ownership to producers and will enhance the possibility of success. The lessons learned can be used by other states in developing similar approaches.

VIRGINIA BEEF CATTLE EFFICIENCY PROGRAM

John B. Hall, Virginia Tech

Background

Beef cattle (not including the feedlot industry) account approximately 10 to 11% of the anthropogenic greenhouse gases, particularly methane, produced by the US. Although 23 % of the US beef cattle herd is located in the southeastern US, these herds are among the most inefficient in the US. This inefficiency is primarily due to small part-time producers who do not utilize good management practices. In addition, most calves are sold as feeders; therefore, producers know little about the ultimate product they are producing or the feedlot efficiency of the calves they produce. It has been estimated that the US beef industry uses only 35 – 45% of the technology available to it. Therefore, considerable opportunity exists to reduce greenhouse gas emissions per pound of edible beef by educating producers to adopt technologies to increase beef cattle efficiency as well as technologies that directly reduce methane emissions. These practices should increase profitability as well.

The Virginia Cattlemen's Association in conjunction with Virginia Tech developed the Virginia Beef Cattle Efficiency program to assist VA cattle producers with improving the efficiency and reducing the environmental impacts of their beef operations. A grant from the EPA-USDA RLEP Program supports this three-year effort. Program partners also include NRCS.

Objectives

1. Conduct one session to prepare trainers for the cow/calf management training sessions.

2. Provide cow/calf management training sessions for producers in 4 locations across Virginia. The goals of such sessions would be to:
    - A. Reduce the number of open (unbred) cows carried throughout the year.
    - B. Improve calving management
        1. Improve weaning rates and percents
        2. Establish defined calving seasons
    - C. Improve animal nutrition and growth
    - D. Improve livestock genetics
    - E. Reduce time from birth to slaughter by up to 33%.
    - F. Reduce the amount of farm, capital and natural resources required per pound of beef produced.

3. Recruit participants for the ROP. Organize them into groups for education, self-support and continuity of support.

4. Develop a basic beef producer's manual.

5. Document the changes in beef cattle management practices as a result of the VA Beef Cattle Efficiency Program. Estimate the impact of these changes on reduction of methane emissions.

Program Areas

The VA Beef Cattle Efficiency Program (VABCEP) is divided into 2 components the VA Cow-Calf Management Course and the VA Retained Ownership Program. The VA Cow-Calf Management Course began in October of 1998. The expansion of the VA Retained Ownership Program associated with the VABCEP will begin in spring 1999.

The VA Cow-Calf Management Course focuses on teaching the basics of sound beef management to increase efficiency of cow-calf production. The primary objectives of this program are: 1) increase reproductive efficiency, 2) improve genetic and biological composition of cows and calves, and 3) enhance nutritional management of cowherds. This program is designed for the beginning to mid-level producers. It combines at home learning through a new cow-calf manual and an Internet website. The unique components of this program are an on-line discussion group and hands-on workshops. Hands-on activities help build the understanding and confidence of producers to adopt new practices. The on-line discussion group allows instructors to post answers to questions where all students can see them. In addition, the discussion group allows producers to learn from one another and build some interdependence.

The VA Retained Ownership Program builds on the existing retained ownership program sponsored by VCA and VA Tech Extension. The program focuses on increasing the number of producers retaining ownership of their calves through the feedlot, and enhancing producers understanding and use of the data they receive on their calves. The primary goals are: 1) improve the quality of the product produced from VA calves, 2) increase efficiencies in the feedlot, 3) improve profitability of beef operations, 4) reduce time from birth to slaughter. Learning activities include introductory meetings, development of small producer groups, tours of feedlots and processing facilities and newsletters and reports.

Program status

The VA Cow-Calf Management Course has begun and has generated great interest by producers. One hundred and ninety-one producers are participating in the 1998-1999 sessions of the course. These producers come from 35 different counties in VA and 3 surrounding states. Some farms are represented by more than one participant in the course. Several husband and wife or parent-child groupings are represented. Producers were given a survey at the beginning of class to assess the demographics of the audience. One hundred and thirteen farms responded to the survey. The average age of producers is 47 and they have an average of 10 years (range 0-30 yrs) in the cow-calf business. Most (>60%) of the participants have off-farm jobs.

Table 1. Lists other characteristics of producers in the first year of this course.

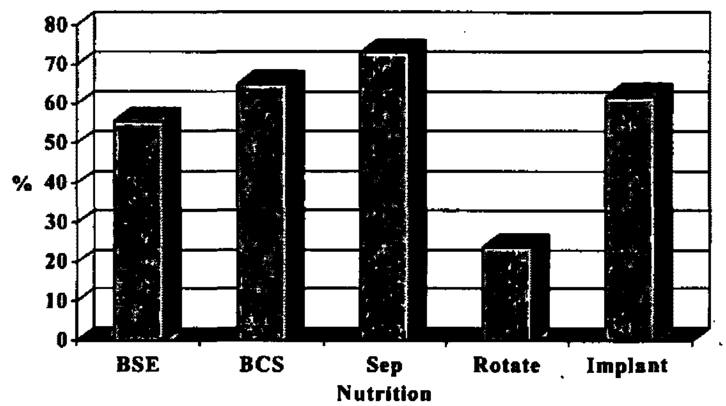
Characteristic	*Amount*
Farm size	100-200 acres
Number of Cows	50-99
Commercial cow/calf operations	81%

The southeast is often portrayed as having terrible reproductive performance and calving rates. Recent surveys by APHIS put the percentage of cows that wean a calf in the 75-80% range for the southeast. A large survey in 1992 of VA beef producers reported the average as 92%. Both surveys may be incorrect due to sampling error. Reproductive performance as reported by producers in the VA Cow-Calf Management Course is listed in table 2. In reality, calving and weaning rates for producers in the upper southeast and mid-Atlantic states are probably in the range of 85%. It is obvious that there is some room for improvement. In addition, individual responses to the survey indicated that producers might have difficulty in accurately assessing reproductive performance. For example, the high reported calving percentage compared to the low rate of producers pregnancy checking their cows.

Reproductive Trait	Response
Percentage of cows that calve	85-90 %
Percentage of cows that wean a calf	90-95 %
Percentage of operations that pregnancy check	50%
Average length of the calving season	90+ days (many 60-90 days)

Many of the producers entering this course presently fail to use basic technologies proven to increase beef cattle efficiency (figure 1). However, early indications are that producers are beginning to adopt these technologies as a result of the course. An end of course survey will be taken to assess adoption rate.

Operations that do not....



BSE = Breeding Soundness Exam of bulls; BCS = Body Condition Scoring of cows; Sep Nutrition = Separating Age groups for feeding; Rotate = some form of rotational grazing; Implant = Use growth implants.

The new VA Cow Calf Management Handbook is under development and approximately 50% complete. The new website and discussion groups are active and continue to be updated. Some locations are using the discussion group to its fullest. Over 50% of the participants have Internet access. Participants receive materials approximately 2-3 weeks before the next workshop.

Hands-on workshops are well received with many positive comments by producers as to the additional value of these workshops over traditional lectures/meetings. Extension agents, extension specialists, veterinarians and experienced producers conduct the workshops. Four workshop locations run simultaneously and each location conducts 5 workshops between October and March. The same producers attend all 5 workshops at a given location. Each location teaches the same basic information, but customizes the program to the location's climate and production schedule.

The VA Retained Ownership Program currently has over 3000 head of cattle on feed in feedlots in Kansas and Nebraska. Most of these cattle are a result of recruitment efforts that occurred before RLEP funding began. A few new producers have entered the program as a result of the retained ownership program. The newly hired technician is compiling feedlot and carcass data from these cattle and will be assisting in the presentation of this data to producers. Three information and recruitment meetings are being planned for the spring and early summer. A trip to feedlots is planned for January. This portion of the VABCEP will continue to expand in 1999.

Future Plans and Potential impacts

The VABCEP is targeted to continue for a total of three years. Two locations for the 1999-2000 class of the VA Cow Calf Management Course have been identified. Final revisions to the handbook and website will be made this spring. Yearly follow-up surveys will be made of all participants. Responses by the participants will be used to modify the program. The VA Retained Ownership Program major thrust will begin in 1999.

The impacts of this program can be significant even if only modest results are achieved. The impacts of the VABCEP program if 1000 herds in the state with an average of 80 head (approximately 11% of the total VA herd) are reached are indicated in Table 3. These projections are an example of the powerful effect increased efficiency of beef production can have on the kg of greenhouse gases per lbs. of beef produced. It may be that increases in lbs. of beef per cow will be easier to obtain than decreases in methane output per cow.

Table 3. Some potential impacts of increased efficiency in beef production from 80,000 cows on greenhouse gas emissions from beef cattle

Efficiency change	Impact
5% reduction in methane produced per cow	**280,000 kg less methane produced per year**
5% improvement in conception and weaning rates	**2 million more pounds of calves per year; minimal increase in methane (only that produced by calves until weaning)**
50 pound increase in weaning weight	**3.4 million more pounds of calves; no additional methane produced**

ECONOMIC ANALYSIS OF ROTATIONAL & INTENSIVE GRAZING SYSTEMS

Tom Hogan, ICF Inc.

The purpose of this project is to determine the economic advantage of proper grazing management in a beef cattle agribusiness in the southeast. Six candidates were chosen in two states, three from Virginia and three from South Carolina. Each candidate farm offered something a little different as far as size and scope of the operation. Two candidates, one from each state dropped out almost immediately upon receipt of the "required information" form. One candidate from Virginia and the two remaining from South Carolina seemed willing enough but as with the majority of people involved in agriculture, they possessed less than adequate records and were therefore slow in responding.

Mr. Alan Graybeal, a demonstration farmer from Blacksburg, VA was very cooperative, had adequate records, and appreciated the value of the information which he received from the Ruminant Livestock Efficiency Program. Mr. Graybeal is about to complete his second year of the project on 185 acres of his farm. Each day he becomes more and more impressed by the results he is getting with his new grazing system. In fact he discussed the development of a more intense system during an August 25, 1998 visit, as well as making additional adjustments to other areas of their farm.

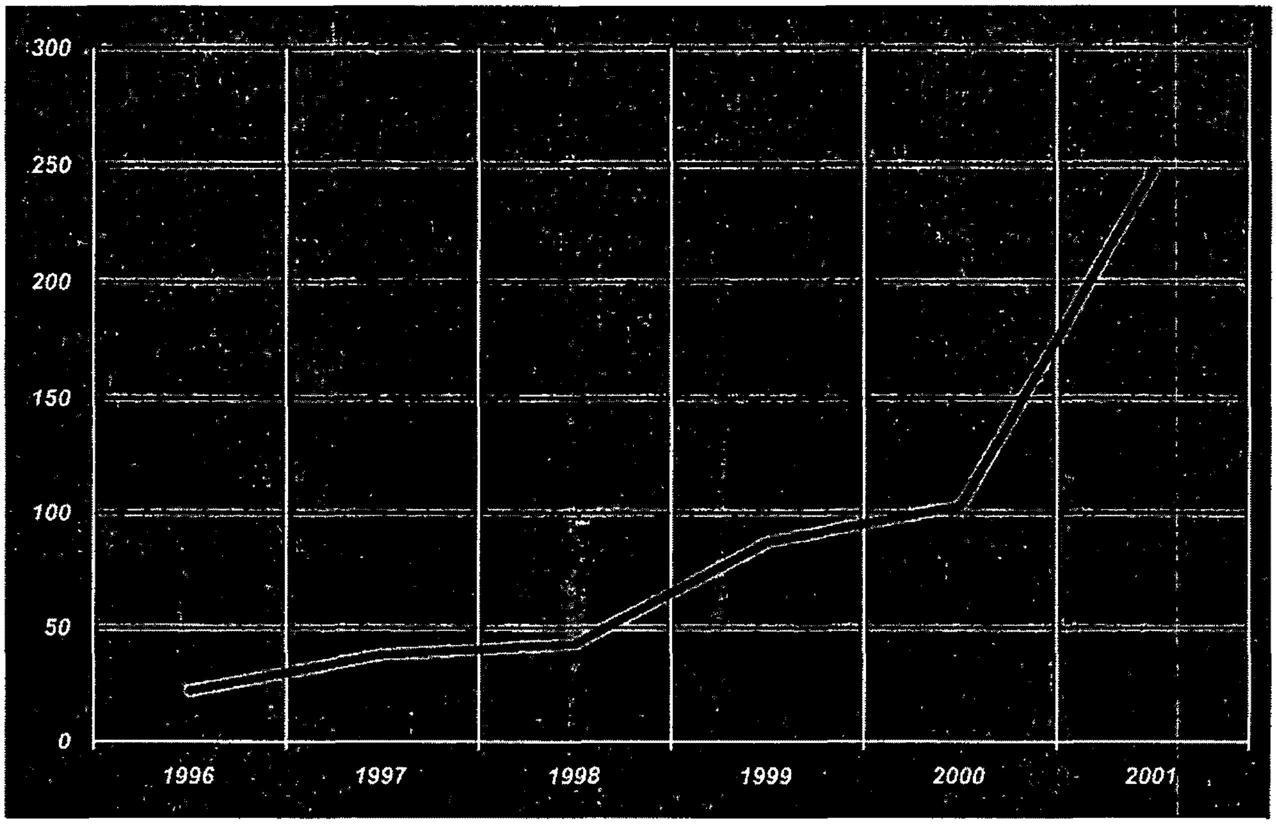
An Integrated Agribusiness Management System analysis was performed on Mr. Graybeal's operation with results that were much better than expected. Though his continuous grazing program with stocker animals indicates a slight profit in FY 1996 ($22.42 / acre), the very next year (FY 1997) on a partial rotational system the cow-calf enterprise increased Net Revenues by 70.3% to $38.19 / acre. By the end of FY1998 the Net Revenues will have almost doubled over that of FY 1996 to $42.93 / acre.

This is only the beginning and is fairly typical of the many improved grazing systems used and/or implemented here in the U.S. and in five foreign countries. By FY 2001 Mr. Graybeal's farm will be producing Net Revenues of $247.95 / acre. More than enough cash flow to service the debt on additional land in Virginia, typically priced around $3,000 / acre, if he cares to expand his operations.

The average progress forecast for the other three operations involved in this project is also significant. These producers can reduce their production costs from an average of $0.82 / pound weaned (FY1995) down to $0.51 / pound of calf weaned (FY2000). Many of the same management techniques and systems that were proven successful by Mr. Graybeal will be employed by the three other cooperators. Certainly the grazing system is not the only major change being implemented on these operations, however it is the most economically significant move.

The graph below indicates the rate of progress that has been made on Mr. Graybeal's operation.

Profit Per Acre from Implementing an Improved Grazing Management System



(pre-1998 actual, beyond 1998 projected)

Conclusion

Improved grazing systems are more than economically viable. They are especially affective in the Southeast where the growing season is long and more often than not adequate rainfall can be expected. They provide efficiencies that were previously unrecognized i.e. cattle handle more easily as they are used to being handled and moved. A grazing system where larger groups of cattle are kept in small paddocks, close at hand, also lends itself well to projects such as Artificial Insemination, individual identification and performance analysis as well as preconditioning.

The investment required is minimal in comparison to the return both economically and ecologically. Net Revenues can push upwards of $250 / acre, as has been indicated with the Graybeal project.

DEMONSTRATION FARM ACTIVITIES SOUTHEAST REGION

Sid Brantly, USDA NRCS

Background

A total of 48 Ruminant Livestock Efficiency Program Demonstration Farms have been established in the states of Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Florida, Louisiana, and the Caribbean Area. These 48 sites are used to demonstrate resource management systems with increased production efficiency levels that reduce net greenhouse gas emissions.

