Asia-Pacific Network for Global Change Research

Impact of Global Change on the Availability of Fodder & Forage and Performance of Livestock in South Asia

Final report for APN project 2005-24-NSG-Babar

The following collaborators worked on this project:
PI Name, Institution, Country, Email
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Impact of Global Change on the Availability of Fodder & Forage and Performance of Livestock in South Asia

2005-24-NSG-Babar

Final Report submitted to APN

Overview of project work and outcomes

Non-technical summary

A proposal entitled "Impact of Global Change on the Availability of Fodder and Forage and Performance of Livestock in South Asia" was submitted in 2004 for APN funding. In response APN provided 20000 US$ for conducting a scoping workshop to further sharpen the methodologies of the proposal. On 15-16th Dec, 2005 this scoping workshop was conducted. Many eminent scientists from the region engaged in livestock and fodder research, and also two Canadian Scientists engaged in monitoring GHG emissions from Livestock systems, gathered at a workshop held at Lahore, Pakistan. The participants discussed the looming crisis of global warming that threatens food security in the region. An inventory of local research was discussed as were methods for monitoring GHG emissions from ruminant livestock systems. Potential strategies, crops, and feeding strategies that simultaneously improve performance and lower GHG emissions were identified. These suggestions have been incorporated into this proposal. The revised proposal was again submitted within the due date to APN to consider for funding.

Objectives

The main objectives of the project were:

1. Clarify the methodology of GHG emissions from ruminant livestock in the already submitted proposal to APN.
2. Modify the proposal in terms of objectives clarity methodologies of estimation of GHG on different feeding systems and their effect on performance of livestock.
3. Awareness, capacity building and clear understanding of GHG problem in the sub continent with reference to livestock systems.

Amount received for each year supported and number of years supported

Allocation of US $ 20000 at one time in 2005, received 16000 as first installment in Nov. 2005

Participating Countries

Pakistan, India, Bangladesh, Nepal and Canada (Honorary consultancy)

Work undertaken

A two day scoping workshop was arranged at Pearl Continental hotel, Lahore, Pakistan on 15-16th Dec, 2005 to discuss different aspects of GHG emission from livestock and its estimation methods.

Results

An inventory of local research was discussed as were methods for monitoring GHG emissions from ruminant livestock systems. Potential strategies, crops, and feeding strategies that simultaneously improve performance and lower GHG emissions were identified. In the light of this scoping workshop, the initial proposal is revised and submitted again to APN for consideration for funding.

Relevance to APN scientific research framework and objectives

APN has a mandated focus on climate change and variability, along with stress on social and economic factors of the broader population. This project directly links climate change with fodder production and its quality, and analyzes the physiology & production performance of livestock emissions of different gases by the animals. Better understanding of these interacting variables directly helps to develop strategies to mitigate the harmful impacts of livestock related gas emissions and thus directly impact socio-economic welfare of large populations in South Asia. Since, much of the livestock in rural areas are managed by the poorest of the poor, women and other disadvantaged groups the project can directly help reduce abject poverty.

Self evaluation

When the original proposal was submitted in 2004, the methodologies of estimation of different gases from the livestock were not very much clear. We were planning to construct hoods for estimation of methane and other gases emitted from livestock but full methodology was not very much clear. But now after this 2 days workshop, many things are very much clear and the research team is now capable to work on this important field of global changes.

Potential for further work

The PI is in close liaison with its research team in India and Bangladesh. I myself visited many places where this type of research is going on in advanced countries and got some opportunity to observe the practical methodologies of different GHG emitted from livestock and its estimation. The workshop provided the opportunity for the collaborators to discuss different aspects of the proposed project and sharpen the focus and methodologies of the proposal. Similarly the team make a working group with Canadian Scientists engaged in this type of research and will discuss this issue with them in future too, especially when the original research work will start.

Publications

This section should include refer to peer-reviewed publications, reports, proceedings, CD-ROMs, websites, etc., that were produced (or are pending) as a result of the contribution from APN to the project.

NIL

References

No

Acknowledgments

The proponent and his team acknowledge

- All the team members of APN specially Dr. Linda Stevenson, Ms. Maricel A. Tapia, Programme fellow and Kathleen Landauer of START office and all other staff of APN secretariate and START office, USA.
- Within the country (Pakistan) thanks are also due for Vice chancellor, University of Veterinary and Animal Sciences for all types of support, Dr. Talat Naseer Pasha, Dr. M Abdullah, Mr. Asif Nadeem and Mr. Imtiaz Ahmad Sajjid for their day and night efforts to make this workshop successful.
- Dr. Bakshi, Dr. Raisul Alam for continuous support and suggestions for the workshop.
- Canadaian experts Dr. Alan Fredeen and Mr. Micheal Mike for their work for the improvement of proposal by incorporating all received suggestions.

Technical Report

Preface

The original proposal was submitted in 2004 for APN funding. In response APN provided 20000 US$ for conducting a scoping workshop to further sharpen the methodologies of the proposal. On 15-16th Dec, 2005 this scoping workshop was conducted. Many eminent scientists from the region engaged in livestock and fodder research, and also two Canadian Scientists engaged in monitoring GHG emissions from Livestock systems, gathered at a workshop held at Lahore, Pakistan. The participants discussed the looming crisis of global warming that threatens food security in the region. An inventory of local research was discussed as were methods for monitoring GHG emissions from ruminant livestock systems. Potential strategies, crops, and feeding strategies that simultaneously improve performance and lower GHG emissions were identified. These suggestions have been incorporated into this proposal.

Table of Contents

1.0 Introduction

Asian sub continent has 20 percent of the world's human population and 21 percent of the livestock population. The livestock production systems in these countries are almost same. Livestock farming is the major component of Agricultural activities. The countries of the region have small farmers with 1-5 ruminants per family. Global change directly affects fodder and livestock production. Pakistan, India, Bangladesh, and Sri Lanka are facing similar problems with livestock fodder and forages and solutions found through this research will have widespread applicability in the region and else where (like other parts of the Asia and Africa).
Climate changes during the 1990's have signaled serious consequences worldwide. The global mean surface temperature has increased 0.6^{o}C during the 20th century and much higher changes are expected in 21st century (IPCC, 2001). The role of ruminants in converting forages to high quality human food is being challenged currently by the global warming phenomenon. Ruminant production contributes to climate change through emission of three primary GHGs: CH_4, N_2O, and CO_2. We estimate that direct CH_4 from ruminants in India, Pakistan and Bangladesh totals about 950 MT CO_2 equivalents (IPCC , 1996) – a significant total. This needs to be further examined, since livestock types and feeding practices differ significantly from studies used to develop IPCC estimates. Buffalo numbers in the region exceed 125 million (FAOStat, 2005). Though economically sustainable, the high roughage diets fed to ruminants in South Asia may generate high levels of CH_4, relative to diets fed in other parts of the world.

2.0 Methodology

A two day scoping workshop was arranged at Pearl Continental hotel, Lahore, Pakistan on 15-16th Dec, 2005 to discuss different aspects of GHG emission from livestock and its estimation methods.

3.0 Results & Discussion

An inventory of local research was discussed as were methods for monitoring GHG emissions from ruminant livestock systems. Potential strategies, crops, and feeding strategies that simultaneously improve performance and lower GHG emissions were identified. In the light of this scoping workshop, the initial proposal is revised and submitted again to APN for consideration for funding.

The issue of global worming and global changes is a neglected area in South Asia. The scoping workshop helps to understand the issue of global warming and impact of global changes on livestock production systems in a clearer manner. The participants discussed the issue in full detail. The workshop also helps in capacity building as many eminent scientists from different countries as well as from different provinces of Pakistan engaged in livestock production related activities participated in the workshop. The research team understood the methodologies to be adopted in conducting the research which are presented in the revised proposal. Special attention was given in the workshop to understand the methodologies to estimate different gases effecting the environment by the livestock. Now the engaged team has more understanding about doing their research work under the revised proposal submitted under APN 2005 calls.

4.0 Conclusions

When the original proposal was submitted in 2004, the methodologies of estimation of different gases from the livestock were not very much clear. We were planning to construct hoods for estimation of methane and other gases emitted from livestock but full methodology was not very much clear. But now after this 2 days workshop, many things are very much clear and the research team is now capable to work on this important field of global changes.