In addition to the primary objective of demonstrating methodologies to reduce methane production per pound of beef produced, there have been other benefits that have accrued to the Ruminant Livestock Efficiency Program. Some of these "spin-offs" include increased profitability, better erosion control, improved pastureland health, enhanced and maintained wildlife habitats, improved water quality, carbon sequestration in the soil and special attention to wise riparian area grazing management.

Goals

A summary of individual farm demonstration goals (as stated by demonstration farmers):

- Implement conservation practices that will improve forage quality for livestock and wildlife.
- Implement grazing strategies that will ensure long term persistence of legumes in the forage base.
- Improve management and production efficiency.
- Reduce inputs through use of solar energy.
- Increase income and lower operating costs.
- Enhance land quality for agricultural use.
- Improve management of cattle, control the breeding season, and improve weaned calving rate.
- Improve resource conditions and increase grazing efficiency.
- Target resource problems such as nutrient loading, runoff, species composition, and water quality.
- Improve forage utilization and grazing efficiency.
- Make the enterprise sustainable and profitable.
- Improve fertility of soil (pH is very low in some fields).
- Renovate pastures and control weeds.
- Develop a pasture rotation of 7 days or less and improve water conditions.
- Increase conception rates and improve weaning weights of calves.

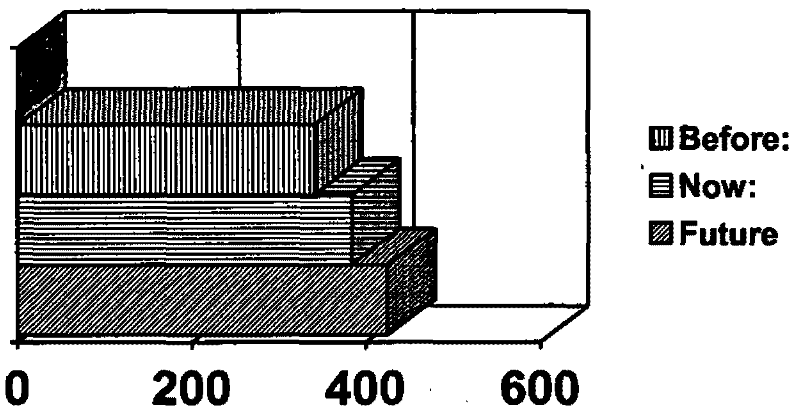
- Have a 90-day calving season instead of year-round.
- Stockpile fescue, establish warm season forage, and renovate pastures.
- Implement pasture rotation, improve water facilities, and herd health.
- Improve pasture quality, water quality, and utilization of forage.
- Purchase less feed and comply with state water quality rules.
- Implement a more efficient grazing system.
- Establish a controlled breeding season and rotational stocking system.
- Improve animal production through pregnancy checking, improved genetics, and supplemental feed analysis.
- Improve forage production and quality.
- Utilize cow/calf identification and improved record keeping..
- Improve nutrient management and animal waste utilization.
- Monitor quality of supplemental feeds.
- Improve livestock efficiency through better forage management and livestock distribution.
- Improve utilization of resources to demonstrate increased production and profit.
- Improve livestock efficiency through better grazing management.
- Demonstrate intensive grazing land management for the purpose of helping livestock producers realize greater profits and to manage their land resources in an environmentally sustainable manner.
- Establish improved grasses and legumes, treat severely eroded areas, and provide high quality water.
- Improve overall efficiency of the livestock farming operation through rotation grazing and providing additional water sources to distribute grazing more evenly.
- Provide an easily accessible location to demonstrate land improvement measures and management.
- Install conservation practices on the land that will improve livestock production and health.
- Improve hay production efficiency and livestock forage management efficiency.
- Improve soil conditions and grazing forage quality and quantity.
- Producers seek to improve the efficiency and profitability of their dairy operation. They also desire to minimize soil loss and address related natural resource concerns.
- Reduce soil loss, establish permanent grass cover, and facilitate farming operation.
- Demonstrate improved grass production on low fertility soils and demonstrate chemical weed control.
- Demonstrate that through a managed rotational grazing system, ample forage can be supplied with reduced use of chemical fertilizers and less use of pesticides. With good forage growing conditions, some of the paddocks can be bypassed, thereby stockpiling forages for later use.

These 48 livestock efficiency demonstrations encompass management of over 3,387 cattle for increased efficiency of production, resulting in lower methane production per unit of beef or milk produced.

For all states reporting complete, qualitative data, the average pounds of beef produced per cow in the demonstration units prior to the demonstration averaged 341 pounds. Currently, those same units average 384 pounds produced per cow, and the projected future production average is 425 pounds.

Production Efficiency

- **Pounds of Beef produced per cow before RLEP**
- **Pounds of Beef produced per cow, with RLEP**
- **Future predictions of pounds of beef produced with RLEP**



The key to these demonstrable improvements in ruminant livestock efficiency seems to be implementation of farm management systems that are:

1) Voluntary, non-threatening, and economically sound;

2) Supported by the research community and the press as sustainable;

3) Presented by knowledgeable, competent staff; and

4) Implemented with "start-up cost" incentives that help overcome marginal returns and capital shortfalls within this segment of the industry

The major components of improved management being practiced on these farms include the following:

Component	Sites practicing component		
	Prior to RLEP	Planned	Underway
Prescribed grazing	6	45	40
Keeping production records	4	39	35
Soil testing for nutrient management	13	44	42
Forage tissue analysis	0	21	13
Dietary supplementation	18	26	23
Fecal analysis for nutrition management	2	36	31
Herd health / wellness program	15	35	34
Pasture / forage improvement	6	32	27
Improved genetics	5	16	13
Managed breeding season	9	27	19
Artificial insemination	1	5	4
Calf marketing plan	6	21	14

Additionally, in fiscal year 1998, NRCS activities in the Southeast Region included providing assistance in livestock efficiency on grazing lands through an animal well being and nutrition monitoring program.

Manure samples were analyzed from 422 specimen submitted to the Grazing Animal Laboratory at Texas A&M University. The samples were collected from mixed warm and cool season pastures, Tall fescue pastures, Bermudagrass, Bahiagrass, and native plant communities in Florida, Alabama, Georgia, Mississippi, Kentucky, Tennessee, South Carolina, North Carolina, and Virginia. The samples collected and submitted were analyzed for % Crude Protein and % Digestible Organic Matter at a minimum.

In some locations, the NRCS agent utilizes the nutritional balance analyzer (NUTBAL) to provide consultation regarding nutrition needs for the producers' herds. NRCS supports providing technical assistance in conservation and management of soil, water, air, plants, and animals. Toward this end, the agency is allocating a portion of its resources to enable us to work on addressing this unmet need in the Southeast. The data is also creating awareness in NRCS conservationists of the role animal nutrition plays in the success or failure of forage management and grazing systems in the region. State Grazing Land Specialists (and Grassland Specialists, Agronomists) are beginning to build databases for forages in their respective state, by forage species, by month.

A summary of these results from 405 specimen is given below. Please remember this summary data is inclusive of all of the kinds of pastures and forages described above, as well as a large geographical and physiographical area. The graph "Regional Data for all Pastureland" (with correction line for October and November samples from hunting areas in South Carolina) indicates that average forage quality remains above minimum requirements for mature, dry cows yearlong; and for lactating cows with the exception of protein levels in December and January. The reality is, of course, that forages are well above these levels in the regions with more palatable, perennial C3 forages (northern areas, piedmont and upper coastal plains), and generally much less in the southern coastal plains and peninsular Florida.

Summary of forage sampling results

July 97
58 samples
11.7 average cp
64.1 average dom

Aug 97
49 samples
11.3 average cp
63.1 average dom

Sept 97
51 samples
11.1 average cp
61.2 average dom

Oct 97
30 samples*
12.0 average cp
54.1 average dom

Nov 97
28 samples*
11.1 average cp
52.1 average dom

Dec 97
15 samples
8.2 average cp
59.9 average dom

Jan 98
20 samples
9.88 average cp
60.17 average dom

Feb 98
22 samples
11.54 average cp
63.45 average dom

Mar 98
18 samples
12.7 average cp
63.8 average dom

Apr 98
15 samples
16.9 average cp
66.9 average dom

May 98
39 samples
14.6 average cp
66.2 average dom

Jun 98
60 samples
12.3 average cp
64.0 average dom

*50-60% of the samples in October and November are for testing plant materials on the Western Piedmont Hunting Area in South Carolina. These samples reflected digestible organic matter content ranging from a low of 32% to a high of 59% (the average of which was 45.4% in November and 46.5% in October). Without this influence, Southeast Region DOM for October averaged 62.9% and November averaged 60.8%.

**The estimated number of demonstration sites practicing components of farm management systems is derived from data sheets with qualitative information from thirty-six sites in the southeast, and verbal reports or personal knowledge from the other twelve. When reports indicate a practice is implemented but not planned, it is presupposed that the reporter thought marking one category prohibited marking another. Thus, this summary presumes a component that is underway was also planned.

cp = dietary crude protein
dom = digestible organic matter

EXTENSION ACTIVITIES IN UTAH

Roger E. Banner, Utah State University

RLEP-related extension activities occurred in three programmatic areas in 1998, the NRCS-USU video production on plant-herbivore interactions, Western Integrated Resources Education (*WIRE*), and the Utah Grazing Lands Conservation Initiative (*GLCI*).

NRCS-USU Plant-Herbivore Interaction Video

This video production stems from a short course offered by Dr. Fred Provenza for NRCS personnel at the national level since the early 90's. It is based on the Plant-Herbivore Interaction program of research that Dr. Provenza has led since the late 70's. I have helped teach this offering since the early 90's and continue to work with Dr. Provenza to emphasize the practical applications of this work. The video being produced is directed toward livestock producers and technical specialists (professionals) dealing with herbivores on rangelands and pastures. It covers basic mechanisms of diet and habitat selection and feeding behavior that increase understanding of issues related to grazing management.

The principles addressed in this video apply to grazing management and habitat use by herbivores regardless of geographic location. For this reason we made a concerted effort to take video footage in as many different environments across the United States as possible. Our crew made visits to New Mexico (Chihuahuan Desert rangelands), Louisiana (coastal marshes), New York (orchardgrass pasture for dairies), Missouri (tall fescue pasture for beef cattle) and Wyoming (Rocky Mountain rangelands) to obtain footage and interview producers and technical specialists. The finished product will consist of one overview video (30 minutes) covering the topic of plant-herbivore interactions and six in-depth videos (30 minutes) covering subtopics. A detailed publication with emphasis on practical application of science-based knowledge is also being published to complete the package. The NRCS plans to distribute the package to all field offices and to make it available to anyone interested at reasonable cost. We also have plans to make this package available to extension agents and specialists in Utah and around the country through the Extension Service. The package will be provided to all *RLEP* participants when available. If possible we would like to offer satellite broadcasts and to make the package available in electronic format as well.

Western Integrated Resource Education (*WIRE*)

WIRE schools with the objective of improving decision-making and production efficiency by farmers and ranchers were offered in Wyoming, Montana, Idaho, and Utah in 1998. Abbreviated sessions were also taught in Queensland as part of an Australia-USA exchange designed to share information and educational approaches. The Queensland Department of Primary Industries is also making efforts to assist agriculturalists in adapting to change and employing sound management practices by offering numerous programs such as *FutureProfits*, *Beef Plan*, *Building Rural Leaders* and others. Meat and Livestock Australia (MLA), now called the Meat Research Corporation (MRC), co-sponsored the exchange the with *WIRE* programs in Wyoming and Utah by providing round-trip transportation for the *WIRE* contingent. Team members from Wyoming and Utah participated in the exchange. Members of the *WIRE* contingent participated in various reviews, workshops, and programs to learn firsthand what is being done in Queensland and how the efforts are being made. Generally speaking, livestock and grazing management are carried out in Queensland and Northern Australia in a much more extensive manner than we experience here. This is related to size of operations and land area involved as well as the value (price) of livestock. Most of the research and education emphasis is placed on setting stocking rates for continuous grazing. While there is considerable interest among producers in intensive grazing management, pasture rotation, and improved livestock distribution, little emphasis is being placed on intensifying grazing management by government research and extension personnel.

Grazing Lands Conservation Initiative (*GLCI*)

The Utah *GLCI*, a coalition of 15 groups of producer organizations and related support entities, worked at and received funding for the first time since the effort was begun in 1995. Up until 1998, the coalition had only been able to develop a mission statement and strategic plan, to publish a brochure, and to help sponsor a few local tours due to the fact that no funding was received from the earmarked *GLCI* funds provided NRCS. Through my efforts and insistence by coalition members from Utah producer groups, the coalition was successful in obtaining $30,000 of earmarked *GLCI* funds from NRCS and a $12,100 Environmental Quality Incentive Program (*EQIP*) grant to carry out an educational efforts in Utah. Since receiving funding, the Coalition has completed a work plan and begun implementing it. The Coalition has taken steps to update and reprint our *GLCI* informational brochure, developed a traveling display for promoting grazing land conservation at producer group annual meetings and conventions, and developed a web page (http://www.usu.edu/~utahglci/grazing.htm). Plans call for sponsoring pasture walks and state and local tours, sponsoring demonstration practices, and producing educational materials such as fact sheets on practices and conservation funding opportunities.

Future Plans

Future plans are based on continuing a programmatic effort to improve pasture and rangeland grazing management by working in these same three areas, NRCS-USU Video production, *WIRE*, and Utah *GLCI*. Some information on planned activities is provided in the discussions above. Information and materials will be shared widely as they become available.

ENHANCING CONSERVATION MANAGEMENT VIA NUTRITIONAL PROFILING OF LIVESTOCK ON GRAZING LANDS: THE NRCS NATIONAL EVALUATION OF FORAGE QUALITY AND ANIMAL WELL-BEING PROGRAM

Arnold Norman, NRCS Grazing Lands Technology Institute

One of the driving concepts of USDA's Natural Resource Conservation Service is to address critical needs of Soil-Water-Atmosphere-Plants-Animals and Humans or SWAPA+H, on private lands in the USA. Over the years, the agency has targeted programs that address soil, water, air and plants issues on croplands and grazinglands, with narrower emphasis on human issues (economics, anthropology) and even less focus on animals. Recent analysis has indicated that improved grazingland management can be attained when there are programs that link the human element more directly with the animal component interacting with natural resources under the control of individual landholders. Given the complexity of grazingland environments, difficulties arise in determining management and animal response relationships in these complex management environments.

For the past two years, USDA-NRCS Grazing Lands Technology Institute (GLTI) and the Ranching Systems Group (RSG) at Texas A&M University have been implementing a program that allows livestock producers to use direct feedback from their animals on a near real-time basis to improve their understanding as to how conservation practices impact performance of their animals in grazingland situations. A comprehensive program involving over 240 NRCS conservationists working with over 550 ranchers in 44 states, has been organized to assist landholders in improved decision making as it relates to management of the livestock within the context of conservation planning.

There are several major components associated with the program. First, the GLTI, within NRCS, provides overall program coordination and collaborates relationship with the RSG a part of the Center for Natural Resource Information Technology at Texas A&M University. GLTI is based in Ft. Worth, Texas, and provides expertise and funds, training in animal nutrition concepts and technical support to NRCS field personnel working with landholders in the program. RSG's primary responsibility is to provide the analytical capacity for assessing diet quality of free-ranging animals via the Grazingland Animal Nutrition (GAN) Lab, support for the Nutritional Balance Analyzer decision support system (NUTBAL) and technical training in use of the technology with landholders.