5.0 Future Directions

The PI is in close liaison with its research team in India and Bangladesh. I myself visited many places where this type of research is going on in advanced countries and got some opportunity to observe the practical methodologies of different GHG emitted from livestock and its estimation. The workshop provided the opportunity for the collaborators to discuss different aspects of the proposed project and sharpen the focus and methodologies of the proposal. Similarly the team make a working group with Canadian Scientists engaged in this type of research and will discuss this issue with them in future too, especially if the original research work will start.

References

IPCC 1996. Guidelines for national GHG inventories. Reference manual. Chapter 4: Agriculture. Intergovernmental Panel on Climate Change. http://www.ipcc.ch/.

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Appendix

Appendix-1 Workshop Program

Workshop on
Impact of Global Change on the Availability of Fodder and Forage and Performance of Livestock in South Asia
December 15-16, 2005
Hotel Pearl Continental, Lahore

PROGRAM

Inaugural Session **December 15, 2005**
(Thursday)

Chief Guest: **Mr. Babar Yaqoob Fateh Muhammad**
Secretary to the Government of the Punjab
Livestock & Dairy Development Department, Lahore

Moderator: **Dr. Masroor Ellahi Babar**
Department of Livestock Production
University of Veterinary & Animal Sciences, Lahore

09:00	Registration of Participants
09:45	Participants to be seated
09:50	Arrival of the Chief Guest
09:55	Recitation from the Holy Quran
10:00	Welcome address by Prof. Dr. Manzoor Ahmad Vice Chancellor, University of Veterinary and Animal Sciences, Lahore
10:15	Introduction of APN and Aims & Objectives of the workshop Dr. Masroor Elahi Babar, Principal Investigator
10:30	Key Note Address: "Global Change Research for Sustainable Development in South Asia" Dr. Amir Muhammad, Chairman, Pakistan Global Change Research Committee
11:00	Inaugural address by the Chief Guest
11:15	Tea break

Technical Session - I

Fodder and Forages in Livestock Production

Chairman: **Dr. Amir Muhammad**
Chairman
Pakistan Global Change Research Committee, Islamabad

Moderator: **Dr. Muhammad Aslam**
Institute of Animal Nutrition and Feed Technology
University of Agriculture, Faisalabad

11:45-12:30	Importance of fodder and forages in livestock production in South Asia, Mr. Sartaj Khan, NARC, Islamabad
12:30-13:30	*Lunch and Prayer break*
13:30-14:15	Environmental factors affecting yield and nutrient composition of fodder and forages, Prof. Dr. Muhammad Raisul Alam, Country Coordinator, Bangladesh
14:15-15:00	Sustainable development of livestock production system and global changes Prof. Dr. Ghulam Habib, NWFP Agriculture University, Peshawar
15:00-1545	Strategies to improve fodder quality and utilization by livestock, Dr. Shahid Rafique, NARC, Islamabad
15:45-16:00	Comments of the Chairman
16:00-16:30	*Tea Break*
19:00	*Dinner*

December 16, 2005 (Friday)

Technical Session - II

Environmental Issues in Livestock Production

Chairman: **Dr. Abdul Ghaffar Khan**
Director, Animal Nutrition Program
NARC, Islamabad

Moderator: **Dr. Makhdoom Abdul Jabbar**
Department of Animal Nutrition
University of Veterinary & Animal Sciences, Lahore

09:00-09:45	Nitrous oxide production by ruminants by different types of fodders and its dangers to atmosphere. Mr. Michael Main, Nova Scotia, Canada
09:45-10:30	Ruminant animal nutrition; production, measurement and mitigation of green house gases. Prof. Dr. Alan Fredeen, Nova Scotia Agricultural College, Canada
10:30-11:00	*Tea Break*
11:00-11:45	Effect of environmental factors on the productivity of livestock. Prof. Dr. Talat Naseer Pasha, University of Veterinary and Animal Sciences, Lahore
11:45-12:30	Comments by the Chairman
12:30-14:00	*Lunch and Prayer Break*

Concluding / Recommendation Session

Chief Guest: **Prof. Dr. Manzoor Ahmad**
Vice Chancellor
University of Veterinary & Animal Sciences, Lahore

Moderator: **Prof. Dr. Ghulam Habib**
Department of Animal Nutrition
NWFP Agricultural University, Peshawar

14:00-15:45	Impact of Global Change on the Availability of Fodder and Forage and Performance of Livestock in South Asia – Research Proposal Dr. Masroor Ellahi Babar, University of Veterinary and Animal Sciences, Lahore
15:45-16:45	Recommendations on the proposed research project
16:45-17:00	Vote of thanks by Prof. Dr. Talat Naseer Pasha, University of Veterinary & Animal Sciences, Lahore
17:00-17:15	Comments of the Chief Guest
17:15	*Tea Break*

Appendix-2 List of Participants

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Funding sources outside the APN

NIL

Glossary of Terms

GHG- Green house gases
CH_4 Methane
N_2O Nitrous oxide
CO_2 Carbon dioxide

Address of the Chief Guest

Distinguished participants of the workshop, this is a matter of great honor for me to address such a learned gathering of environmental and nutrition scientists who have gathered here to discuss the most threatening issue of greenhouse gas emission from the animals and its effects on today world. This earth is our asset which we received from our fore fathers and taking its care is our responsibility. We have to owe this to our coming generation preferably in a better shape than today.

Ladies and gentlemen, it is now a well established fact that the accumulation of green house gases mainly carbon dioxide, methane and nitrous oxide in the atmosphere is contributing to an increasing earth surface temperature. The accumulation of these gases is known to be increasing at rate from 0.3 to 0.9% per year, largely because of anthropogenic effects on the carbon and nitrogen cycles. The intergovernmental panel on climate change has asked the nations to quantify the amount of gases they produce and to develop research to limit further emissions.

Methane is a greenhouse gas whose atmospheric concentration has increased dramatically over the last century. Next to carbon dioxide, the methane is the largest potential contributor to warming of the earth. Methane released to the atmosphere by domestic ruminants livestock is considered to be one of the three largest sources on a global scale. The emission of methane by cattle, buffalo, sheep and goat represents a carbon loss pathway that results in reduced productivity. If the energy that is lost in generating methane could be rechanneled into weight gain or milk production, it would be cost effective to the producer as well as provide a means of reducing methane emissions to the atmosphere.

In spite of the importance of greenhouse gas issue, it is a neglected area of research in Pakistan. This is a blessing that we have some world recognized breeds of cattle, buffalo, sheep and goat in Pakistan that can compete with the best breeds of the world. But, some modern research especially on the issue of gases emission through these animals is needed at this time. I am very much pleased that today's workshop will open some new horizons in this important but neglected field of animal sciences. I am confident that the learned participants will discuss thoroughly the issue and will cover all aspects concerning this issue. The recommendations of this workshop will be highly important to develop future strategies in this field and to some modifications in the research proposal.

I know that University of Veterinary and Animal Sciences is actively engaged in research on different aspects of livestock production and now they are going to start a project which is of national importance. I congratulate the Vice Chancellor of the University and the proponent of the proposal for designing and planning a research proposal of this type. May Allah give us the powers to contribute a few things in the field of science and to spend all our efforts for the betterment of our country.

WELCOME ADDRESS

Mr. Babar Yaqoob Fateh Muhammad , Secretary Livestock and Dairy Development department Govt. of Punjab,

Dr. Ameer Muhammad, Representative of Asian Pacific Network in Pakistan,

Dr. Alan fredeen and Mr. Michal Mike, Nutrition and Green House gasses experts.

Dr. Raisul Alam from Bangladesh and Dr. Bakhshi from India,

Learned participants of the workshop,

Deans, Directors of different Faculties and the Directorates of the university,

Ladies and gentlemen

It is a matter of great pleasure for me to welcome all the participants of this scoping workshop organized by University of Veterinary Sciences, Lahore in collaboration with Asian Pacific Network on “Global impact on the availability of fodder and forage and performance of livestock in south Asia.”