Researchers in RSG have developed nutritional monitoring technology, which allows the prediction of dietary crude protein (CP) and digestible organic matter (DOM) of free-ranging livestock via sampling of fresh feces. The fresh fecal samples are sent to GAN Lab via 2-day priority mail in an insulated mailer and results returned to the client rep (conservationist in this case) within 48 hours after receipt of the sample. The monitoring technology is made possible by a breakthrough in using near infrared reflectance spectroscopy to determine a suite of chemical bonds in feces, a secondary product of digestion, which can be used to predict primary components, CP and DOM, in the diet of the animals in an accurate manner. When NIRS is coupled with the analytical capacity of the NUTBAL decision support system, NRCS personnel have the necessary tools to determine the nutritional status of free-ranging livestock. They can then make recommendations to land managers concerning nutrient inputs, grazing adjustments, general husbandry, nutrient management and economic payoff of a variety of animal production practices.

Training is one of the critical elements of the program, because many of the NRCS personnel have limited backgrounds in animal nutrition. Recent advances in our understanding of ruminant nutrition have made training critical for even the most recent graduate from a natural resource or agricultural academic program. GLTI has organized a series of regional, 2-day training workshops each year where agency personnel, cooperating ranchers, extension personnel and in some instances, researchers attend the training sessions. The principle objective of these sessions is to cover critical nutrition concepts with the primary focus being on factors affecting nutrient intake. Trainees are provided copies of the NUTBAL software and subjected to a series of "cases" to solve in group settings. To help reinforce learning, RSG and GLIT has created a series of training documents that cover the same materials as well as two, 15-minute videos that emphasize the underlying concepts driving the use of the NIRS/NUTBAL systems and preparation of advisories for clients. CD-ROMS of the videos are also available to agency personnel and ranchers to view on portable or desktop computers. GAN Lab also maintains a geo-referenced database of all results from the fecal scans as well as digital photos of animals, vegetation and landscapes associated with the samples. National nutritional quality maps can rapidly be developed and made available to the advisors. A webpage is maintained on the Internet to provide sources of information on feedstuffs, breeds, literature and examples of success stories pertaining to use of the system.

Once an individual has been trained, a contact is made with key producers in a conservationist's region and critical herd and pasture management information acquired. Proper representation of the landscape, environmental conditions, and the client's animals, husbandry practices, feeding and grazing programs are critical to the usefulness of the advisories provided. Typically, the landholder receives the insulated mailers, samples the herds, and mails the samples to GAN Lab. Sometimes, NRCS personnel visit the ranch to acquire the samples. The method of sampling depends on the nature of the working relationship between the landholder and the advisor. When the NRCS advisor gets the results from GAN Lab, approximately four days after collecting the sample, the herd is profiled in NUTBAL and the herds' nutritional balance is determined. An advisory is written and provided to the client, generally with a follow up phone call and site visit to discuss actions and anticipated next sample date. Typically, 12 samples are collected each year on a ranch to determine the temporal changes in diet quality and assess opportunities to improve nutrient inputs and grazing practices.

To reinforce the process, GLTI and RSG jointly offer advanced training workshops for NRCS personnel and their clients where they bring cases to solve as a group. New emerging science, enhancements in the NUTBAL software, improved advisory techniques and general concept reinforcement are the primary topics at these sessions. Approximately 6-12 beginning and advanced training sessions are offered each year in the program. Approximately one-third of the 250 NRCS advisors have received advanced training. These individuals serve as an informal network of expertise to the remaining personnel.

Two of the strengths of the program are the strong feedback mechanism to the science, and user the friendliness of the NIRS/NUTBAL system. The broad variety of ecosystems covered by the program, coupled with the diverse set of livestock operations, allows robust testing of the system and immediate feedback to the technology development process. This facilitates rapid design changes and identification of gaps in our scientific understanding of grazing animals.

A recent meeting of key NRCS advisors discussed a series of critical benefits of the NIRS/NUTBAL system. These benefits included: 1) greater landholder understanding of the impact of their management decisions on the nutritional well-being of the animals, 2) more efficient use of nutrients to mediate deficiencies, 2) improved animal performance (conception and weaning weights), 3) reduced costs of production, 4) more efficient use of pastures, and 5) greater awareness of the role of conservation in meeting the nutritional needs of their animals in a more environmentally friendly manner.

CARBON SEQUESTRATION THROUGH IMPROVED PASTURE MANAGEMENT

Richard T. Conant and Keith Paustian
Colorado State University

Abstract

Improved pasture management can potentially sequester substantial amounts of atmospheric carbon. The purpose of this study is to quantify the storage potential for the Southeastern United States. Our study includes collection and analysis of field samples, compilations of state-wide pasture land use data and simulation modeling of soil C dynamics.

Five farms have been selected in Virginia to study the effects of conversion to pasture and changes in pasture management on C storage. These farms are located across the central and western parts of the state, represent the Piedmont and mountains and Valleys regions, and occur on widely distributed soil series. Data collected at these sites will include organic C, rapidly mineralizable C, POM C, and soil physical characteristics. Additionally, primary productivity and other data will be collected to permit a more mechanistic understanding of C sequestration. Model parameterization will be based on these data and information on land use.

Numerous land use datasets have been collected using surveys and remote sensing. However, the datasets were collected at different resolutions, used different classifications, and differ in frequency and time of sampling. Since spatial and temporal projection of C sequestration potentials relies heavily on these data, comparisons are underway to determine their congruity and which are most useful.

As this work proceeds, there are a number of international C emission issues that need to be addressed under the United Nations Framework Convention on Climate Change. These issues include C emissions trading, determination of acceptable C sinks under the Kyoto Protocol, and how the magnitude of those sinks can be verified. Based on early discussion, it appears that C sinks due to land use change, likely including changes in farming practices, will be allowable. As a component of this project we will test a method to document C sequestration, and determine whether it meets the requirements of the Kyoto Protocol. Emission trading coupled with verifiable C storage may add an additional financial incentive to the list of reasons for adopting improved pasture management.

Introduction

The most recent assessment of the Intergovernmental Panel on Climate Change concluded that "the balance of evidence suggests a discernable human influence on global climate," because of continued increasing atmospheric concentration of CO_2 and other greenhouse gasses (Houghton *et al.*, 1996). The IPCC report went on to explain that human induced climate change may have significant adverse impacts on agricultural production, coastal regions, and ecosystems (Houghton *et al.*, 1996). These and other findings have led to resolutions regarding limitation of greenhouse gas production, including the internationally agreed upon Framework Convention on Climate Change and the Kyoto Protocol.

The goal of the Framework Convention on Climate Change (UNFCCC) is to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (Article 2)." More recently, the Kyoto Protocol set specific greenhouse gas emission limitation goals for developed countries. Under the Kyoto Protocol, net CO_2 emissions for the United States in 2010 must be seven percent less than net emissions in 1990. Additionally, all Kyoto Protocol signatory nations must make demonstrable progress toward their 2010 emission goals by 2005. Emission reduction goals can be reached a number of different ways. Carbon dioxide emissions to the atmosphere can be directly decreased through a variety of political and technological means. Net emissions may be decreased by removal of CO_2 from the atmosphere, or increasing C sequestration. Finally, the Kyoto Protocol allows for C emission transfers and joint implementation, letting countries transfer C emission credits internationally.

Gross CO_2 emissions from the burning of fossil fuels have continued to increase in the US (Figure 1; Marland *et. al.*, 1998). Continued difficulties in lowering CO_2 emissions have turned the focus to C sequestration as a method of reducing net CO_2 emissions. A variety of technological mechanisms have been suggested for increasing C sequestration, but land use change and changes in land management offer an alternative method to store large amounts of C (Bruce *et al.*, 1998).

The potential for C storage in soil has received more attention recently because there is a large potential for long term C storage that may be relatively inexpensive (Bruce *et al.*, 1998). Total soil C typically decreases by 20-40% following conversion from forest or grassland to agriculture (Davidson and Ackerman, 1993). Soil C loss typically decreases over time and most of the C loss occurs over about 20 years (Davidson and Ackerman, 1993; Johnson, 1992). All or part of the C that was lost to the atmosphere due to conversion could potentially be transferred back to the soil if the land were converted back to forest, if tillage decreased, or if residue inputs increased (Lal *et al.*, 1998).

Improvements in pasture management could lead to C sequestration over time, in a manner similar to that observed under improved agricultural practices (Fig. 2; Donigan *et al.*, 1994; Bruce *et al.*, 1998). Soils with the largest potential for C sequestration are those that have lost significant portions of soil C in the past due to poor management or those with a history of cultivation (Bruce *et al.*, 1998). Conversion of cropland to pasture or more intensive management of pasture could potentially sequester 0.2 Mg C per hectare per year (Bruce *et al.*, 1998).

Large areas of pasture land in the Southeastern United States prompted an investigation into the potential for C storage under improved pasture management. This paper describes: (1) the approach used for determining the potential for C sequestration in pasture soils with improved pasture management; (2) methods used to verify changes in pasture soil C storage; and (3) model simulations of C dynamics to make site, state, and regional level projections. Anticipated results of this study are discussed with reference to the Kyoto Protocol and the expected developments at COP4.

Field sample collection and analysis

We plan to use a broad-based approach to field sampling, focusing on examining paired plots of improved and unimproved pasture. Additionally, where available, comparisons will be made between native soils (under forest) and agricultural soils. This paired plot approach substitutes space for time, and changes in C pools over time in response to management changes can thus be determined. Analysis of soils under paired plots will allow us to determine the amount of C lost following conversion from forest to pasture, the amount of C sequestered following conversion from row crops to pasture, and the potential for C sequestration following improved pasture management (Fig. 2). The paired plot approach requires that sites be chosen carefully to ensure that differences between sites are the result of differences in management rather than other characteristics such as soil, topography, hydrology, etc.

Sites selected in Virginia are located at five farms that span the Piedmont and Mountain and Valleys regions of the central and western portions of the state. Paired plots within these farms offer the opportunity to study conversions from forest to pasture, from agriculture to pasture, from poorly managed pasture to intensive management, and comparisons between long term hay production and pasture.

Sample collection will focus first on collecting data that are useful for quantifying differences in soil C pool size with changes in land use. But the data are also intended to be used to identify mechanisms leading to changes in soil C pool size following changes in management. For this reason, net primary production will be measured for a number of the plots in poorly- and well-managed pastures. We expect that increased production on improved pasture leads to soil C sequestration.

Sample locations will be chosen to limit variation due to factors other than management. Topography, hill-slope position, aspect, and soil series and associated characteristics will be held as consistent as possible between the fields. Three microsites will be established within each field to be sampled. Each will be sampled according to the methodology described in the sampling instructions for the Soil Carbon Enhancement Project. Microsites within a field will be located on ridgetops and within the same soil series within each farm. Soil samples will be collected using a 2.5-inch diameter soil core. Six replicates will be collected at each microsite. Four of the cores will be 50cm deep and the other two will be 1m, with the deep samples located randomly within each microsite. Depth increments will be 0-10cm, 10-20cm, 20-50cm, and 50-100cm. Each sample will be stored separately in a one-gallon freezer bag. Bags will be labeled with pre-printed labels indicating farm, field, microsite, sample, and depth.

Following collection, samples will be stored on ice in coolers and returned a cold room for temporary storage. Samples will remain packed in coolers and will be shipped to Fort Collins. Upon return to Fort Collins, samples will be transferred to cold ($4^{O}C$) storage. Samples will be stored in sealed plastic bags during processing, until samples have been oven-dried.

Samples will initially be passed through an 8mm mesh sieve and 200g subsamples will be collected for further preparation and analysis. Coarse root material remaining on the sieve will be collected from three samples from each microsite (determined at random). All soil samples will then be passed through a 2mm-mesh sieve, and root material will be collected from the sieve and picked from the sieved soil for the same subset of samples mentioned above.

Following sieving, a portion of each sample will be air-dried. Dried soil will be used for POM C determinations, and for 200d incubations to determine active C fractions (Cambardella and Elliott, 1992). A portion of each sample will be oven dried. These oven-dried samples will be analyzed for soil moisture, texture, and pH. A portion of each sample will be ground to fine powder. Finely ground samples will be analyzed for total C, total N, and organic C (if significant amounts of carbonate are present).

Verification of changes in C stocks

A key component of this project is the establishment of microsites that can be relocated and resampled. Though the primary goal of the field sampling is to quantify C sequestration following pasture improvement, the Kyoto Protocol states that C sequestered be "measured as verifiable changes in carbon stocks (Article 3.3)." A key component of verification is thus determining appropriate methods for confirming changes in C storage. We propose to follow a method of intensive sampling developed for an intensive C sequestration study in Canada (Ellert and Bettany, 1995).

Within each field to be sampled three microsites will be established. Microsite locations will be identified using differential GPS and established benchmarks. Microsites will be two meters by five meters and six samples will be taken around the perimeter of each microsite in specific locations (Fig. 3). The microsites are small enough so that lateral variability is limited, but large enough so that they can be intensively sampled, and resampled numerous times in the future. Relocateable electronic marking balls will be buried 75cm deep in the northwest corner of each plot. Thus, once the general area within each field is located using GPS, the precise location of the microsite can be identified with a marker locator. These sites can be resampled in the future with minimal influence due to the natural variability in soil characteristics, thus establishing changes in C pools over time in response to improved pasture management.

Modeling

Modeling will be done using the Century ecosystem model (Parton *et al.*, 1988). Initially the model will be parameterized for each field within a farm using data collected in the field. Model inputs will include soil physical characteristics, information about land use collected from farmers, and extant data such as air photos. The model will be used to project the effects of changes in pasture management on long term C storage potential. As mentioned above, field data collection will aid in making modeling projections by focusing on variables that influence soil C sequestration.

One of the goals of this project is to develop estimates of regional C sequestration potential and their distribution over space and time. To achieve this goal, we need to develop information about current and past land use in the Southeast region. Available survey data include the NRI, NASS, and Agricultural Census. Remotely sensed data are available at different resolutions and use different methods of land characterization (not always identifying pastureland). A comparison of the different data sets is underway to determine how well they agree with one another. One of the limitations is that the datasets are all relatively recent (1982 or later) except the Agricultural Census. Comparison of these datasets at the county scale might allow us to parameterize them with each other permitting more extensive and intensive use of the datasets (i.e., Fig. 4).

Summaries of the National Resources Inventory data confirm that significant areas of the Southeast region are devoted to pasture land (Fig. 5). Furthermore, between 1987 and 1992, pastureland increased by 400,000 acres, with increased pastureland in every state but Virginia and Florida (Fig. 6).

Implications of the Kyoto Protocol

The Kyoto Protocol is a set of international agreements that limits greenhouse gas emissions for developed countries. The Protocol includes a variety of methods for net emission reduction including developing sinks, carbon trading, and the Clean Development Mechanism (CDM). There are numerous questions left unanswered by Kyoto Protocol, many of which are to be resolved at the Fourth Conference of the Parties (COP4) in Buenos Aires November 2-15, 1998. Among the outstanding issues to be resolved at COP4 are carbon emission trading, protocols for verifications of sinks, and types of sinks to be allowed under the protocol.

The issue of sinks is first dealt with under Article 3.3 of the Kyoto Protocol, where it is stated that

"... net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments."

This clearly indicates that sinks will be an important part of C balance calculations, but is not clear on the issue of which sinks may be applied. It is also unclear whether limits to forestry activities apply to forestland use change or to all human-induced land use change. Article 3.4 of the Protocol goes on to explicitly state that this is an issue that needs to be resolved. Agricultural soils are specifically mentioned as a potential sink in Article 3.4.

Another important issue to be resolved at COP4 is methodology for verifiable quantification of C sinks. The Protocol states that sinks are to be identified through changes in C stocks over time, but technical methods to quantify changes have yet to be fully defined.

The other main issues to be dealt with at COP4 are the flexibility mechanisms of the Kyoto Protocol. One of these is the Clean Development Mechanism (CDM). The CDM allows for transfer of C emissions and sinks between countries. The CDM (Article 12) allows emitters or countries to pursue C sequestration projects (mainly forestry) in Annex I countries (countries with fully developed market economies). These projects would be paid for by emitters and would be used to offset emissions. The CDM encourages sustainable development in Annex II countries, contributes toward the environmental goals of the UNFCCC, and assists other Annex I and Annex Ia countries (countries without fully developed market economies) in meeting the requirements of the Kyoto Protocol.

The other flexibility mechanisms to be discussed deal with the issue of emission trading. Under the framework of the Kyoto Protocol, emission trading could evolve in one of two ways. Emission trading could arise through the development of domestic emission trading programs. Within any developed Annex I country a domestic C emission trading program may be developed. This would allow carbon emitters with large impediments to emission reduction to buy emission credits from other emitters that can more easily reduce emissions. This creates an economically efficient situation where the most easily obtained emission reductions are valuable to both parties. This system of tradable emission credits has the potential to develop similar efficiencies internationally. Discussion is underway in the United States to examine the development of a tradable emissions credit program modeled after the tradable SO_2 emission program implemented by the USEPA acid rain program (Solomon, 1995).

A formal emission trading program is more efficient, but more difficult to develop than the other C emission trading scenario under the Kyoto Protocol, Joint Implementation (JI). Joint Implementation allows emitters to trade C emission credits without the benefit of a domestic emission trading system. Joint Implementation is not as efficient because emitters must identify the cost of CO_2 emission reduction for their potential trading partners. Though less efficient, JI will likely be a major method of C emission transfers between countries, as it is unlikely that all Annex I countries will establish domestic emission trading programs (Kopp and Toman, 1998).

There are other issues regarding the CDM and JI that are to be addressed at COP4. For example, Article 17 of the Kyoto Protocol states that emission trading shall be supplemental to emission reduction, but several nations are making this a major part of their policies. Japan recently announced that it plans to meet 67% of it's reductions by emission trading within Japan, with other countries, and through increased forest cover. Cost estimates for implementation of the Kyoto Protocol generated by the Clinton administration suggest that the United States intends to buy emission credits to ameliorate 85 percent of what is needed to meet Kyoto, instead of making those reductions in the American domestic economy (Kopp and Anderson, 1998). However, C trading is already occurring both within and between Annex I nations, and between other Annex I nations and Annex II nations. Trades have taken place between U.S. and Canadian power companies, between Costa Rica and three Norwegian power companies (Goodman, 1998), and between a power company and a State Forest in Australia (Washington, 1998).

The potential value of C emission credits as commodities are difficult to predict based on the limited number of concluded trades. Current C sequestration sales have been near ten dollars per ton (Goodman, 1998), but some predict that prices may rise to $100 per ton. At the current price of $10 per ton, improving pastureland may be worth about $0.40-4.00 per acre per year, though, as mentioned, this figure could increase 10 fold. In addition to the direct benefit to farmers, C sequestration in improved pasture will be beneficial to the US as a whole, as the Southeastern U.S. has the potential to sequester 2.7 Tg. C $year^{-1}$ through pasture improvement alone (Table 1). This is about 0.7% of the amount needed to meet the requirements of the Kyoto Protocol. If more land is converted from crops to pasture, there is potential for much more C sequestration in pastureland.

Conclusion

This study is designed to quantify the potential for C sequestration in pasture soils with improved management. We will gather data on both changes in C pools with changes in land use (including pasture improvement) and on the mechanisms responsible. Our understanding of C storage mechanisms in pastures and information about land use history and land use change will permit us to generate accurate local and regional estimates of C sequestration potential.

This work was prompted by international agreements to limit CO_2 emissions and the potential to offset emissions with C sinks. One of the main issues regarding the Kyoto Protocol is verification of C storage. We will test a method to verify C sequestration through changes in C stocks. In addition to the benefits associated with increased soil organic matter, the development of emissions trading offers potential income for farmers converting to improved pasture management.

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LIVESTOCK SYSTEM GREENHOUSE GASES

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Introduction

Changes in livestock production systems directed at improving efficiency and simultaneously decreasing methane commonly result in multiple or ripple effects on the system. These indirect, non-methane related effects might repress or enhance other greenhouse gas (GHG) emissions from the livestock and/or supporting systems. In light of the Kyoto objective(s) of quantifying and reducing overall greenhouse gases, inherent system variations or effects of mitigation strategies must be viewed in a holistic manner. This project attempts such a summation as illustrated by Figure 1.

Matrices of GHG emissions are being constructed for nine representative locations of three industry segments, dairy, cow-calf and feedlot in the U.S. The first stage will determine the relative component strengths of representative cattle production system emissions of; a) enteric methane, b) manure methane, c) fossil fuel carbon, d) soil carbon sequestration, and e) nitrous oxide emissions.

These will be aggregated and expressed as global warming potential (GWP) per kg milk and or meat produced by each system. Secondarily, the emissions and associated financial impacts in response to changes in management practices, forage utilization, production levels or other mitigation strategies will be examined. Policy recommendations may be formulated based upon the emissions and financial impacts, depending on decision-maker objectives with respect to each.

Prior estimates of total GHG's from dairy cattle in the U.S. (Johnson, et al., 1997) and England (Jarvis and Pain, 1994) indicates 45% or more of the GWP to stem from CO2 and/or N2O. The U.S. dairy system sums to approximately 1400 g of CO2 equivalent per kg of milk produced. The non-methane portions included about 6% from fertilizer related N2O and 47% from fertilizer and farm operation related fuel. The British system characterized an intensive dairy system as producing much more N2O, nearly 3 g/kg milk, or about 1000 g as carbon dioxide equivalent GWP per kg milk. Soil carbon sequestration has largely been undefined in these systems, but has the potential of adding 100 or more, or offsetting 300 or more g of GWP/kg of milk.

Progress

The initial effort examines a Marathon county, WI dairy system. It is currently characterized as 16 production classes representing herd dynamics during various phases of growth and physiological function. Body weight, gain, mortality, days in class, etc are defined, the nutrient requirements and diet quality projected in a manner similar to methods used previously for whole country scenarios (Johnson, et al. 1993, Gibbs and Johnson, 1993). Typical individual feedstuffs, cropping system, hectares, fertilizer, fuel, etc. was then projected and all GHG's summed and related to costs and products. The information to construct these matrices has been garnered from many sources including; NASS, NAHMS, Cattle-Fax, NRC, IPCC, NSF, DHIA and extension service personnel. The current representation of the 100 milking cow WI dairy (Table 1) has 164 head, with 43 and 93 % replacement and calving rates and requires 358 ha of land, principally for corn and soybeans. This system produces 1559 g of CO2 equivalent per kg of milk if soil carbon sequestration is in equilibrium (Table 2). About 38% of this arises from methane, 35% from fuel use and the balance, 27%, from nitrous oxide. Use of best management practices for these crops may offset about 1/4th of these through increased soil-C sequestration.

The next scenarios will examine these GHG outputs from dairies in CA, cow-calf production in WI, VA, AL, TX and UT, and feedlot systems in TX and IA. When these are completed, evaluation of mitigation strategy effects on GHG per product and herd income will be conducted. Mitigation strategies include increased productivity, forage utilization, product fat content and age at slaughter. Ultimately this approach will allow GHG and economic impact analyses of any beef or dairy system management change or mitigation effort.

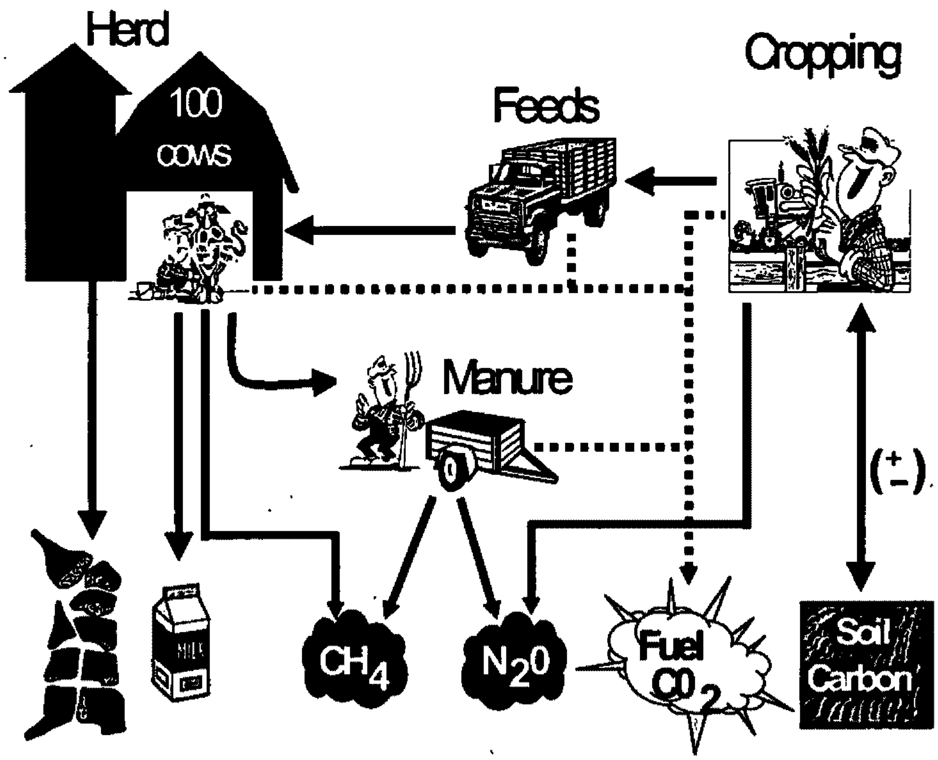
Table 1. Characteristics of representative Marathon County, Wisconsin dairy (100 milking cows).

Animal Dynamics		Feed Characteristics	
Total head	164	Average, TDN %	66
Milk/cow, kg/year	7169	Pasture, ha	39
Replacement, %	43	Alfalfa hay, ha	45
Calving rate, %	93	Corn silage, ha	10
Mortality, 1st month %	5.6	Corn grain, ha	145
Mortality, cows, %	3.8	Soybeans, ha	115

Table 2. Current estimates of Wisconsin dairy greenhouse gases per kg milk.

Source	Gas	g/kg milk	CO_2equiv
Enteric	CH_4	21.9	548
Manure	CH_4	2.1	52
Farm Operations	CO_2	190	190
Crop fertilizer	N_2O	1.3	416
Fuel	CO_2	353	353
Soil-Carbon (normal)	CO_2	0	0
Total greenhouse gases			1559
Soil Carbon (BMP)	CO_2	-398	-398
Net Effect with Best Management Practices			1161

Figure 1. Products and GHG from Cattle Production



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APPLICATION OF STRATEGIES TO MITIGATE METHANE EMISSIONS FROM RUMINANT LIVESTOCK

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Overview

The goals of the program are to develop methods of reducing cattle methane emissions by enhancing animal productivity and to transfer this technology to cattle producers. These efforts in mitigation include not only methane emissions resulting from enteric fermentation but also those associated with manure management. In addition, we intend to extend our work beyond the borders of the United States to work with others worldwide in measurement and mitigation of methane associated with domestic livestock. This important work will help facilitate the successful implementation of the Clinton-Gore Climate Change Action Plan.

Specific objectives:
1) The development of economically viable strategies to reduce methane emissions from ruminants
2) The transfer of information to livestock producers on how to implement these strategies
3) The development of sampling protocols for measuring methane emissions from manure handling systems
4) To continue to transfer to interested groups worldwide, the technologies for sampling and reducing methane emissions.

The project began in October 1997 and continues until September, 1999. Work completed as a part of this project has been reported at the annual meeting at the American Society of Animal Sciences meeting in Denver, CO and has been published in the *Farmer-Stockman*. This work includes an evaluation of apple pomace silage as a feed ingredient for growing beef heifers and measurements of methane emissions from suckling calves and growing bulls, information that has been missing from ruminant methane inventories. In addition, workshops were held to train scientists from the U.S., Europe, Mexico and South America in the use of the SF_6 tracer technique.

Management conditions

Measurements of CH_4 emissions were made from growing beef heifers fed ensiled apple pomace, suckling calves and growing bulls. These measurements were made to evaluate the methane reduction potential of an available by-product feedstuff and to provide estimates of methane production from grazing suckling calves and bulls for inventory purposes.

Supplementation of diets with ensiled apple pomace for growing steers and heifers could reduce the cost of feeding because transportation is the only cost of the apple pomace. The use of the apple pomace by cattle producers would have the added advantage of using a product currently considered waste and spread on fields. To prolong the storage life and enhance the feeding value, apple pomace was ensiled with rolled barley and alfalfa hay. Growing heifers (n=24) were assigned to one of three diets; 0% ensiled apple pomace, 25% of the diet DM as ensiled apple pomace and 50% of diet DM as ensiled apple pomace. Body weight gain, diet digestibility and CH_4 emissions were measured every 21 days then the diets were switched. Feed intake was monitored daily.

Four suckling calves approximately four months of age were separated from their dams and moved to a room for six hour CH_4 emissions estimates. All calves had been grazing pasture for approximately two months prior to these measurements. While in the room calves had access to alfalfa hay and water.

Four growing bulls were fed a diet consisting of 60% corn silage and 40% concentrate, to enable body weightgains of greater than 1.36 kg/d. Bulls were moved into a room for measurement of CH_4 and had ad libitum access to their diet and water.

Table 1. Summary of CH_4 emissions from heifers fed three levels of ensiled apple pomace, suckling calves and growing bulls.

Management Condition: Ensiled apple pomace feeding, calf and bull emissions									
Animal Type: Growing beef heifers fed ensiled apple pomace silage									
Characteristics of Animals Measured									
	CH_4 Emissions (g/hd-day)			Live Weight (kg)		Weight Gain (kg/day)		Dry Matter Intake (kg/d)	
TRT	Mean	SE	n	Mean	SE	Mean	SE	Mean	SE
0	274.3	.72	4	227	.95	1.04	.04	7.5	.18
25	284.6	.72	4	227	.95	.97	.04	8.95	.18
50	242.4	.72	4	227	.95	.85	.04	7.67	.18
*Extrapolated from room tracer 6 hr measurement (n=4)									
Management Condition: Growing Bulls									
Animal Type: Growing bulls fed 40% grain and 60% alfalfa hay									
	CH_4 Emissions (g/hd-day)			Live Weight (kg)		Weight Gain (kg/day)		Dry Matter Intake (kg/d)	
TRT	Mean	SE	n	Mean	SE	Mean	SE	Mean	SE
1	227.4*	--	3	498	4.5	3.1	.4	30	--
Management Condition: Suckling calves									
Animal Type: 4 mo. old suckling calves									
	CH_4 Emissions (g/hd-day)			Live Weight (kg)		Weight Gain (kg/day)		Dry Matter Intake (kg/d)	
Sampling	Mean	SE	n	Mean	SE	Mean	SE	Mean	SE
1	46.80	--	4	206	.5	.9	--	--	--
2	58.56	--	4	206	.5	.9	--	--	--
*Extrapolated from room tracer 6 hr measurement (n=4)									

Implications

Economics of implementation:

Because the ensiled apple pomace was not utilized as well for growth of beef heifers, as indicated by tabular nutrient values, the economic value of apple pomace in diets was low. When utilized at 25% of the ration dry matter, the value of the ensiled apple pomace was $0.052/kg DM, and when incorporated at 50% of the ration dry matter, the value of the apple pomace was $0.044/kg DM. The costs of the apple pomace for shipping were $ 0.0776/kg DM, and were $ 0.033/kg DM for ensiling (Table 2). The costs of shipping the product must be minimized for apple pomace to be competitive as a feed ingredient.