The issue of global change and its effect on fodder and forage livestock production is a issue of the day. In its recent report presented to the Prime Minister of Pakistan the Globe Change Impact Studies Centre of Pakistan concluded that global warming will lead to increasing evaporation from the oceans and precipitation over the mountainous regions will have higher contents of rain and lesser of snow and will mostly appear as extreme events. This he said will result in an increase in fluctuation in the availability of water in the Indus river system as melting of additional glaciers will increase the flow of water which if not stored will go to waste. This is directly affecting the climatic temperature and physiology of plants and animals. The single most effect of environmental change is the shortage of waters which has adversely affected the crop and fodder production in the region. I feel pleasure that our research team has come up with research proposal on this important issue and trying to contribute in this area. I want to ensure the collaborators that they will have our full cooperation in all aspects of the project. I also want to ensure that Asian Pacific Network that the university will cooperate to the maximum for initiating such type of research. Like wise the support provided to the University of Veterinary and Animal Sciences Lahore by the Punjab Government has been a source of great encouragement to us and I hope both Asian pacific Network and Secretary Livestock will find means to give an efforts continuous boost and encourage.

Respected guests, as all of you are aware; fodder has got a pivotal role in rearing of livestock. In Asian countries like Pakistan, it is a cheapest source of livestock feeding and is being used since centuries. The fodder production covers 16-17% of irrigated area of Pakistan and this share is constant for last many decades. Total area under fodder cultivation is 2.5 million hectares which produces 56 million tones of fodder. The livestock population is gradually increasing but the stagnant fodder production has resulted in deficiency of fodder for livestock. According to an estimate, the fodder is deficient by 40% in meeting the feed requirement of livestock in Pakistan. The fodder production is not similar in all the provinces in the country and the greatest share (82%) is contributed by Punjab Province followed by Sindh and then other provinces.

Other than regional differences, there is great variation in the yield and quality of fodders grown during different seasons of the year. The summer fodders are usually characterized by high per acre yield but low protein contents whereas winter fodders have high protein but low energy. This variation in the quality of fodder adversely affects the productivity of animals.

Other challenges in the field of fodder production include the introduction of high yielding multi-cut fodder varieties to reduce the fodder shortage and lean periods, appropriate crops for sheep and goats, introducing grazing system instead of cut and carry method of feeding which involves lot of labor, introducing appropriate crops for grazing like Mott grass and rye grass, preservation of fodder in the form of hay and silage and mot of all, mechanization of farm operations.

The university is well aware of the problems being faced by the farmers. To enhance fodder production in the country we have initiated organized efforts and for this purpose a working group o fodder has been established where participation of experts from the university, government organization concerned with fodder production, farmers and private seed companies has been ensured so that a change could be brought with the collaboration of all the stake holders. Realizing the importance of fodder, a block of 226 acres of land at Bhuneki campus has been allocated for fodder production. We are also planning to establish a Fodder Research Centre of improving the quality and per acre yield of fodder in the country.

For the financial assistance for this workshop, I am thankful to Asian Pacific Network and its representative in Pakistan, Dr. Amir Muhammad, who himself is a moving symbol of scientific research in the field of global changes. I am thankful to the Secretary Livestock and Dairy Development Department for his gracious presence in spite of his busy schedule. I am thankful to Dr. Alan Fredeen, Professor of Nutrition, Nova Scotia Agricultural College Canada and Mr. Mike, Green house Gas expert who has come from Canada on our request to contribute to this workshop. Thanks to Dr. Bakhshi who has participated from our neighboring country, India and Dr. Raisul-Alam, a former graduate of our university, who has come from Bangladesh on a very sort notice.

In the last but not the east, I would like to thank all the participants of the workshop and hope that this workshop will contribute significantly to the present knowledge and future research horizons in this inevitable area of animal science.

Environmental factors affecting yield and nutrient composition of forages

M. Raisul Alam

Dept. of Animal Science, Bangladesh Agricultural University, Mymensingh

Introduction

Intensity of agricultural practices determines the level of food production and the state of global environment. About half of the global usable land is already in pastoral or intensive agriculture. A doubling in global food demand projected for the next 50 years poses huge challenges for the sustainability of food production, aquatic ecosystems and the services to the society. Grassland covers 40 percent of the earth's surface are home to most people and living in susceptible arable lands. The world's grasslands have declined as a consequence of overgrazing, their ability to support human, plant and animal life. Agriculture, urbanization and industrialization are also transforming grasslands. Environmental change over the next 100 years, due to the warming effect of the accumulation of gases in the atmosphere, will clearly necessitate changes in resource allocation and utilization in the world. Majority of scientific experts around the world believe that the climate change is already occurring by human activities, by use of fossil fuel, deforestation and agricultural practices and that the developing countries in particular would be more vulnerable to the continuously changing climate. Major contributor to the climate change is the man-made greenhouse gases, such as carbon dioxide, methane and nitrous oxide to the atmosphere. The accumulation of gases is causing the climatic change globally, as evident from the increased frequency of floods, droughts, cyclones and torrential rains in the recent past.

Ruminant livestock are the efficient user of natural grassland and perform numerous functions in agricultural systems of the world. They produce meat, milk, generate cash income for rural and urban people, provide traction and transport, and produce value added goods that can have multiplier effects and create a need for variety of services. Available reports on the impact of global climate change on agriculture show that the tropical and subtropical countries would be more vulnerable to the potential impacts of global warming. Plant environment in year to year, season and geographical location can effect on growth and maturity and consequently, forage quality. This complicates prediction of nutritive values of forages and their variation in the utilization by ruminants. Plant environment such as temperature, moisture, sunshine, soil composition and diseases often influences on forage quality by changing chemical composition and senescence and limit intake and digestion. Sustainable livestock production in South Asian region is constrained by production and feeding of quality forages which is affected by climate and soil. However, very limited works have been conducted on the effect of environmental changes on forage yield and quality in Asian region and warrant investigation. This paper highlights the factors that are responsible for plant production and their quality.

Environmental factors responsible for climate change

Greenhouse effect

The most important greenhouse grasses are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halocarbons, ozone, aerosol and water vapour. Carbon dioxide is the important greenhouse gases being added continuously to the atmosphere by human activity. Table 1 summarizes the changes in concentrations of the major greenhouse gases.

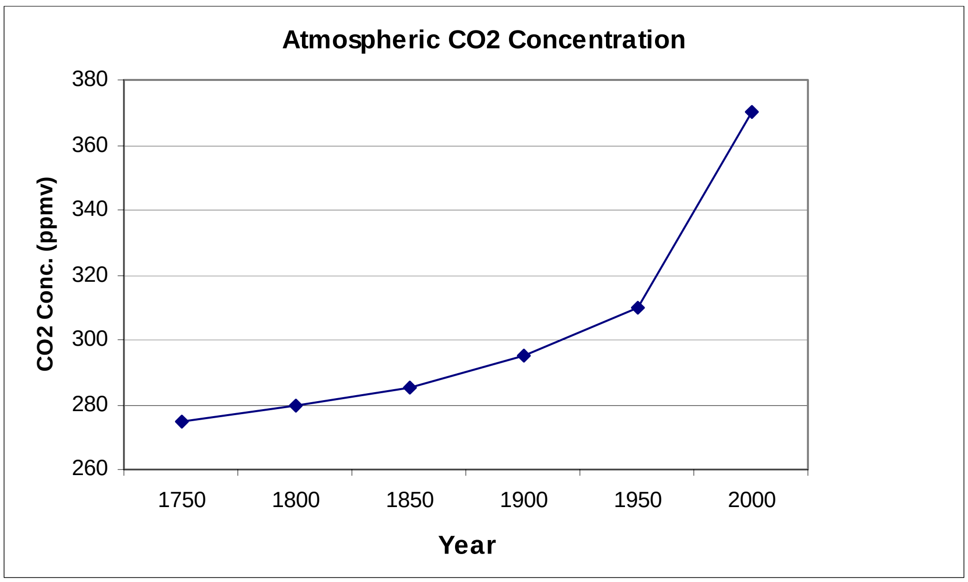
Table 1. The 'Pre-industrial' and 1998 concentration of greenhouse gases

	CO_2 (ppm)	CH_4 (ppb)	N_2O (ppb)
Pre-industrial concentration:	Approx. 280	700	270
1998 concentration	365	1745	314
Rate of change per year	1.5	7.0	0.8

* Source: IPCC, 2001

The global reading of carbon dioxide suggests a note of increase of about 0.3% per year and will rise from present level of 370 ppmv to 600 ppmv by the end of 21st century (Hughton *et al.*, 1990; Figure 1). Human contributes at an average rate of 1.9% per year (Marland, 1990; Watson *et al.*, 1992) mostly by developed nations, estimated to be 18.9 tones and 8.9 tones per year by America and U.K. as compared to only 1 tone by India. Deforestation also caused global carbon dioxide emission of 1.6 gigatones per year (Watson, *et* al., 1990, 1992). Total annual carbon dioxide released in Bangladesh from fossil fuel and biomass combustion estimated in 1990 was approximately 13.5 to 15.5 and 61.2 thousand Gg, respectively (Ahmed *et al.*, 1996; DOE, 1997; Table 2).

Figure 1. The exponential rise in atmospheric CO_2 concentration



*Source: Houghton *et al.*, 1990

Methane is the second most important greenhouse gas after carbon dioxide. It accounts for one fifth of the global warming effect compared to one half for carbon dioxide and one twentieth of nitrous oxide. Methane is produced from fossil fuel, burning of wood, by certain anaerobic bacteria fermentation of organic material in swamp and rice field, and ruminant animals during anaerobic fermentation in the rumen which accounts equivalent to 18% of total global production and greenhouse gas (FAO, 1994). Rice field contributes about 10-15% of total global methane emission (Neue, 1993). The estimated methane emission in Bangladesh from distribution channels of natural gas, from wet rice cultivation and from enteric fermentation of livestock is given in Table 2.

Table 2. Carbon dioxide and methane emission in Bangladesh

Source of emission	Quantity (Gg)
CO_2 from primary energy source	15473
CH_4 from rice field	439
CH_4 from ruminant livestock	453

* Source: Ahmed *et al*., 1996

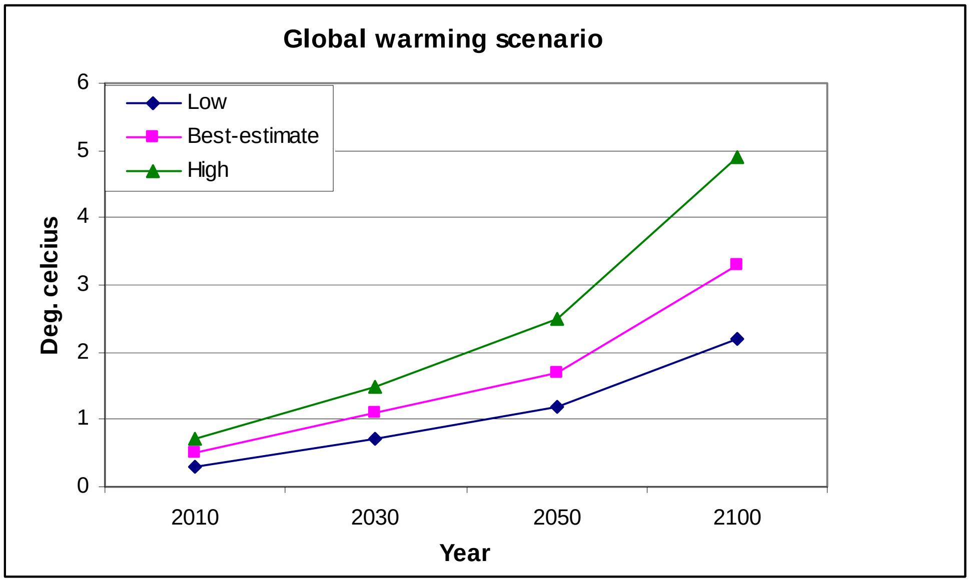
Nitrous oxide is a naturally occurring greenhouse gas produced through microbial action in soil, burning of timber, decay of crop residues and combustion of fossil fuels. Use of nitrogenous fertilizers and pesticides accelerates its rate of release. The amount of nitrous oxide in the atmosphere is very small and an annual increase has been about 0.2 – 0.3% (Watson *et al*., 1992). It is extremely long lived and has 250 times the capacity of carbon dioxide to trap heat and warm the atmosphere.

Many other compounds such as Halocarbons, are radiatively effective and long-lived greenhouse gases. Damage of ozone layer in the atmosphere reduce the absorption of ultraviolet radiation and protects plants and animals from its damaging effect.

Effects of greenhouse gases on climate change

The impact of a gas depends on its greenhouse properties, its concentration and lifetime in the atmosphere and depending on its radiative effect, is referred to as its global warming potential. If current trends in atmospheric emission continue, the combined radiative effect of greenhouse gases by around the year 2030, be equivalent to doubling the carbon dioxide concentration. The resulting change in the radiation balance is expected to increase annual temperature of the planet including sea surface temperature. The greenhouse gas-induced rising of temperature was estimated by IPCC (1990) was at a rate of 0.3^0C per decade, reaching 3.3^0C by the year 2100 (Figure 2).

Figure 2. Global warming scenario by year (^{0}C)



*Source: Bretherton *et al*., 1990

Impact of climate change on Agriculture

The concentration of carbon dioxide in the atmosphere is increasing steadily and expected to double by the end of 21st century (Houghton *et al*., 1990). Increase of atmospheric carbon dioxide has effect on photosynthesis in plants and is almost certain to cause a relatively large increase of air temperature, which in turn will affect the growth and yield of crops (Ziska *et al*., 1996). It is known that an increase in atmospheric carbon dioxide will increase the yield of agricultural crops. A doubling of carbon dioxide stimulates net photosynthesis by 30 – 100% (Pearcy and Bjorkman, 1983) and decrease transpiration, resulting greater water use efficiency in plants. The C_3 plants constitute 95% of world's biomass and are more effective on fixation of carbon dioxide than the C_4 plants and can increase biomass production by 30% at higher carbon dioxide concentration (Kimball *et al*., 1993). Increased temperature and light enhance the positive response to elevated carbon dioxide levels (Gifford and Morison, 1993). But nutrient deficiency in soil lowers the response.

Effect of temperature and greenhouse gases

The concentration of carbon dioxide and other greenhouse gases of the atmosphere have been increasing along with the increase of global temperature. Studies indicated that the temperature is expected to rise to 0.26^0C for doubling of carbon dioxide concentration (Idso, 1982a,b). Such a change in warming and in hydrological regimes could have effects on agriculture. The carbon dioxide-induced warming would result in an almost equally rise in minimum and maximum temperature (Kukla and Karl, 1993). Higher cold season temperature may lead to earlier ripening of annual crops and diminishing yield per crop. Winter kill of pests is likely to be reduced at high latitude, resulting in greater crop losses and higher need for pesticides. High temperature will allow for more plant growth at high latitude and altitudes. Despite of advances of crop varieties and irrigation systems, agriculture in South Asia is vulnerable to weather-related hazards. Temperature and related weather elements including greenhouse gases affect the climate events that are damaging to agriculture. Depending on rainfall and soil condition temperature changes may effects on the yield. Higher temperatures are usually cause higher evapotranspiration and greater moisture stress during the growth of plants. A rise of 3^0C temperature would cause an 11% decrease in soil OM at a depth of 30cm and effects plant on growth was predicted (Boul *et al*., 1990). However, a rise in temperature may behave differently for different climatic environments. Table 3 show the effect of temperature on plant growth of different crops.

Table 3. High temperature effect on key development stages of some crops

Crops	Effects
Wheat	Temperature >30^0C for more than 8 hours can reverse vernalization
Rice	Temperature >35^0C for more than 1 hour at anthesis cause higher percentage spikelets sterility.
Maize	Temperature >36^0C pollen lose viability
Potato	Temperature >20^0C depress tuber initiation and bulking

* Source: Acock and Acock, 1993

Increased temperature would affect the crop calendar by reducing the length of effective growing season, where more than one crop is grown or fodder is cultivated in between the cereal crop. Droughts in cropping season may affect crop yield due to uneven rainfall, higher evapotranspiration, low humidity and high wind speed. Similarly, most of the forage varieties may be sensitive to high temperature with yields decreasing with the increase of day light temperature. Increased soil temperature enhanced the methane emission from soil. Methane and nitrous oxide are both products of agricultural systems. Atmospheric concentrations of these gases will lead to direct effects on animals and plants. Khan *et al*. (1996) reported that the yield of naturally gown pasture in Bangladesh in between the wet season in summer monsoon and dry period in winter was influenced probably by climate such as soil moisture and temperature for plant growth.