Table 2. Cost of ingredients and total mixed rations fed to growing beef heifers.

		Treatments		
Ingredient	$/kg of DM	0% Ensiled Apple Pomace	25% Ensiled Apple Pomace	50% Ensiled Apple Pomace
Bluegrass hay	0.072	0.043	0.025	0.007
Alfalfa hay	0.154	0.154	0.154	0.154
Ensiled apple pomace	0.11	0	0.028	0.055
Barley	0.123	0.027	0.027	0.027
Urea	0.44	0.004	0.004	0.004
Trace mineralized salt	0.26	0.001	0.001	0.001
Dicalcium phosphate	0.41	0	0.001	0.001
$/kg DM of total mixed ration		0.101	0.112	0.120
$/kg of BW gain		0.728	1.002	1.083
kg gain/kg CH4 produced[1]		5.29	4.75	4.89

[1]One liter of methane = 0.7162 g

Methane emissions from calves were approximately 2.2 g CH_4/hd-hr or 52.7 g CH_4/hd-d. These rates approximate those from sheep and reflect the degree of grazing activity of these calves. Emissions from calves will increase as the calf's intake of milk declines and forage intake increases prior to weaning. Whether this amount of CH_4 is an important contributor to an inventory remains to be investigated.

As expected, bulls emit CH_4 at the same rate as cows. To add bulls to the inventory estimates of intake should be made and the same diet factor measured with cows can be applied. The bulls in these measurements produced 227 g CH_4/hd-d. Feed intake of bulls during the breeding season is likely to be difficult to estimate.

Summary

One of the objectives of this project was to determine if ensiling of apple pomace would increase its storage life as a feed. This was successful. The ensiled apple pomace was a stable product and no deterioration of quality was observed after 4 months of storage. When the ensiled apple pomace was fed to growing beef heifers as part of a total mixed ration, the apple pomace reduced methane emissions on a per animal basis, but increased methane emissions on the basis of kg weight gain per kg methane produced.

Given feed prices current in October, 1997, the apple pomace was economical at about $0.066/kg DM. However, weight gains of heifers fed the ensiled apple pomace were less than expected and the concentrations of serum urea-N indicated a need for more crude protein in the diets. Thus, the apple pomace may have affected utilization of dietary crude protein and performance of heifers fed the apple pomace may have been improved by more crude protein in the diet. This project has demonstrated that apple pomace can be used in diets for growing beef cattle, but also clearly identifies the need for further work on factors which influence successful incorporation of agricultural byproducts in diets of livestock for reduced methane emissions.

REDUCING METHANE EMISSIONS FROM BEEF COW HERDS IN RANGE BASED MANAGEMENT SYSTEMS

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President Clinton's Climate Change Action Plan calls for "improved ruminant productivity and product marketing" to reduce greenhouse emissions. This plan further details that such efforts include regional field studies to (1) refine emission estimates and (2) identify management strategies that simultaneously improve productivity and profitability of farming operations throughout the U.S. and reduce methane emissions. It also charges that educational efforts be developed to disseminate this information.

To date, little has been done to investigate the possibilities of reducing methane production by beef cattle on pasture or rangeland through improved management. We are conducting this project to establish some baseline information on methane production by beef cattle during the annual production cycle. We are investigating seasonal levels of methane emissions produced under traditional and improved grazing and herd management strategies on pasture and rangeland in Utah. Field study results from this project will have implications for Utah ranches, as well as operations throughout the Intermountain West. These results should strengthen the scientific basis for improved production efficiency, improved overall land management, improved economic well being of producers, and reduced methane emissions from grazing beef cattle. We will integrate field study findings into extension education programs for livestock producers and land managers. These educational efforts will attempt to extend the field study results to Utah producers, as well as throughout the Intermountain West. Extension networks and cooperation already exist throughout the West and efforts under this program will be integrated into the efforts of this network. This extends the impact to the largest number of beef cows. Educational efforts will be designed to illustrate the relationships between economic efficiency and methane emissions, so that producers become aware of the win-win situation of simultaneously improving ranch finances and the environment. Finally, general relationships identified through field study and extension efforts of this project should provide insight for development of beef cattle methane reduction strategies in other regions and global environments.

Objectives

Field Studies. Studies have been conducted to document methane emissions under a variety of grazing and livestock management conditions. The overall objective is to investigate the influence of grazing and livestock management alternatives on methane emissions to estimate annual emissions from grazing beef cattle and to evaluate the influence of some alternative management strategies to reduce methane emissions. Specific objectives being evaluated are:

1. To compare methane emissions from beef cattle grazing seasonal rangelands in native, unimproved conditions to rangeland improved by seeding to improved grass

species.

2. To evaluate the influence of grazing intensity upon the methane emissions of beef cattle grazing irrigated meadow pastures.

3. To evaluate the methane emission response to an alternative management strategy wherein feeder cattle are at slaughter weight by shortly after weaning (about 10 months of age).

4. To develop an estimate of yearly methane emissions from grazing beef cows based on data collected herein.

Extension. Adoption of methane reducing technologies by beef cattle producers hinges on maintaining or improving individual producer profitability from complex crop and livestock production systems. Our objective is to effectively disseminate information on profitable and environmentally sound management systems that reduce methane emissions. This includes identification and analysis of relevant policy options that will provide incentives to beef cattle producers to adopt practices that reduce methane emissions. It also includes integration of results of field study efforts into existing and new extension education programs for producers in Utah and throughout the western U.S.

Approach

Field efforts were designed to establish a methane emission baseline for cattle in a variety of temporal and spatial environments. The intent is to measure methane emissions from three discrete locations when grazing at each location is most appropriate to encompass some of the most common vegetation types and seasons of use. Combining this seasonal data should provide an estimate of annual methane emissions from beef cattle enterprises using similar resources. Second, each trial will compare alternative management strategies for forage or livestock management to provide an overview of possible emission reductions from improved management practices. The alternatives selected for evaluation are hypothesized to provide significant positive responses and are selected to represent groups of similar strategies, including grazing management, forage improvement, or livestock management. Two field seasons of sample and data collection from grazing livestock have been conducted for each experiment described herein. The final phase of the project, to complete laboratory and data analysis and publish results in appropriate journals, is in progress.

Initial extension activities have focused on development of a framework for presentation of results in an enterprise level model. This will be used in the near future to present results to livestock producers and land managers, culminating with publication of results in media accessible by livestock producers.

Progress Of Work And Principal Accomplishments

1. Nutritional and methane emission responses of beef cattle grazing improved forage species for rangelands.

Alternative forages on foothill rangeland in the Intermountain West are being evaluated at the Utah Agricultural Experiment Station (UAES) Tintic Research Site. Treatments include native rangeland and pastures seeded to four improved forage species, including 'Hycrest' crested wheatgrass (*Agropyron desertorum* X *A. cristatum*), 'Nordan' crested wheatgrass (*A. desertorum*), 'Vinall' Russian wildrye (*Psathrostachys junceus*), and 'Syn-A' Russian wildrye. Pastures of each species are established in a randomized complete block design with three replicates. Seasonal grazing of foothill rangeland occurs during the spring and fall, so our sampling occurred during an approximate 30 day grazing season during each spring and fall. Specifically, grazing trials were conducted during fall 1995, spring 1996, fall 1996, and spring 1997. Trials were conducted with nonlactating beef cows during fall and cow-calf pairs during spring. During the first two trials, sixty cows were used, so each pasture (6.88 ha) had four cows. Sulfur hexafluoride (SF_6) boluses (to sample methane emissions) were placed in three cows per pasture in replicates one and two, and in two cows per pasture in replicate three. During the last two trials, 45 cows were assigned similarly so each pasture had three cows and all cows received a SF_6 bolus. Cows were adapted to pasture forage for 14 days before data collection. Methane was sampled on replicate one and half of replicate two from days15 to 20 and on the other half of replicate two and replicate three from days 22 to 27. Feces were collected every other day for 10 days, so samples were collected from cows on each pasture for a total of five days. Heifers fitted with esophageal fistulae were used to collect diet samples. Fecal and diet samples are presently being analyzed in the laboratory.

Animal performance and methane emission responses from the first two sampling periods are presented in the following two tables. These preliminary data suggest that variation exists among species, and the species of choice depends on the season of use. For example, native rangeland species provided the lowest methane emissions in fall, but were among the highest in spring.

Methane emission and performance responses of beef cows grazing dormant forages during October 1995.

Species	CH_4 (g/d)	CH_4 (g/d/kg BW)	Wt. change (kg)	BCS change
Native mixture	87.0	.150	-40.6	-.6
'Nordan' crested wheatgrass	110.7	.204	-42.5	-.7
'Hycrest' crested wheatgrass	124.3	.223	-46.9	-.7
'Vinall' Russian wildrye	154.6	.282	-10.6	-.4
'Syn-A' Russian wildrye	99.1	.179	-20.6	.2

Methane emission and performance responses of beef cows grazing vegetative forages during May 1996.

Species	CH_4 (g/d)	CH_4 (g/d/kg cow BW)	CH_4 (g/d/kg calf BW)	Cow Wt. Change (kg)	Cow BCS Change	Calf Wt. Gain (kg)
Native mixture	244.6	.510	2.48	-19.0	.1	18.5
'Nordan' crested wheatgrass	251.1	.491	2.32	-8.6	-.1	23.2
'Hycrest' crested wheatgrass	226.7	.429	2.63	-5.0	.1	27.6
'Vinall' Russian wildrye	262.4	.502	2.65	-9.9	.2	25.0
'Syn-A' Russian wildrye	259.1	.477	2.79	1.6	.3	26.6

Methane emission and performance responses of beef cows grazing dormant forages during October 1996.

Species	CH_4 (g/d)	CH_4 (g/d/kg BW)	Wt. change (kg)	BCS change
Native mixture	217	.38	-17.8	-.39
'Nordan' crested wheatgrass	217	.38	-23.3	-.33
'Hycrest' crested wheatgrass	196	.36	-14.4	-.56
'Vinall' Russian wildrye	257	.46	2.5	-.25
'Syn-A' Russian wildrye	237	.43	6.1	-.17

Methane emission and performance responses of beef cows grazing vegetative forages during May 1997.

Species	CH_4 (g/d)	CH_4 (g/d/kg BW)	Wt. change (kg)	BCS change
Native mixture	324.6	.57	103.3	.81
'Nordan' crested wheatgrass	287.5	.54	143.9	.83
'Hycrest' crested wheatgrass	321.1	.58	156.1	.97
'Vinall' Russian wildrye	296.1	.59	126.1	.67
'Syn-A' Russian wildrye	324.6	.63	106.1	.69

2. Nutritional and methane emission responses of beef cattle to grazing management (stocking rate) on irrigated pastures.

Grazing intensity is being evaluated on irrigated pastures at the UAES Panguitch Farm. The current vegetation on the pastures is a mixture of cool-season grasses, including quackgrass (*Agropyron repens*), smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*). This is typical of the vegetation on many irrigated pastures in the valleys of the Great Basin. Two trials were conducted during the summers of 1995 and 1996. Cow/calf pairs were assigned to one of four stocking rates ranging from 6.2 to 16.8 and 4.2 to 10.6 AUM/ha in 1995 and 1996, respectively. Cows were assigned to each treatment group by age and weight for the summer grazing period. Sulfur hexafluoride boluses were placed in five cows per treatment. Methane emissions were determined during two periods during the summer grazing season (July and August) with 5 days of sampling per period. Feces were collected for 10 days during each collection period. Rumen fistulated cows were used to collect forage samples for nutritional analyses. Fecal and diet samples are presently undergoing laboratory analyses.

Methane emission responses are presented in the following table. In general, animal performance increased (data not shown) and methane per unit of animal weight decreased as stocking rate decreased. However, the level of these responses was less than reported in previous research comparing animal responses across stocking rates.

Methane emissions by beef cows grazing irrigated pasture during 1995 and 1996.

	1995					
	Period 1 (July 11-16)			Period 2 (Aug. 22-27)		
Stocking rate (AUM/ha)	g/d	g/d/kg cow	g/d/kg calf	g/d	g/d/kg cow	g/d/kg calf
6.2	216	.404	1.371	196	.344	.906
8.4	167	.331	1.318	119	.220	.611
12.2	153	.302	1.068	195	.329	1.067
16.8	196	.391	1.300	144	.263	.676

	1996					
	Period 1 (July 2-8)			Period 2 (Aug. 20-25)		
Stocking rate (AUM/ha)	g/d	g/d/kg cow	g/d/kg calf	g/d	g/d/kg cow	g/d/kg calf
4.2	276	.516	1.88	330	.560	1.32
5.8	331	.613	2.33	319	.540	1.28
8.4	295	.575	2.03	323	.579	1.34
10.6	310	.601	2.68	216	.418	1.13

3. Nutrient intake and methane emission responses of cows and calves in a "slaughter-weight at weaning" program.

An ongoing project at the UAES is being conducted to develop an alternative beef production strategy wherein the feeder animal is at slaughter weight by about 270 days (nine months) of age. This is shortly after weaning, as opposed to more traditional systems wherein cattle are slaughtered at 12 to 18 months of age. This system requires the use of cows with greater genetic potential than the average cow used in traditional systems. The influence of this difference in genetic potential on nutrient requirements, efficiency of nutrient utilization, and resultant methane emissions of the cow is being documented. Cattle currently involved in this program are being compared to typical beef cattle from the UAES beef cowherd. These cattle have been kept on common forage resources throughout the trial. This includes grazing during spring, summer, and fall, primarily on irrigated pastures, and being housed in drylot and fed hay- or straw-based diets during the winter. Two trials were conducted during the summers of 1995 and 1996 at the UAES facilities at Logan using 10 cow/calf pairs. Cows with calves that should reach slaughter weight at 270 days (9 months) of age (ESW, 5 pairs) have been compared to cows with calves that should reach slaughter weight at 12 to 18 months (control, 5 pairs). Methane emissions, animal performance, and nutrient intake were estimated three times during each summer grazing season (June, August, and September). Methane samples were collected for 5 days during each collection period and feces were collected for 10 days. Rumen fistulated cows were used to collect diet samples for nutritional analyses. Preparation of samples for laboratory analysis and performance data analysis is in progress.

Methane emission responses are presented in the following table. In general, methane emitted per unit of cow weight was similar, but methane emitted per unit of calf weight was less because the ESW calves were heavier than control calves.

Methane emissions by cows with control or early-slaughter weight calves.

	1995		1996	
	Control	ESW	Control	ESW
Period 1	June 19-24		June 13-20	
g/d	168	178	249	229
g/d/kg cow BW	.274	.276	.433	.415
g/d/kg calf BW	.974	.866	1.91	1.64
Period 2	Aug. 2-7		Aug. 5-10	
g/d	186	182	256	264
g/d/kg cow BW	.319	.289	.450	.470
g/d/kg calf BW	.781	.659	1.27	1.24
Period 3	Sept. 18-23		Sept. 16-22	
g/d	99	61	281	291
g/d/kg cow BW	.164	.096	.477	.517
g/d/kg calf BW	.359	.197	1.07	1.02

4. Nutrient intake and methane emission responses during winter feeding of cows.

A sub-trial of the ESW trial was conducted during winter feeding of the cows to compare the influence of grass hay- or ammoniated cereal straw-based diets on methane emissions of cows. Eight cows (four in each feed treatment group) were used to sample methane during the winter feeding period. Methane samples were collected two times during each winter feeding period. Cow performance and feed intake were also measured. Data analysis is in progress.