Soil impact on plant

Soil structure of farmland is deteriorating by use of unbalanced inorganic fertilizer and led to micronutrient deficiencies. Soil erosion depleting yields and poses a long-term threat to sustainable yield. Decrease in p^H values and OM content, depletion of N, Ca, Mg and K are the cause of reduced yield of crops grown in eroded soil (Halim and Rahman, 2001). The authors tabulated (Table 4) possible effects on environment by intensive farming system. Gradual deterioration of climate and soil in tropical countries by environmental degradation may also have affected forage quality grown in this region. Possible effects are discussed in the following sections.

Effect on quality of forages

The performances of livestock fed on tropical forages are usually lower due to poorer feeding value. The feeding value depends on the chemical and physical composition of the forages which is related to soil condition, forage species, stage of growth and the plant part being eaten. Climate and soil environment are prime determinants of the yield and quality of forages. The following sections review on climate and nutritional factors influence the nutritive quality of forages.

Table 4. Possible cause-effect relationship of farming development and environment

Causes		
Primary	Intermediate	Possible effects
Intensive cereal crop cultivation	Elimination of pulses & oil seed & temporary grazing land	Shortage of animal feed crop by products.
	Increase use of chemical fertilizer, pesticides	Changes in soil composition deficiency in OM nutrients.
	NH_4 emission	Decrease of soil moisture holding capacity.
	CH_4 emission	Climate warming.
Replacement of local varieties	Loosing species diversity	Elimination of genetic resources.
	low quality of straw	Shortage of livestock feed reducing soil OM content.
Increasing N-fertilizer use	Increase in NO_3 conc. in soil and water	Damage to human and animal health.
	Increase of N_2O level	Climate warming, Destruction of ozone layer
Increasing pesticide use	Air and water pollution	Health hazards.
	Soil pollution	Reduction in nutrients availability, beneficial effect of macro and micro organisms.
	Pest resistance of insect and microorganism	Crop yield reduction.

*Source: Halim and Rahman, 2001

Climate

Wilson (1982) compiled data on digestibility of wide rage of tropical and sub tropical grass species grown in different seasons and predicted that highest DM digestibility in spring, then falling gradually in summer to winter in drier and monsoon tropics. These general climatic trends due to temperature, day length and climatic variables were suggested. Temperature has greater influence on forage quality and adaptation of forage species in an environment. Growth temperature of plant species in cool season is 20^0C and in warm season from 30-35^0C. Plant produces highly digestible sugars from photosynthesis due to low temperature sensitivity and in warmer condition rate of plant development is greater than in cool condition which reduces leaf/stem ratio, their digestibility and lower forage quality (Nelson and Moser, 1994). Ohlsson (1991) found that a temperature increase from 10 to 20^0C lowered digestibility by 5 to 7% in temperate pastures. Each degree increase of temperature can decrease of digestibility by 0.3 to 0.7% units. Temperature also affects the yield of forages. When grown under lower than optimal temperature higher yield can be obtained and above the optimal for growth can cause early maturation and blooming. Elevated temperature depressed digestibility is associated with higher indigestible cell-wall (NDF) concentrations (Buxton and Fales, 1994). The effect of temperature on DM digestibility of plant fractions is shown in Table 5. High temperature has effect on DM digestibility in both tropical and temperate grasses and a small effect in legumes. The apparent beneficial effect of tropical legume on leaf DM digestibility warrant further investigation. Differences in climate and soil condition have influence on pasture quality. The quality of forages grown in tropical climates is usually less than temperate grasses which is associated with a higher fiber content and lower DM digestibility (Table 6). The values of intake of tropical grasses are usually less than temperate grasses grown at same time. This is associated with higher fiber content and larger quantities of indigestible fiber.

Table 5. Effect of temperature on DM digestibility

Average change in DMD (% units) per ^{0}C increase in growth temperature				
	Grass		Legume	
	Tropical	Temperate	Tropical	Temperate
Tops	-0.60	-0.56	-0.28	-0.21
Leaf	-0.57	-0.64	+0.19	-0.09
Stem	-0.86	-0.76	-0.27	-0.22

*Source: Wilson and Minson, 1980

Table 6. DM intake and digestibility of tropical and temperate grasses

Grass	DM Intake ($g/kgW^{0.75}/d$)		DM Digestibility (%)	
	Range	Mean	Range	Mean
<u>Tropical</u>				
C. gayana, D. decumbens, P. maximum, P. dilatatum S. splendida	48 – 68	56	57 – 67	62
<u>Temperate</u>				
D. glomerata, F. pratensis, L. perenne & multiflorum	58 – 85	71	65 – 80	71

*Source: Minson, 1980

Difference in exposure of forage plants to shade in different seasons may lead to high lignifications and low digestibility of cell wall (Deinum *et al*., 1968; Masuda, 1977) lowers soluble carbohydrate level (Smith, 1973) and increase in cell wall content (Deinum and Dirven, 1972), This may led to up to 15% less intake and 38% lower weight gain observed in sheep (Hight *et al*., 1968). These effects may be extended in cloudy and wet weather. Legume grown in over wet conditions showed no consistent trend of lowering DM digestibility or crude protein content (Peterschmidt *et al*., 1979). These conditions in grasses can reduce crude protein and cell wall content without affecting lignin content in herbages (Pate and Snyder, 1979).

Drought

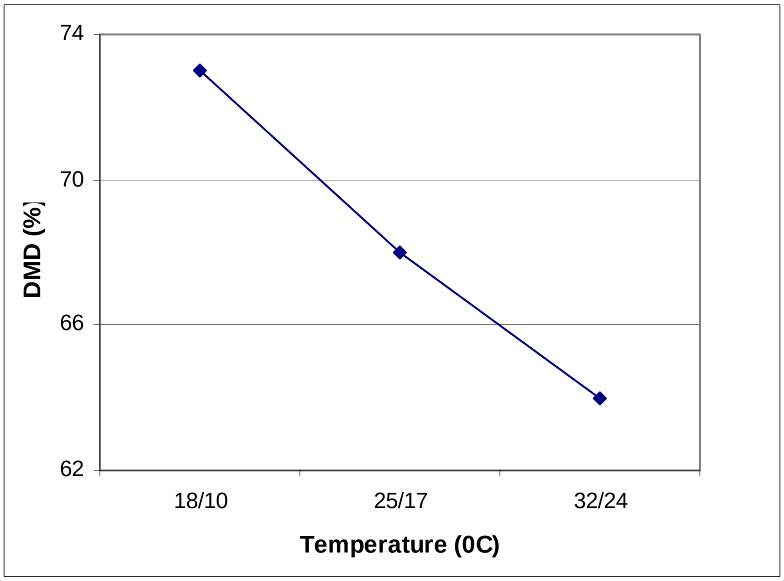
Severe drought may stop growth and kill all above ground herbage and limit livestock production due to dead herbage and insufficient supply. Moderate moisture stress has either no effect or increases the digestibility due to slow growth of stem and resulting leafier sward (Wilson, 1981). This is important for plants grown in wet watered condition. Water stress has major limitation to growth of forage and to yield than to quality. Water stress has to shown increase the composition of leaf tissue and forage quality such as increase in N content (Wilson and Ng, 1975), most minerals (Rahman *et* *al*., 1971) and soluble carbohydrate (Ford and Wilson, 1981). Water stress on Alfalfa was shown to reduce yield by 49%, increased leaf/stem ratio by 18% and increase digestibility of stem by 8% by delay of maturation of plant. It also increased CP in stem by 10% and decreased in leaves by 14% (Halim *et al*., 1989). Similar trends were also found in forage legumes and grasses (Table 7). Phosphorus is often at a low concentration in water-stressed forage (Rahman *et al*., 1971) and could be a limitation to animal production where soil phosphorus levels are low. Increase of alkali or hydrocyanic acid and tannins contents may arise and affect palatability of forages (Hoveland and Monson, 1980). In situation of excessive rainfall or lowland areas grasses in over wet conditions may contain low CP and high call wall content (Pate and Snyder, 1979). Significance to nutritive value is that decrease of cell wall digestibility due to greater lignifications usually occurs at high growth temperature (Ford *et al*., 1979). Table 5 shows a clear effect of high temperature in quality of grasses compared to legumes. High growth temperature increase maturation of plant tissue and plant of similar age is of higher digestibility when grown at low temperature (Figure 3). Frost although insignificant in

Table 7. Effect of drought on yield and composition of forage legumes and grasses

Species		Yield (t/ha)		CP (% DM)		NDF (% DM)	
		Control	Drought	Control	Drought	Control	Drought
Alfalfa	Total	5.9	4.4	19.3	19.5	45.3	40.5
	Leaf			27.5	25.0	27.3	26.6
	Stem			12.6	14.1	60.2	54.3
Red Clover	Total	6.6	4.0	20.5	20.7	39.8	36.7
	Leaf			25.6	23.2	32.5	33.3
	Stem			11.7	13.7	52.4	46.6
Broom grass	Total	4.3	3.8	14.5	15.3	62.8	59.2
	Leaf			18.9	17.6	56.1	56.0
	Stem			8.1	11.3	72.8	64.5
Timothy	Total	4.7	2.7	14.7	16.5	60.6	55.9
	Leaf			18.1	17.0	54.9	55.6
	Stem			9.4	14.9	69.4	55.6

*Source: Cited by Buxton, 2004

Figure 3. Effect of temperature on DM digestibility of leaf of average six grasses



*Source: Wilson *et al*., 1976

tropical climate, may also bring a decline in nutritive quality of grasses and tropical legumes in terms of N content and digestibility (Wilson and Mannetje, 1978).

Shade also has greater effect on forage yield than quality. Kephart and Buxton (1993) found 43% reduction of yield, 3% NDF content and 5% increase of digestibility of grass by imposing 63% of shade. This has also increased CP content by 26%, being grater for leaf than stem.

Nutritional factors

The chemical composition of plant varies between the species and also affected by genetic and environmental factors. Pasture intakes is usually limited by the level of fiber in the plant if protein, vitamins and minerals are insufficient quantity. Intake of herbages is restricted when CP levels are below 7% (Minson, 1980); this limitation occurs mostly in tropical grasses and not for legume. Increase in CP content above this critical level requires application or content of N fertilizer in soil. It stimulates new growth of plant tissue which has high protein and low cell wall and lignin content (Ford and Williams, 1973) leading to higher DM digestibility. However, application of N fertilizer may lead to rapid growth of plants to maturation and consequently accumulation of indigestible fraction of plants and lower concentrations of minerals in forages. Pasture grown in soil deficient in minerals such as P, K, Ca and S may lead to low contents of these minerals. Feeding these minerals to animals grazing these deficient pastures may improve herbage palatability and DM intake and digestibility by either improving their supply to the animal or change in the structural composition of the grasses (Wilson, 1982). Greater feeding values of forages were shown to achieve if the mineral content in soil is sufficient and their uptake by plants is not limited (Table 8). The tabulated values indicate that application of S Fertilizer in pasture increased the DM intake and digestibility, the improvement in nutritive value being greater than S supplementation. This demonstrated that S deficiency in pasture may be overcome by application of S fertilizer, raise S level in plant and increases the yield and leaf percentage.

Table 8. The effect of fertilizer and supplementary sulphur on the intake and digestibility of Pangola grass

	No supplement			S supplement		
S fertilizer (kg/ha)	0	66	Difference	0	66	Difference
S intake (g/d)	0.58	1.45	0.87	1.37	2.05	0.68
DMI (g/W$^{0.75}$/d)	44.4	64.1	19.7	56.8	64.7	7.9
DMD (%)	55.2	60.2	5.0	60.6	58.6	-2.0

*Source: Rees *et al.*, 1974

Pests and diseases

Infestation of pests and diseases due to favourable condition of environment may influence both yield and quality of forages and diseases reduce yield and quality, whereas insects can reduce yield more than quality. Disease can reduce digestibility and nonstructural carbohydrate concentration in plants and cause leaf loss. Under warmer and humid conditions fungal and bacterial pathogens are also likely to increase in severity and plants would be more prone to diseases (Beresford and Fullerton, 1989).

Conclusion

The greenhouse gas of carbon dioxide, methane and nitrous oxide, being constantly added to the atmosphere by human activity, are the potential source of global warming. Environmental degradation caused by gradual increase of global temperature, drought and depletion of soil composition affecting plant production, their yield and quality. The important environmental influence on forage yield and nutritive quality are growth temperature and soil properties. High environmental temperature accelerates growth and maturation of plants and increase in tissue cell wall content, lignifications and decrease in DM digestibility. High sunshine and moderate water storage is beneficial to the quality of grasses but severe droughts are known to lower nutritive value and limit animal production. Forage grown in deficient soils lack adequate quantity of nutrients, depress intake and digestibility. Improvements in the nutrition of animals feeding tropical forages will come from overcoming soil nutrient deficiencies and control of greenhouse grasses which affects their productivity and composition.

Need of future research programme

The following research areas are recommended for the present research proposal to offset the adverse effect of environment on forage and livestock production:

1. Identification and study of environmental constraints for forage production
2. Effects on forage yield and nutritive values
3. Effect on livestock production
4. Development of management systems for improving forage supply and ruminant production

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Methods for evaluating greenhouse gasses from ruminant livestock systems.

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Abstract.

Livestock systems worldwide contribute significantly to greenhouse gas emissions. There is a clear need to strengthen the base of infrastructure and expertise in greenhouse gas (GHG) monitoring from livestock systems in South Asia. This includes capacity for monitoring of CH_4 eructed by livestock, N_2O emitted from soils, and CH_4 and N_2O emitted from manures. Open circuit calorimetry (whole body chambers or hoods) are the best methods for monitoring methane eructed by stall fed livestock, while the SF_6 tracer technique is most applicable to free ranging livestock. Whole barn chambers and micrometeorological methods are far more costly and technically intensive, and not applicable to individual livestock or statistical comparison of treatments. N_2O from soils is most easily monitored using static soil cover chambers; although a host of more complex and costly methods have been employed. Similar techniques may be applied to monitoring manures as are applied to soil monitoring, with appropriate modifications depending on the manure characteristics. Modeling can be usefully employed to estimate GHG emissions associated with energy consumption, to strengthen results obtained by field monitoring, and to estimate total system GHG emissions. Details on the standard methods are presented. Successful application of methods requires that certain basic concepts, design details, and protocols be observed. From the point of view of cost and practicality, standard methods are recommended for application in South Asia.

Introduction:

Ruminant agriculture generates greenhouse gasses (GHGs) in the form of methane eructed from the rumen, methane and nitrous oxide emitted from stored manures, and nitrous oxide from soils where feed is grown, especially after fertilizing with livestock manures. Livestock systems contribute approximately 15% of direct methane emission worldwide. About 75% of this is expelled directly from digestive tracts, while the remainder is produced by stored manures (IPCC, 2001, Moss et al., 2000). Ruminant animals contribute the majority of this. Agriculture has been identified as a major source of GHG in Pakistan (Bahadar Khan and Baig, 2003). In light of the importance of livestock production to GHG emissions, and the importance of livestock raising in the South Asia region, research on GHG emissions from livestock in the region is essential. This demands a careful evaluation of the applicable techniques.

This paper will discuss methods of monitoring greenhouse gas emissions from livestock systems, with particular emphasis of open circuit calorimetry and SF_6 tracer methods for monitoring eructed methane, and static chamber methods for monitoring N_2O fluxes from soils.

Background: Sources of GHGs from Livestock Systems.

Methane emission from ruminants has long been an interest of ruminant nutritionists, because it represents lost feed energy, and also is an important endpoint of biochemical pathways in the rumen. Methane is generated by methanogenic bacteria and fungi in the rumen that utilize carbon and hydrogen substrates. Methane is a major sink for surplus H in the rumen, especially during formation of acetate. Over 85% of the methane produced by ruminants is produced in the rumen and eructed, mixing with the breath. The remainder is generated in the hindgut. A portion of the gasses produced in the hindgut are absorbed in the bloodstream and exit the body through the lungs. Therefore, the great majority of methane produced by the ruminant is expelled through the nose. McAllister et al. (1996) and Moss et al. (2000) summarize the state of the science in understanding sources and significance of methane emission from ruminant digestion.