Methane emissions were similar from cows receiving either diet during either period in the first year of sampling (see following table).

Methane emissions of cows wintered on grass hay or ammoniated straw

	g/d		g/d/kg BW	
	Grass Hay	Amm. Straw	Grass Hay	Amm. Straw
	Year 1			
Period 1 (Dec. 1995)	144	122	.25	.22
Period 2 (Jan.-Feb. 1996)	221	241	.38	.41
	Year 2			
Period 1 (Dec. 1996)	264	274	.43	.41
Period 2 (Jan. 1997)	222	232	.35	.34

5. Nutrient intake and methane emission responses during finishing of weaned calves.

Another sub-trial of the ESW trial was conducted during finishing of the weaned calves to evaluate the potential of such a system to reduce methane emissions through the shortened life of the feeder calf. Calves were weaned in November and put onto a finishing ration. Eight steers (four of each treatment group) were retained to sample methane during the finishing period. Methane samples were collected two times during each finishing period. Steer performance and feed intake were also measured.

Performance was similar among steers from each treatment during finishing. However, because the ESW steers started at over 100 kg heavier than control steers, they reached slaughter weight 77 days sooner, thus cutting total methane emitted to reach slaughter almost in half (see following table).

Performance and methane emissions by early-slaughter-weight or control calves during finishing

	Control	ESW
Initial weight, kg	296	400
Final weight, kg	515	498
Age at slaughter, d	401	324
ADG, kg d^{-1}	1.39	1.39
Feed intake, kg d^{-1}	13.5	16.0
Feed efficiency, kg kg^{-1}	10.0	11.6
Daily methane, g d^{-1}		
Period 1	165	161
Period 2	212	239
Daily methane, g d^{-1} kg BW^{-1}		
Period 1	.52	.38
Period 2	.55	.48
Daily methane, g d^{-1} kg ADG^{-1}		
Period 1	140	80
Period 2	117	135
Total methane, kg	30	17

Implications Of Results

When linked with other nutritional variables, evaluation of methane emission will provide an opportunity to consider energetic efficiency in ruminants. Increasing retained energy through decreased gaseous energy loss will fulfill the dual goals of increasing production efficiency and reducing methane emission by beef cattle. This affords the opportunity to simultaneously increase profitability and the public image of the livestock industry. During this project, we have evaluated applied management alternatives to determine if they are both nutritionally superior and environmentally sound. Specific conclusions include:

1. Variation in animal performance and methane emissions existed among species and cultivars adapted for revegetation of arid rangelands.
2. Animal performance and diet quality were depressed by increasing stocking rate, but less than expected. Animal response appeared to be less sensitive to grazing management on improved pastures than on rangelands.

3. Production of calves using an accelerated growth program reduced methane emission per unit of calf body weight by the cow during the suckling phase simply because total daily methane was divided by greater calf body mass.
4. Winter feeding of cows using chemically treated low quality forage yielded similar methane emission to feeding grass hay.
5. Early slaughter steers performed similarly and emitted similar methane amounts to control steers on a daily basis. However, methane emissions per unit of body weight were less because of greater body weight. Additionally, total methane emitted during the finishing period was reduced by 57 percent because ESW steers were slaughtered 77 days sooner than control steers.

Our preliminary conclusion is that methane emission reduction is most sensitive to manipulation of animal management rather than manipulation of forage or grazing management.

CONTRAINTS FOR IMPROVED LAND AND ANIMAL MANGEMENT AMONG BEEF CATTLE PRODUCERS IN UTAH

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Previous social survey research among 2,520 beef producers in Utah, who also had permits to graze public lands, identified two main groups in 1993: (1) A minority (32%) of pro-active managers who adopted novel land- and animal-management technology and practices and therefore invested and innovated (i.e., intensified, diversified, and/or extensified) within their production systems; and (2) a majority (68%) of passive managers who tended to be more conservative and did little to change. By the mid-1990s, it was speculated that pro-active management was on the rise in Utah because beef producers anticipated reduced access to public grazing, and in preparation for this sought to improve their production systems on privately owned land.

Pro-active management intervention can have benefits for operations including improved production efficiency and profitability. Another consequence of improved efficiency could also be reduction in rates of methane emission from grazing ruminants. Methane is a potent greenhouse gas that is negatively implicated as one contributor to global warming. The EPA has identified a possible opportunity to reduce methane emissions from ruminants via management innovation - this was the main reason the EPA had interest in technology transfer among Utah beef producers and funded some of the work reported here. Research was commissioned by the EPA as a pilot project to address the following objectives: (1) Refine and up-date estimates of the proportions of Utah's beef operations that have been pro-actively or passively managed during the 1990s, and determine factors that most influence management behavior; (2) identify prominent forms of producer innovation and estimate the impact these innovations could have on mitigating methane emissions from beef cattle; (3) determine constraints which preclude more beef operators from becoming pro-active managers; and (4) provide a social survey methodology that would allow the EPA to address similar issues in other locations. The primary focus of EPA-funded work was to collect data on a previously unsurveyed group in Utah - beef producers who operated solely on private land. Little was known about the numbers, resources, or management strategies of this group. A secondary focus of EPA-funded work was then to combine previous results from permittees with those of private-land-only operators into one comprehensive analysis.

Work documented in this report covers the period 1992-97. Mail and phone surveys of 192 to 340 randomly selected, public-grazing permittees were funded by the USDA Sustainable Agriculture Research & Extension (SARE) program and the Utah Agricultural Experiment Station (UAES). Phone survey of 201 randomly selected, private-land-only operators was funded by EPA and implemented by the Utah Agricultural Statistics Service (UASS). All surveys included questions that solicited information on: (1) The resource base for each operation; (2) opinions of managers regarding production innovation, technology transfer, and how operations have changed over time; (3) views of operators regarding their management strategies, goals, and future concerns; (4) what factors were perceived to have had the greatest effects on management strategies; and (5) the priority needs of operators for applied research. Questions were posed as multiple choice, short answer, or ranking exercises. Data were analyzed using descriptive statistics and logistic regression.

We identified a subpopulation of 2,547 private-land-only producers, which brought the total population of relevant producers for Utah to about 5,067 operations including permittees. Compared to private-land-only producers, permittee operations were much larger - permittees ran 5.6 times more cattle and managed 15 times more private land, on average. Permittees derived 49% of their annual income from livestock production compared to only 17% for private-land-only producers. Private-land-only producers obtained 76 % of their annual income from "off-ranch" and therefore were part-time (e.g., hobbyist) livestock producers in the extreme. Far more permittees were involved in livestock production as a core business. Seventy percent of permittees and 90% of private-land-only operators considered themselves to be passive managers throughout the 1990s. Only 10% of operations, and up to 13% of the beef cattle inventory, have been subjected to proactive management in recent years. The main reasons stated by producers for passivity were: (1) pending retirement and declining health for up to 39% of the producer population; and (2) economic constraints such as low beef prices and non-competitive rates of return on investment in their grazing operations. Only 22% of permittees experienced any cuts of AUMs on public land between 1993 and 1996, and these were typically only temporary. This suggests that implementation of grazing reforms on public lands has been slow to occur, and thus permittees have refrained from going ahead with private-land investments. The main reasons stated by a minority of producers for proactive management were: (1) to increase productivity and profitability; and (2) maintain a rural lifestyle with a social value for being a "good" manager. Logistic regression analysis revealed that proactivity was significantly ($P< 0.01$) and positively associated with: (1) Gross annual income; (2) willingness to assume debt to improve operations; (3) whether or not a producer was a permittee; and (4) number of social memberships, seen here as a proxy for wealth and community stewardship values. As one indicator of the role of wealth in innovative behavior, about 60% of the small subgroup of proactive, production intensifiers were not seeking grants or cost shares to help fund their land management improvements - these were commonly self-funded efforts that cost from $5,000 to $250,000 to implement. Finally, producer priorities for applied research were dominated by (1) pasture (e.g., forage) improvements (in case the technology is needed); (2) policy; (3) economics; and (4) technology transfer.

It is concluded that proactive management in Utah is most constrained by macro-level forces such as demographics and low beef prices and micro-level factors such as level of personal income and debt tolerance. As long as the population is becoming elderly, beef prices are fluctuating and unattractive, alternative (off-ranch) investment is attractive, and/or implementation of more strict policies for use of federal lands remains fuzzy, passivity will prevail. For most producers, however, it is important to note that passivity is probably a wise survival strategy given the wide array of economic and ecological risks and uncertainties they routinely encounter. Proactive managers, in contrast, are those in the minority with the financial resources to invest - perhaps even indulging a few whims - and thus take large risks that returns on such investments may not be lucrative over the short- to medium-term. Impact of innovation and investment on improved management of beef cattle in Utah, and hence mitigation of methane emissions from grazing ruminants via altered management systems, remains elusive.

The scenario above describes a simple state-and-transition model for the beef producer population.. Traditional extension efforts, in and of themselves, should therefore not be expected to have much impact in stimulating a land use revolution per se in Utah. More focus on larger, risk-tolerant operators could yield more impact to this end per unit of extension effort. Relatively more attention could also be given to some aspects of policy to stimulate broad-based, positive change.

BEEF EFFICIENCY PRODUCTION AND TALL FESCUE TOXICOSIS: 1996-1998 PASTURE RESEARCH IN TENNESSEE

John C. Waller, Henry A. Fribourg, Mitchell A. Zuckerman, and Teri Ingle

INTRODUCTION

Tall fescue is a cool season perennial grass which, since its major spread in the 1940-1950s, has become the predominant forage in the transition zone of the eastern US. About 15 million ha are currently grown in the US. Problems with poor performance of animals grazing tall fescue have been observed since at least the 1950s. The decreased animal performance, known as tall fescue toxicosis and caused by the fungal endophyte, *Neotyphodium coenophialum,* is characterized by diminished weight gain, heat intolerance, slightly elevated body temperature, rough haircoat, reduced voluntary forage intake, and decreased calving rate.

Beef cattle grazing E- tall fescue pastures have improved animal performance over those grazing E+ pastures. Reductions in cattle average daily gain (ADG) have been related in part to alterations of cattle grazing behaviors on E+ pastures due to the increased heat stress characteristic of tall fescue toxicosis.

Methane produced by enteric fermentation in domesticated livestock is of interest because it represents an energetic inefficiency of microbial fermentation and because of the role CH_4 is suspected of playing in global warming scenarios. Tall fescue pastures managed in different ways provide an economically important experimental situation to study whether CH_4 emissions from cattle can be mitigated with improved management strategies. In this report, CH_4 emissions from beef steers and cows grazing different tall fescue based pasture systems are related to animal performance at different seasons of the year.

MATERIALS AND METHODS

Pastures and Animals

Eight 1.2-ha pastures at the Blount Unit (35 49 N, 83 13 W) of the Knoxville Experiment Station were used to measure CH_4. Four well-established >Kentucky-31' tall fescue pasture systems were used: (1) E+, (2) E-, (3) alternating groups of four 20-cm drill rows of E+ and E- tall fescues (E+/E-); and (4) E+/clover >Regal=, where there was about 25 to 35% clover in spring each year, decreasing to 15 to 20% in summer.

Two pasture systems of about 4 ha each at the Holston Unit (35 57 N, 83 51 W) of the Knoxville Experiment Station were also used: (1) an unimproved pasture (UP) typical of the region [E+ tall fescue, bermudagrass, Kentucky bluegrass, other grasses and weeds], and (2) a well managed E+ tall fescue/clover pasture using the best management practices (BMP) adopted by superior producers in the region. The BMP pasture contained 35 to 40% ladino white clover in spring each year, decreasing to 15 to 25% in summer.

Phosphorus and K fertilizers were applied to all the pastures (except for UP at the Holston Unit) in winter or early spring of each year to maintain a medium soil test level of fertility. In early spring and in early September each year, all pastures except the pastures containing clover and the UP received 56 kg $N*ha^{-1}$ applied as ammonium nitrate. The UP at the Holston Unit had received no inputs in pasture management, such as fertilization, seeding of improved species, and mowing, in the recent past. Pastures at Blount and the BMP at Holston were clipped occasionally -- in June and August -- to remove tall fescue seedheads and excess mature growth. There were between 900 and 1500 $kg \cdot ha^{-1}$ of available dry matter forage at all times, as confirmed every 21 d by clipping $10 \cdot ha^{-1}$ forage strips measuring 53.3 x 304 cm in each pasture. This management provided enough forage to allow adequate voluntary intake by the cattle. Within each pasture, artificial or natural shade, fresh water, and mineralized salt were provided *ad libidum*.

Two Angus steers were placed on each pasture at the Blount Unit, and two pastures of each of the four systems were used. Four steers and four cow/calf pairs were placed on each of the two pastures at the Holston Unit. The steers used each year were weaned stockers selected from the spring calf crop of the Tennessee Agricultural Experiment Station herd. Mature (> 3-yr old) Angus cows from the Knoxville Experiment Station spring calving herd were pregnancy checked and eight pregnant cows were selected each fall. All cows and steers used were allotted to pasture systems on the basis of age, weight, and body condition. The experimental animals were weighed every 21 d while on pasture. Body condition scores on a 9-point scale were recorded for cows at the beginning of the spring and at the end of the summer grazing seasons.

Methane

The SF_6 Tracer Method. The Washington State University method for measuring eructated CH_4 involves placing a permeation tube with a known SF_6 permeation rate in the reticulum. Eructated gas is then constantly sampled through a collection device worn by the animal. Methane emission rates from each animal are calculated using the rate of SF_6 permeation from the tube and the concentrations of CH_4 and SF_6 in the collection canister. In order to achieve proper quality control, since molecules of SF_6 tend to reside in plastics and other materials to which they are exposed, and to provide better laboratory conditions for the gas chromatograph (GC), three separate laboratories were used. The first one housed only the GC and supporting equipment. The second was used as a work space, where collection halters and canisters were constructed, repaired, and prepared for field use and GC analysis. The third, in a separate building, was established to load and calibrate the SF_6 permeation tubes.

In 1997, each brass permeation tube used had been 3.175 cm long with an outside diameter of 1 cm, weighing 30.5 g. The inside cavity had a 0.5-cm diameter and a 2.8-cm depth. One end of the tube was engraved with a unique identification number. The other end was machined for a swagelok nut. The open tubes were immersed in liquid N to freeze the container, and then filled with gaseous SF_6 by syringe which solidified upon contact with the brass tube. The amount of SF_6 was sufficient to provide gaseous emission until the projected termination of the experiment and met the requirements of Food and Drug Administration (FDA) Investigational New Animal Drug Use (INAD) number 9542. The filled permeation tubes were then sealed with a thin piece of Teflon through which the SF_6 would be emitted, a stainless steel frit, and secured with a swaglok nut. Loaded permeation tubes were placed in a flask kept in a water bath placed under a fume hood at rumen temperature (approximately 39 degrees C) to mimic the emission rates of the permeation tubes within the reticulum. The emission rates were calibrated by weighing the permeation tubes weekly for two months. A weight decay emission rate was then calculated for each numbered tube. Permeation tubes with an emission rate greater than 800 $ng \cdot min^{-1}$ were selected for administration to the experimental animals. In 1998, the tube length was increased to 5.08 cm with an inside cavity depth of 4.5 cm. Consequently, the weight of the empty permeation tube was increased to 40.5 g. These modifications were made to assure that the permeation tube would remain at all times in the lowest part of the reticulum and would give off SF_6 into the collection canister at a rate that would result in easier detection with the GC.