Measuring methane fluxes from ruminants is time and labour intensive. Traditionally, expensive whole body open circuit calorimetry chambers were used. Hoods that cover just the head have also been widely used, and are considerably less costly. More recently, the SF_6 tracer technique is becoming widely employed. Finally, a number of studies have examined whole herd emissions using whole barn chamber techniques, field chamber or wind tunnel techniques, and open air micrometeorological techniques.

Unlike methane where agriculture is only one of several sources, agricultural activities are the primary source causing increasing N_2O in the atmosphere. N_2O is produced primarily from soil during denitrification under semi-anaerobic soil conditions. Faculatively anaerobic heterotrophic bacteria use nitrate as a terminal electron acceptor, leading to a reduction pathway of:

NO_3 • NO_2 • NO • N_2O • N_2.

These bacteria utilize carbon substrate for energy. Hence, under conditions of available nitrate and labile soil carbon, when soils are wet, significant denitrification and N_2O emissions can occur. When the soil is more completely anaerobic, much of the N_2O is reduced to N_2, and emission is less. Enrichment of soils with N fertilizers is the main source of increasing N_2O. Manure additions particularly favor N_2O emissions, because manures provide both C and N substrate, and tend to trigger rapid microbiological activity that creates semi-anaerobic zones in the soil, especially when soils are moist. The review of Beachamp (1997) summarizes of the processes of N_2O emissions. Much attention has been paid to livestock systems because of the impacts of manures on N_2O emissions. Intensive dairying has been an area of focus ofr N_2O mitigation (Velthof et al., 1998).

Manures emit methane during anaerobic decomposition and small quantities of N_2O during nitrification/reduction cycles near the surface of the manure. Typically, more aerated manures produce less methane but more N_2O.

Although CO_2 is the dominant GHG gas worldwide, biologically produced CO_2 from livestock systems is comparatively insignificant, because it consists mainly of carbon that was drawn from the atmosphere by photosynthesis and is not part of net C emissions. The exception to this is soil carbon loss or accretion, which has potential to sequester significant quantities of C as long as certain management practices are observed. Ore importantly, mechanized livestock systems based on heavy inputs of fuels and fertilizers consume considerable fossil energy, and indirectly contribute to CO_2 emissions via that route. This can amount to 10 - 20% of the total direct and indirect emissions of the system when life cycle energy consumption is considered (Main, 2001). This is not easily measured, but can be estimated using life cycle assessment and process analysis modeling techniques (E.g. Cederberg and Mattson, 2000).

Methodologies:

1. Respiration Chambers and Hoods

Open circuit respiration chambers allow measurement of gasses produced by an animal or animals housed within a chamber that is sealed except for a controlled and known airflow. A respiration hood follows the same principle, but covers only the cow's head, and is considerably simpler and cheaper. Air is continuously sampled or monitored at the air entry and outlet. Methane flux is calculated as the difference in concentration between the outlet and inlet multiplied by the airflow rate. Measuring at the inlet as well as the outlet is essential in and around livestock facilities where inlet concentrations of gasses vary greatly. Simple, low cost respiration chambers are shown in figures 1 and 2. An example of a hood used is shown in figure 3. A sketch of a simple prototype designed for higher airflows for use in hotter climates is shown in figure 5.

Respiration chambers or hoods typically use a steady state flow of air which is periodically monitored using an anemometer. Airflow must be sufficient to maintain good air quality. A minimum of 80L s^{-1} is suggested for a mature Bovine. Air conditioning is required at lower airflows, to avoid heat stress. Airflow should not exceed 500 L s^{-1}, in order to allow easy detection of changes in methane concentration between inlet and outlet.

Accurate airflow measurements require the outlet be equipped with a straight, smooth round duct at least 1.5 meters long, where air flows with minimal turbulence. Air velocity is measured with an anemometer. A hot wire anemometer is preferable due to its small diameter that can be inserted through a small hole in the duct, but a lower cost vane anemometer can suffice, with less precision. If air velocities are measured in meters per second, and cross sectional area in cm^2, the resulting flow becomes m-cm^2 s^{-1}. This quantity multiplied by 10 yields L s^{-1}.

Figure 1: Exterior of low cost respiration chambers at NSAC.

Figure 2: Cow in respiration chamber, NSAC

Figure 3: Methane monitoring hood used at University of Guelph, Ontario, Canada.

Monitoring gas concentrations can be done by continuous real time monitoring or by slow sampling. Because eructations of methane occur for 10-20 seconds every 2-5 minutes, concentrations of methane at the outlet of a chamber are very dynamic. Monitoring or sampling techniques have to accommodate this.

Real time monitoring normally uses an infrared absorption instrument drawing sample periodically from sample ports. Multiple sampling points can be multiplexed to a single instrument and monitored on a cycle. This demands some ability to buffer the dynamics of gas concentrations at the outlet, as multiplexing slows the sampling cycle to the point where peaks of methane concentration could be missed. This can be easily accomplished by drawing air continuously through a vessel of sufficient volume, from which sub-samples are periodically drawn for monitoring. Real time monitoring is ideal, but instrumentation is costly.

The alternative is to draw samples for later analysis on laboratory instruments. In order to integrate variations in concentration, a slow sampling technique is recommended. In this case, gas bags are slowly, continuously filled using small diaphragm pumps equipped with a restrictor tube (microbore or capillary tubing). The rate of fill is controlled by the size and length of the restrictor tubing. Frequent sample cycles (1/2 to 1 hr) yield information on the dynamics of emissions through the day, but generate a large number of samples. A more reasonable sampling cycle is 1 sample per 6 hours. This coincides with a need to periodically check animals in chambers.

Slow sampling employs gas storage bags. Laboratory and environmental companies sell special fluoropolymer bags (Tedlar), or bags with foil layers, equipped with valves, in various sizes, designed for gas sampling. However, these are very expensive. (A 1 5 liter Tedlar bag typically costs about US$30.) A workable alternative is Mylar balloons into which a Tygon tube is inserted and sealed with PVC tape. A pinch clamp is used to open and close the bag. Tests of gas storage at NSAC (unpublished) showed that these homemade gas bags stored gasses equally as effectively as commercial bags. Standard polyethylene bags are highly impermeable to gasses, and will not work as gas sample bags. Examples of 3 different bag types are shown in figure 4.

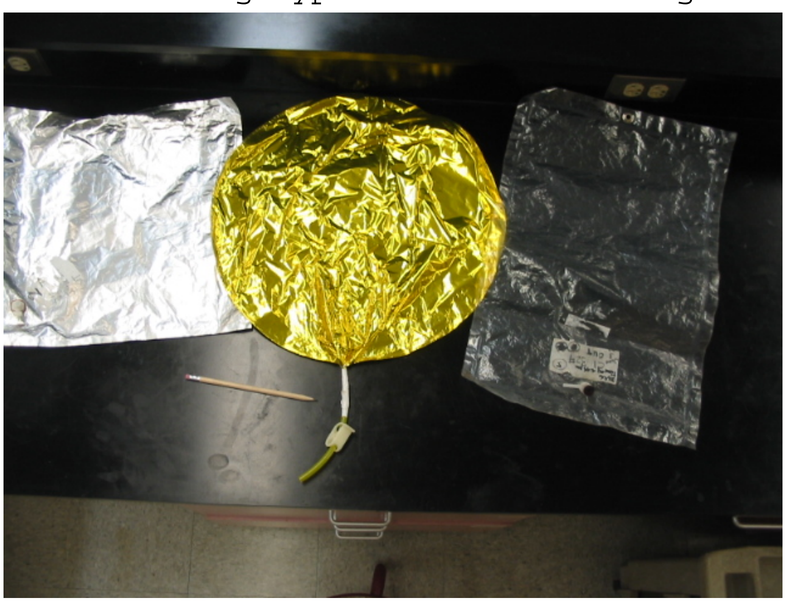

Figure 4: Foil laminate, homemade Mylar and tedlar gas sample bags, all about 5 liters capacity.