Collection canisters were constructed from two 51-cm lengths of 5-cm diameter white PVC tubing to withstand $1.104 \cdot 10^6$ Pa pressure. They were connected to a 1.575-radian elbow, each end closed with an end cap, heated until pliable in an oven, and then bent into an ox-bow shape. A valve connected by Teflon (polytetrafluoroethylene [PTFE]) tubing to a quick-connect was attached to the top of the canister. The quick-connect could be attached to the collection halter for sample collection and later to the injection port on the GC for analysis. Since the collection system had to be leak-proof, the canisters were checked for leaks by submersion in water. Velcro straps, swivel hooks, and cable ties were used to secure the canisters to the halters worn by the animals.

The collection halters were large, adjustable horse halters, fitted with a leather patch sewn on top of the muzzle to secure the filter end of the tubing system to the halter. The tubing system used on the halters consisted of a 35.6-cm length of 0.127-mm inside diameter stainless steel capillary tubing. The length and diameter of the capillary tubing determined the flow rate of gases through the tubing, and were selected to provide about a 27-hr sample for each collection canister. The capillary tubing was attached to a 46-cm length of flexible Teflon tubing. A quick-connect attached to the other end of the Teflon tubing allowed the system to be connected to the collection canister. The tubing system was checked for leaks with a mixture of alcohol and water, and then attached to the halter with electrical tape. The tape was applied loosely, to allow the tubing system to move laterally, should the animal snag it on obstructions in the field. An in-line 15-μ Nupro® filter was attached to the end of the stainless steel tubing. The system was checked for leaks again. It was also checked to determine whether sufficient gas flow passed through the filter and capillary system by running compressed N gas through the tubing. The filter was then placed within an appropriate length of 2.5-cm diameter PVC tubing for protection and was attached to the leather patch with three cable ties. The leather patch, and therefore the filter inlet, could then be placed on top of the muzzle between the nostrils of the animals. The collection canister and collection halter together weighed about 240 g.

Sampling. Experimental animals were fitted with practice halters and collection canisters 1 wk prior to first use to allow them to become accustomed to the sampling devices. Methane emissions were measured from cattle grazing the eight pastures at the Blount Unit in January, April, May, and June 1998. Measurements were taken from cattle grazing the two pastures at the Holston Unit in February (steers only because cows were calving elsewhere), May, and June 1998. Each sampling period began on Monday in the early morning, and ended the following Saturday morning. Five 24-hr CH_4 samples were taken during each sampling period from each animal.

About 1 wk prior to the first sampling period each year, a permeation tube was administered with a balling gun to each animal. Following the last sampling period each year, the tubes were removed surgically by rumenotomy from the steers. The tubes were not removed from cows, since these animals remained in the herd beyond the time when the SF_6 would be exhausted completely. The heavier permeation tubes used in 1998 were always found at the bottom of the reticulum, whereas the lighter tubes used in 1997 sometimes had to be recovered from within the undigested forage in the reticulum.

On the first day of a sampling period, collection canisters were attached to a vacuum pump in the laboratory to create a negative pressure of less than 6.9×10^3 Pa, producing a canister capable of drawing expelled air samples through the halter tubing system for at least 27 hr. At each location, animals were moved through handling facilities in the early morning, restrained in a head gate where the numbered collection canister and associated equipment were placed on each animal by two trained individuals. The valve on the canister was opened, and the starting time of sampling was noted. The animals were then returned to the appropriate pastures.

Additional canisters were placed near the experimental pastures to monitor background levels of CH_4 and SF_6 daily during each sampling period. Measured background levels of CH_4 and SF_6 were not considered large enough to warrant inclusion in the calculation of daily cattle CH_4 emissions.

Canisters were replaced each morning during the sampling period. Canister pressure at time of removal from the animal was used as an indicator of sample flow through the collection system. A pressure reading between 5.52×10^4 Pa and 7.59×10^4 Pa indicated that the tubing system was functioning properly. A reading approximating atmospheric pressure was evidence of a leak in the collection system. A pressure reading lower than 5.52×10^4 Pa indicated blockage of sample flow through the collection system. The halters on each animal were also visually inspected for clogs and rips, and faulty halters were replaced,

The used canisters were taken from the corral to the laboratory for analysis. Each canister was pressurized with N gas to about 1.242×10^5 Pa, allowing for auto-pressure injection into the GC. A GC fitted with an electron capture detector (ECD) and a flame ionization detector (FID) was used to determine the concentrations of SF_6 and CH_4, respectively, in the canister gas samples. Two sub-samples of each canister were processed through the GC for analysis. The SF_6 and CH_4 concentrations were used along with the known permeation rate for the permeation tubes in each animal to calculate a daily CH_4 emission rate for each experimental animal.

Statistical Analysis

The data were analyzed by analysis of variance using the MIXED procedure of SAS. Data from the Blount Unit were analyzed using the model:

$$y_{ijkl} = T_i + Pa(T)_{ij} + A * Pa(T)_{ijk} + S_l + (T * S_{il}),$$

where y = animal starting weight, ADG or CH_4, T = pasture system, Pa = pasture number, A = animal identification, and S = grazing season.

Models to analyze the data obtained at the Holston Unit included also a variable for animal class. Least squares means were obtained and analyzed using the *pdiff* option. A probability value of $p = 0.05$ was used for rejecting the null hypotheses in all statistical tests. Variability between GC samples was negligible.

RESULTS AND DISCUSSION

General Considerations

Methane emissions among several periods within each season at each location were not statistically different in a preliminary analysis, and were consequently pooled for analysis and in data presentation. Daily CH_4 emissions per animal were combined within each sampling period, and these in turn pooled into seasonal data. On the other hand, both ADG and CH_4 emissions were widely and statistically different from season to season, being significantly larger in spring than in winter.

Methane emissions were also expressed per unit of ADG per animal and per unit of metabolic weight (kg body weight $^{0.75}$). Reporting CH_4 emissions per unit of ADG provided a measure of efficiency, since this expression considers the CH_4 emission per unit of animal performance. Expressing CH_4 emissions per unit of metabolic weight factored the size of each animal into the emission rate, since body mass has been shown to be related to energy expenditure.

Sampling Considerations

Between 75 and 85 % of the total possible samples during each sampling period were actually usable. Sample losses were due primarily to clogging of the halter system with water. The sampling technology had been previously used in the western US under drier conditions than those in Tennessee. Other causes of sample losses included accidental disconnections between the canister and the halter systems by the animals, broken canisters, and breaks in the halter system. The halter system breaks occurred primarily at the union of the capillary tubing and the in-line filter because the design of the waterers in the pastures allowed direct contact of the sampling system with the upper lip of the water reservoir. Other breaks in the halter systems, particularly at the filter and Teflon tubing connections, resulted from animals snagging the equipment on other fixtures in the pasture.

Measurements at the Blount Unit

Steers on the four pasture systems did not differ in initial weight in winter 1998 (Table 1). Among pasture systems, ADG of steers grazing E+ tall fescue was the smallest in winter and spring. Highest ADG were obtained in winter from E- tall fescue and in spring from E- and E+/clover pastures.

While the relationship between ADG and pasture systems was similar to that reported elsewhere, the actual ADG observed were somewhat greater than those reported by others. We have reported elsewhere mean summer ADG of 370 $g{\bullet}d^{-1}$ and 510 $g{\bullet}d^{-1}$ for steers grazing E+ tall fescue and E+ tall fescue/clover pastures, respectively. The difference between the ADG reported here and the earlier ones could be due in part to the higher than normal precipitation in the Knoxville area during spring 1998 grazing season.

Daily CH_4 emissions ranged from 110 to 150 $g{*}d^{-1}$ for the growing steers grazing the tall fescue pastures (Table 1). Although these emissions tended to be greater in spring than in winter, they were not greatly different among pasture systems within season. When CH_4 emissions were expressed per unit of ADG they were generally greater in winter than in spring. The reason for this difference is perhaps related to the greater intake which may have been reflected in a more rapid gain in spring. Mean CH_4 emissions per unit of metabolic weight among the pasture systems followed relationships similar to those for the mean daily emissions.

Measurements at the Holston Unit

There were no differences among mean starting weights within an animal class (steers, cows, or calves) for any grazing season (Table 1). Average body condition scores for cows grazing both pastures were similar at the start and end of the grazing season, and averaged 5.5 on a scale ranging from 1 to 9.

Average daily gain was higher in spring than in winter for steers, and ADG were similar on the two pastures. Mean calf ADG was greater on the UP than on the BMP pasture. This indicated that as the spring season progressed, the higher than normal rainfall resulted in greater than normal forage for cows on the UP pasture and that the BMP pasture was not greater in forage quality or availability than the UP pasture.

Mean daily CH_4 emissions from steers ranged between 95 and 145 $g*d^{-1}$ and between 145 and 170 $g*d^{-1}$ for cows. Emissions of CH_4 from steers in winter were less than in spring.

Mean CH_4 emissions per unit of ADG were quite different between cows and steers because animal sizes and weight gains were dissimilar. Since cow ADG were less than those by steers and these smaller gains occurred on larger animals, the steer ADG are a better reflection of CH_4 production per unit of animal performance. The steers grazing the BMP pasture did not produce less CH_4 per unit of ADG than those on the UP pasture in spring, probably because of the wet season. The lower efficiency (unit of CH_4 per unit of ADG) of cows was related to the fact that the cows used intake energy to provide milk for calves rather than to increase their body weight. This is supported by the fact that the calves on the two pasture systems maintained similar and adequate ADG throughout.

General Discussion and Concluding Implications

When we consider the data reported last year for 1997 and those reported here for 1998, the most significant effects were those of season and animal size. While there were instances where numerical differences were observed, statistical analysis was not able to detect some differences, possibly due to the lack of seasonal repetition and the limited number of animals. We have demonstrated elsewhere in our work the importance of including several years of data in pasture grazing studies to provide observations over a broad spectrum of environmental and climatic conditions. Indeed climatic factors were important during this study, for the Knoxville area experienced two consecutive springs with abnormally high precipitation levels. Elevated spring precipitation levels might have reduced the climatic stresses that pastures undergo during seasons with normal or below normal precipitation, and hence animal performance was better than would be expected with E+ tall fescue pastures when drier and hotter conditions prevail.

We did not measure CH_4 production by calves and thus cannot estimate the total CH_4 production by the cow/calf pair. Development of the rumen in calves depends on access to a fibrous diet and the availability of rumen microbes to inoculate the rumen. Developing calves are considered to be transitional ruminants at around 6 to 8 wk of age, and to become functional ruminants at 8 to 12 wk. Therefore, the calves in this study could have been producing CH_4. Since that was not measured, the efficiency estimated for the cow-calf pair was incomplete. Further studies are needed to investigate the efficiency of the cow-calf pair, rather than just that of the cow, since both contribute CH_4 to the environment. In addition, cows should be evaluated during the remainder of the year when choice of feeding management usually results in positive weight gains for cows.

Differences in CH_4 emissions per unit of ADG were affected by management strategies: less CH_4 was produced per unit of performance by steers grazing pastures with better management practices than by steers grazing pastures receiving fewer management inputs.

Table 1. Mean seasonal ADG and CH_4 emission estimates for steers grazing tall fescue pastures at Blount and Holston in 1998.

Location [H]	Pasture system		Winter Initial weight	Winter ADG	Winter Daily CH_4	Spring Initial weight	Spring ADG	Spring Daily CH_4	CH_4 per unit of ADG Winter	CH_4 per unit of ADG Spring	CH_4 per unit of metabolic weight Winter	CH_4 per unit of metabolic weight Spring
			kg	$g*d^{-1}$	$g*d^{-1}$	kg	$g*d^{-1}$	$g*d^{-1}$	$g*kg^{-1}*d^{-1}$	$g*kg^{-1}*d^{-1}$	$g*100\ kg^{-1}*d^{-1}$	$g*100\ kg^{-1}*d^{-1}$
Blount	E+		256^{a}	390^{a}	110^{a}	316^{a}	540^{a}	147^{ab}	286^{c}	277^{c}	159^{a}	179^{bc}
	E-		264^{a}	530^{c}	120^{ab}	346^{a}	900^{d}	153^{ab}	226^{a}	172^{a}	164^{a}	165^{ab}
	E+/E-		250^{a}	470^{b}	112^{a}	323^{a}	620^{b}	127^{a}	242^{ab}	205^{ab}	160^{a}	151^{a}
	E+/clover		268^{a}	440^{b}	119^{ab}	337^{a}	780^{c}	154^{ab}	275^{c}	195^{ab}	165^{a}	174^{bc}
Holston	BMP	Steer	279^{a}	360^{a}	94^{a}	322^{a}	840^{b}	139^{a}	402^{b}	166^{a}	127^{a}	170^{a}
		Cow	--	--	--	498^{b}	480^{c}	168^{bc}	--	462^{b}	--	158^{b}
		Calf	--	--	--	88^{c}	940^{e}	--	--	--	--	--
	UP	Steer	270^{a}	280^{b}	104^{a}	301^{a}	950^{a}	145^{a}	678^{a}	141^{a}	147^{a}	180^{a}
		Cow	--	--	--	535^{b}	510^{c}	147^{bc}	--	530^{c}	--	126^{c}
		Calf	--	--	--	69^{c}	1020^{d}	--	--	--	--	--

[H] Least squares means for the same variable with the same superscript within a season and location are not significantly different (P<.05

BEEF EFFICIENCY IMPROVEMENT: PRODUCTION MANAGEMENT SYSTEMS RESEARCH IN LOUISIANA

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Introduction

Recent estimates show that about one-half of the beef cows in the United States are presently in the Southern Region. Beef production in the Southeast has traditionally consisted mainly of cow and calf enterprises with the calves sold at weaning. These operations have frequently been shown with low profit potential. Studies have shown that this low income from calf sales is low because the beef production from these calves was less than 90 kg/ha per year. Tremendous amounts of forage growth can occur due to the long growing season (frequently more than 300 days in Louisiana). However, the introduced warm-season perennial grasses that are dominant usually lack sufficient quality for maximum sustained beef cattle weight gain. Controlled-rotation grazing management systems have the potential to maximize both forage and beef production with an increase in the efficiency of beef production.

Techniques to increase production efficiency have been used to identify appropriate management practices that increase livestock productivity. Emission rates of methane for the various grazing management systems and the productivity on these management systems have not been studied. The linking of methane measurement in ongoing grazing management research studies has been designed to compare common animal management practices with planned improved practices. Emission rates of methane from beef cattle consuming different forages, different protein supplements and grazing under different grazing scenarios have been obtained.
Relating the production efficiency of all these management systems to formulate recommendations for area livestock producers is important.

The sulfur hexaflouride (SF_6) tracer technology developed and tested by Washington State University is being used to measure methane emissions from beef cattle in the listed management systems. This tracer technology technique involves using a brass capsule (bolus) of SF_6 gas placed in the rumen of the halter-broken animal being tested. Methane is collected above the muzzle with a collection device attached to a harness. Collected gas is then analyzed on a gas chromatograph machine to determine concentration levels of both SF_6 and methane gases.

All methane emission rates will be linked with a specific class of livestock (mature cows, heifers, calves, etc.), body condition scores, weight (frame scores), forage quality, forage quantity, and livestock's nutritional demands. By linking the methane emission rates to specific forage values and specific livestock requirements, data can be used in determining animal and forage management recommendations to be presented to producers. Models can also be developed to use this data for estimating livestock efficiency from a wide range of livestock operations in the South.

Body condition seems to be the most reliable indicator of well being of an animal. Livestock weight and body condition scores have been determined on all experimental animals before each methane collection period and included in the database. Forage production on each pasture being grazed has been measured with quadrates to determine the total quantity available. Average plant height, phenological stages of development, and days of re-growth have also been recorded by forage species at each grazing site.

PROCEDURE

Animals

Brahman crossbred females have been used in all collection trials. The Simbrah breeding of 5/8 Brahman and 3/8 Simmental is well adapted to the humid conditions of the Gulf Coast region. Weanling heifers were purchased for initial use and retained for breeding and further use in subsequent years as bred heifers and lactating cows. Simbrah cows, aged 3-7 years, in the University herd were selected for use for the duration of the experiment. Thus, several classes of cattle have been available including: yearling heifers (stockers),dry cows, and lactating cows. Age, weight, frame score, body condition score and breeding were recorded and used as a basis for allotment to pastures at the initiation of this experiment.

These animals have been raised and maintained under typical commercial cattle conditions. They are typically handled in working facilities only a few times a year for breeding, deworming, annual vaccination, etc. Therefore, all these animals received extensive training with halter breaking, standing tied, and brushing to be gentled for this research project. Halters and Velcro-attached "dummy"canisters were used on the animals during this training period for acclimation to the methane collection apparatus. All animals were open and implanted with Syno-mate B for estrus control because it was noted that cycling cows tended to damage the collection apparatus. To accommodate the many collections and still evaluate a typical production system, all animals were placed in a fall calving program. The animals were placed with the bulls in December for breeding with the planned calving season of September 15 through December 15.

Both cows and heifers were blocked on weight and age at the beginning of the experiment to either the treatment or control group. Six yearling heifers with an average weight of 823 pounds, and six cows with an average weight of 1180 pounds that had nursing calves were included as tester animals in each experimental herd.

Forages

Pasture treatments include: 1) control -- unimproved pasture that is naturalized revegetated cropland (typical of the area). Multiple species of forages are represented in these pastures. 2) treatment --well-managed warm-season perennial pastures with a base forage of bahiagrass or common bermudagrass, and overseeded with ryegrass for use during the appropriate growing season. Paddock size was approximately 1.5 acres. Each paddock included bahiagrass and bermudagrass and was overseeded with ryegrass in September. The paddocks have been managed intensively with a stocking density of 30-40 animal units/acre/day and an appropriate recovery period between each grazing (15 to 30 days to produce 2000-3000 lb. of dry matter forage per acre). The unimproved pasture was grazed continuously throughout the growing season (March- October) with a herd stocking rate sufficient to maintain 1000 lb/a of available dry matter forage. Preserved forage as hay of bahiagrass has been used during the winter (November - February). A good quality hay and protein supplement has been used for the treatment herd (pasture treatment two) and fair hay has been used for the control herd (pasture treatment one). Limited ryegrass grazing was included as one of the protein supplements included in the collections this year.

Forage samples were collected from each sward both before and after each grazing period to determine quantity available at that physiological state of development and residual forage to determine forage utilization. Samples were analyzed for forage quality components of crude protein, ADF, and NDF. Fecal samples were analyzed at the Texas A&M NIR laboratory for prediction of dietary crude protein and digestible organic matter and the calculation of dry matter intake.

Management

When forage growth of a species is adequate (at least 1500 pounds DM/acre) and animals are adjusted to that particular forage, two classes of cattle have been used to obtain methane emission at each measurement period. Cattle grazed the same forage as the one to be sampled for a minimum of two weeks before the initial sampling period to assure adequate time for rumen microorganism adaptation. Portable corral panels were constructed within the grazing paddock area to facilitate daily sampling of the methane collection canisters on each animal. Five animals of each class were used on each measurement trial.

Daily rotation on the management intensive grazing paddocks (treatment 2) has been compared with continuous grazing on unimproved native pastures (treatment 1) where the available forage may become somewhat limited. Canisters on each animal were used to collect samples of emitted air, exchanged every 24 hours and transported to the laboratory for CH_4 and SF_6 analysis on a daily basis.

Results

Data collection was begun with the cows and yearling heifers on warm season perennials, bermudagrass and bahiagrass, in October and November 1996. Bahiagrass hay with protein supplements of cottonseed meal, urea and corn, and protein blocks were fed during February - April 1997, and again during February - April 1998 with methane collections during each period. New heifers were started in May 1997 on ryegrass and subsequent summer grazing along with the cows that had undergone rumenectomy for perm tube removal. Collections on ryegrass were made with these yearling heifers during February - April 1998. Limited grazing time of one or four hours daily on ryegrass was also used as a protein supplement during February and March for the mature cows.

Collections on bahiagrass and bermudagrass were continued during summer of 1997 with the mature cows. Collections with the original cows on the project had to be suspended until all the SF_6 in the perm tubes had dissipated. New perm tubes were deposited into the cows and collections were resumed on the hay and protein supplement wintering diets.

The methane emissions for the 1997 collections were included in the 1997 annual report. Nutritional analyses of warm-season forages of bermudagrass, bahiagrass and native species suggest that late-summer growth of warm-season perennial grass is not high quality forage and does not support high weight gain or efficient beef production. During this late summer period, the forage will support dry beef cows in a maintenance condition with some slight condition improvement.

The methane emissions of the growing yearling heifers on ryegrass are significantly different at each collection. The weight gain of the different treatments confirms that high quality forage can support excellent rates of gain. When the methane emissions are expressed as methane per pound of weight, the higher rates of gain are certainly more efficient (table 1). As forage quality declined from a digestibility in the 70's to the 60's, the methane emission per unit of gain increased for similar amounts of grazing time. With the high quality ryegrass forage, the additional grazing time is critical to achieve adequate dry matter intake for these stocker animals.

Similar results of methane emissions (table 2) of 0.37 to 0.53 grams of methane per kilogram of bodyweight were obtained in 1998 as 1997 with the protein supplements fed as wintering diets to the mature cows. The highest emission rate was again obtained with the urea supplement diet (0.53). The control level of feeding was designed to maintain or allow a slight weight loss while the treatment was to support at least one pound per day gain. The results show that most of the different feeding regimes allowed weight gains in the desired range.

The use of the "Nut Bal" program to calculate forage intake allows another dimension to be measured. More calculations will be done with this program in which our herd will be more precisely defined to create more meaningful data for this project.

Reproductive Efficiency

Initial data collection on reproductive efficiency began in 1998. The reproductive status of all animals in the methane study was synchronized to produce a fall calving season between September 15 and December 15. Reproductive efficiency will be measured in terms of calving interval, adjusted weaning weights, pounds of calf produced per cow exposed and methane emissions per unit of beef produced.

Treatment and control females were naturally mated to Angus bulls from December 15, 1997 through March 15, 1998. Pregnancy rates established via rectal palpation show that the average days pregnant for mature treatment cows were 146.5, as compared with 111.5 days for the control group. This preliminary data reflects a 21% advantage in calving the interval for the MIG treatment cows.

Weaning weights on all calves born in the fall of 1997 were collected and adjusted according to age of the dam and sex of the offspring. This data is summarized in Table 3.

The treatment group was 64 lb. heavier than the control animals and projects a 13% advantage in weaning weight efficiency. Total forage was affected by a relatively mild winter and a severe spring drought that certainly could have been affected pregnancy rates and weaning weights for both groups.

Table 1. Production measurements on different levels of ryegrass grazing with yearling heifers, 1998

Grazing time	Forage lab analysis				GAN lab		Methane / day			Weight gain lbs/d
	Ryegrass		Hay		Fecal					
	%CP	%TDN	%CP	%TDN	%CP	%DOM	Gm/kg	Gm/MW[1]	Gm/lb gain	
February collections										
1 hr ryegrass	22.0	76.8	9.9	46.9	11.5	67.8	0.41	1.74	411	0.34
4 hr ryegrass	22.0	76.8	9.1	50.2	13.1	68.0	0.36	1.59	160	0.80
March collections										
Ad lib ryegrass	21.1	73.2	--	--	26.5	75.5	0.42	1.61	52	3.0
4 hr ryegrass	21.9	74.8	10.5	46.8	16.7	66.4	0.35	1.33	54	2.4
April collections										
Ad lib ryegrass	14.5	61.9	--	--	16.9	68.8	0.47	2.18	78	2.5
4 hr ryegrass	14.4	65.4	14.2	52.9	12.5	65.5	0.38	1.50	132	1.2

Season average - 4 Hr: gm CH_4/Kg 0.35, gm/MW 1.49, gm /lb gain 116, ADG 1.8 lbs

Season average - *Ad lib*: gm CH_4/Kg 0.44, gm/MW 1.89, gm /lb gain 66, ADG 2.7 lbs

Season average - 1 Hr: gm CH_4/Kg 0.41, gm/MW 1.74, gm/lb gain 411, ADG 0.3 lbs

[1]MW is metabolic weight (weight in kilograms to the 3/4 power)

Table 2. Forage and winter feed supplement effects on cow productivity, 1998

Feed Supplement	Forage lab analysis				GAN Lab Fecal		Methane per day		Calculated Intake** Lbs DM/day			Mean cow Wt lbs.	Wt change ADG lbs.
	Ryegrass		Bahia hay										
	%CP	%TDN	%CP	%TDN	%CP	%DOM	gm/kg	* gm/MW	Hay	Rye	Total		
1 hr Ryegrass	11.6	66.1	8.8	47.1	11.2	65.6	0.32	1.51	11.8	6.9	18.7	1189	-0.3
4 hr Ryegrass	11.6	66.1	9.6	47.6	11.9	65.7	0.41	2.00	8.1	10.2	18.3	1210	1.2
3.6 # conc.	--	--	12.0	46.4	6.4	57.8	0.38	1.82	20.3	--	23.5	1174	1.2
5.4 # conc.	--	--	12.1	46.8	7.2	68.1	0.43	2.08	18.0	--	22.9	1246	2.0
3.6 # conc.[1]	--	--	8.3	45.3	7.7	58.4	0.37	1.77	24.6	--	27.8	1118	-1.6
5.4 # conc.[2]	--	--	9.1	45.8	8.1	57.8	0.53	2.36	23.3	--	28.2	1228	-0.4
4 hr Ryegrass	10.5	54.0	10.5	48.2	12.1	65.0	0.51	2.46	6.3	20.7	27.0	1157	1.6
Ad lib Ryegrass	25.4	70.6	--	--	16.7	68.5	0.51	2.48	--	28.0	28.0	1244	2.0

*MW is metabolic weight (weight in kilograms raised to the 3/4 power)
**Intake calculated using Texas A&M Nut Bal Analyzer
[1]concentrate supplement was 14% CP from ground corn and CSM
[2]concentrate supplement was 14% CP from ground corn and urea

Table 3. Comparison of Adjusted Weaning Weights of >97 calves

	Heifers	**Cows**	**Total**
Control	378	497	448
Treatment	477	536	512
Difference	**99**	**39**	**64**

INFLUENCE OF FORAGE TYPE AND MANAGEMENT OPTIONS ON METHANE EMISSIONS AND PRODUCTION EFFICIENCY OF BEEF CATTLE

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Introduction

The Piedmont area of Georgia has a mild and varied climate which allows the use of both cool season annuals and perennials in beef cattle stockering programs. Cattlemen can and do apply many other management options to enhance the efficiency and profitability of these systems.

One of the most common and basic decisions is to what level should pastures be stocked and how stocking rate impacts cattle performance. Generally cattlemen tend to assume that increasing stocking rate will not have an effect on cattle performance.

Another frequently used strategy is the addition of ionophores which enhances the efficiency of rumen fermentation. Ionophores are commonly used in feed rations and supplements. Bovatec® and Rumensin® are two ionophores that are cleared for use in grazing cattle. The simplest method of delivery is in free-choice minerals.

The objectives of two trials were (1) to examine the effects of Bovatec7 and Rumensin7 versus a control group and (2) examine the effects of stocking rate on the performance and methane emissions of grazing stocker cattle.

Management Conditions

The two trials were conducted at the Central Georgia Branch Experiment Station which is located approximately 50 miles south of Athens in the southern Piedmont. All hereford steers used in the trials were halter broke prior to being used.

Trial 1.

Six 1.0 ha paddocks of wheat-ryegrass were randomly assigned to either a control mineral mix, one with Rumensin® or one containing Bovatec®. Minerals were identical other than the addition of the ionophores and were manufactured by the same company.

Pastures were planted at the end of August and received 150 kg N/ha split into three different applications. Lime, P and K were added according to soil test recommendations.

Three Hereford steers were stocked on each paddock beginning in November. Individual animal weights and forage availability data were recorded every 28 days. Mineral intake was monitored on a weekly basis. Cattle were weighed off after 180 days of grazing (Nov - May). Hay was offered during periods of forage shiortages.

Trial 2.

Four .8 ha paddocks of Jesup (endophyte infected) tall fescue were randomly allotted to either a high (4 steers/paddock) or low (2 steers/paddock)stocking rate treatment. Hereford steers were weighed on test in March and off in June after 105 d of grazing. Individual animal weights and forage availability were monitored every 28 days. Grazing was terminated earlier than expected due to hot dry conditions.

The Jesup tall fescue pasture was a 7 year old stand. Sixty kg N/ha was applied in October and February. Lime, P and K were added according to soil test recommendations. Forage availability was recorded on 28-day intervals.

Methane Collection

One week prior to collection, steers were dosed with Captec chromic oxide boluses, fitted with dummy collection canisters and weighed. At the start of each collection week, collection halters and canisters were changed. Daily esophageal samples, emission samples and fecal samples were collected.

The winter annual forage system was collected in November, December, February, May and June. The Jesup fescue system was sampled in March, April, May and June.

Results

Trial 1.

Mineral intakes of the control and Bovatec7 mineral were not different and met the target intake of 114 g/d. However, the mineral containing Rumensin7 was consumed at a lower level (86 g/d). There was no effect due to treatment on any of the variables measured (Table 1). The expected impact of Rumensin7 on methane emission could be the result of the reduced mineral intake.

Forage availability averaged over 1200 kg/ha during the trial, but was lower than desired in February (< 600 kg/ha). In spite of the forage shortage, animal performance was excellent (> 1.2 kg/d).

Trial 2.

The difference in stocking rate resulted in a dramatic difference in forage available, approximately 1000 vs 2000 kg DM/ha for the high versus low stocking rate. Overall there was no treatment differences for performance, methane emissions or DM intake. However there was a trend for the high stocking rate group to consume forage with a greater DM digestibility. This seems reasonable in that higher grazing pressure should have kept the forage more vegetative. A sampling time effect was different for DM intake with intake being reduced by 40% in May and June as compared to March and April. This change in DM intake reduced daily methane emissions by about 20%. This period effect was likely due to the effect of the endophyte exerting a negative effect on animal DM intake during the hotter months.

Table 1. Summary of steer performance and methane emissions as affected by Ionophore.

	Treatment			
	Control	Rumensin	Bovatec	SE
Initial wt, kg	257	251	249	8
Final wt, kg	482	493	476	17
Wt gain, kg	225	242	227	13
ADG, kg/d	1.23	1.35	1.26	.07
CH_4, g/d	152	157	151	13
CH_4, g/kg gain	122	116	120	5
DM intake, kg/d	11.4	11.0	12.2	.4
DM digestibility, %	77.8	78.0	77.9	.7

Table 2. Summary of steer performance and methane emissions as affected by grazing pressure

	Stocking Rate		
	Low	High	SE
Initial wt, kg	326	324	7
Final wt, kg	407	405	2
Wt gain, kg	81	81	7
ADG, kg/d	.77	.77	.07
CH_4, g/d	127	121	6
CH_4, g/kg gain	165	157	16
DM intake, kg/d	6.1	6.5	.3
DM digestibility, %	70.4	72	.5

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