In both chambers and hoods, the design is such that air enters the unit mainly at one location, and exits at one location. A well designed chamber must be tested for leaks using a smoke generator to fill chambers with smoke, and putting them under slightly positive pressure in order to locate and seal leaks. Under operation, a chamber or hood should be under very slightly negative pressure. Thus, when the door is open for very brief periods, gasses will not escape, but a small amount of air enters. The errors accumulating for occasionally opening the chamber are small since the air entering through a door is nearly the same as that being measured at the normal inlet, and the period of opening is normally very brief relative to the time that the chamber is operating. For instance, opening a door 12 times a day for 30 seconds each time is only 0.42% of 24 hours. If the inlet air concentration was 1 ppm different than the normal inlet, this would affect the result by less than 0.02% of the true value. However, normal protocol is to keep doors and hatches sealed, and minimize periods of opening doors.

Hood design:

In a chamber, the animals are housed completely inside, whereas in a hood the chamber covers only the head. The side facing the shoulder of the animal is constructed of a heavy tarp or canvass with a drawstring opening where the animal's head passes through. The animal is secured in the hood by a halter

The sketch of a hood shown in figure 5 is designed with a large air duct to allow high air flow rates – up to 400 L/s – to allow use in a warm climate without air conditioning. Animals experience some discomfort in hoods because they cannot turn their heads as normal. In chambers, animals experience some isolation distress. Both these factors require some acclimatization to the equipment before conduction trials.

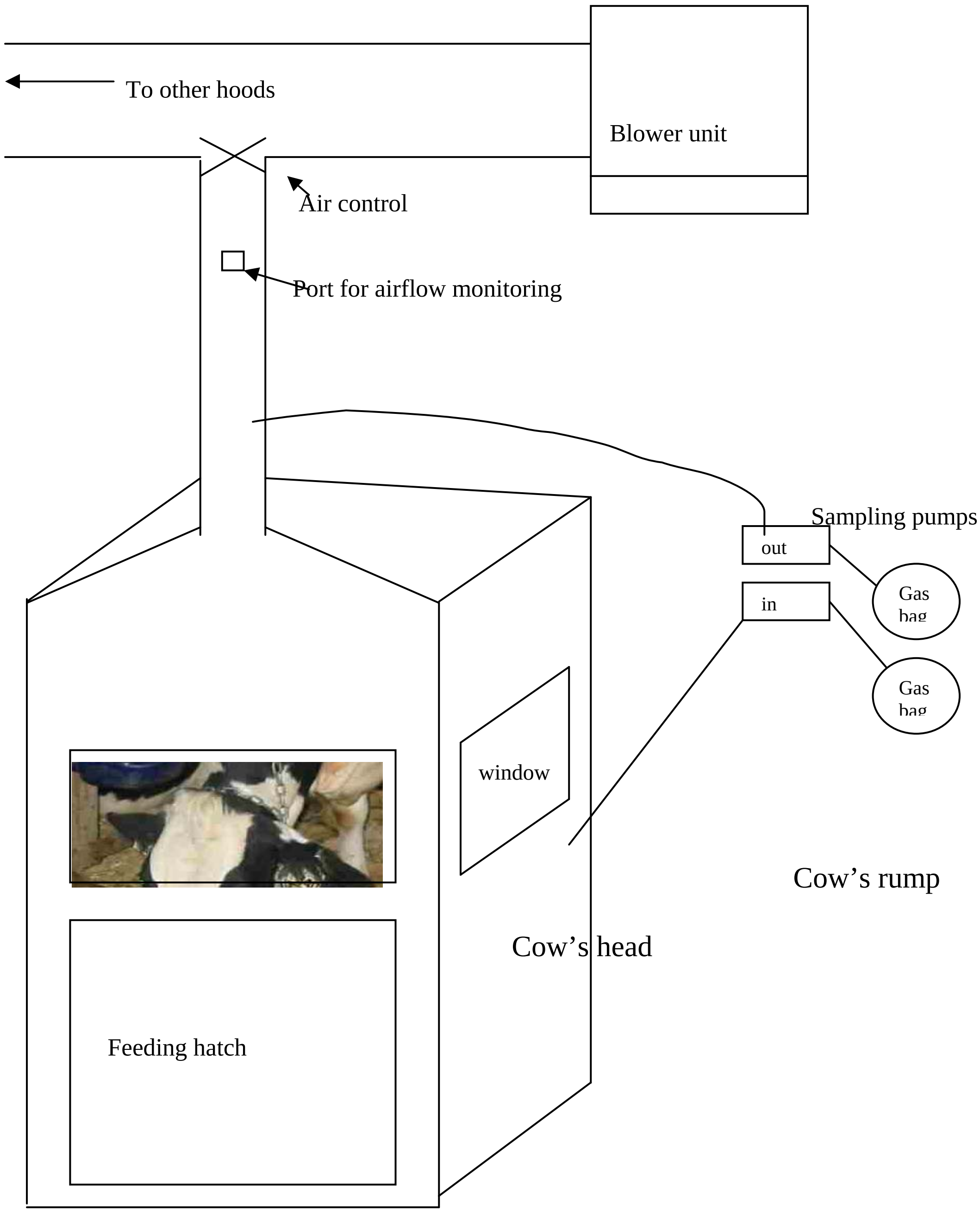

Figure 5: Sketch of a simple high airflow hood system.

Either infrared absorption or gas chromatography may be used for gas analysis. A Fourier Transform Infrared Spectrophotometer (FTIR) can be converted to a gas monitoring instrument with the addition of a multi-path gas cell, a vacuum pump, and a pressure gauge. FTIR can give simultaneous measurement of CO_2, CH_4, NH_3, and a range of other infrared absorbing species. However, common gas cell volumes vary from 100-2000ml, requiring considerable volumes of sample. Gas chromatography requires samples of 20 ml or less. A flame ionization detector is required for CH_4 analysis, while a thermal conductivity detector is best suited for CO_2 analysis. Methane separates on a number of porous polymer packed columns (*Hayesep* or *Poropak*), about 1/8″ x 1M, using helium carrier gas. Samples must be loaded to columns using sample loops and valves rather than injection. GC is the most common method, mostly because the instrument is more common and familiar in most labs. Dedicated laser infrared instruments offer high precision and speed for real time monitoring, but too expensive for chamber applications that do not need this level of precision or speed. If GC is used, air samples from chamber inlets and outlets can be collected in gas bags, and then transferred via syringe into evacuated blood sampling tunes. This allows easy sample shipment for analysis in a central location. 12ml screw top exetainers tubes equipped with a second Teflon-silicon septa work well for this purpose, and will store gasses for several weeks if necessary. Normally, air samples should be analyzed within a few days of sampling. When samples are stored for longer, vials containing standard gas mix should be stored along with air samples to correct for any changes that occur over time.

In measuring any gas, the gas laws apply. This means that temperature and atmospheric pressure must be monitored. At standard temperature and pressure, the volume of 1 mole of ideal gas is 22.414 liters. Real gasses behave closely to ideal gasses except at extreme temperatures and pressures. Standard temperature is 277K (4C) and standard pressure is 1 atmosphere = 760 mm Hg = 1.013 bar = 101.3 kPa. It is easiest to use the constituent laws rather than the combined gas law to make conversions from volumetric measurements to mass fluxes. (Mass or molar fluxes are a more exact quantity.) Boyle’s law states that the volume of fixed molar quantity of a gas is inversely and linearly proportional to the absolute pressure. Charles law states that the volume of a fixed molar quantity of gas is directly and linearly proportional to the absolute temperature. Hence, at an atmospheric pressure of 100.5 kPa and temperature of 30C, the volume of 1 mole of gas is 22.414L * 101.3kPa/100.5 kPa * 303K/277K = 24.71L. If methane is present in a concentration of 50ppm (v/v), the mass of methane per liter is equal to the molar mass of methane divided by the molar volume, multiplied by the proportional content. In this case, 1 liter of air at 50ppm contains: g CH_4 = (16 g/mol) * (1 / 24.71 L/mol) * (50parts/10^6parts) = 3.24 x 10^{-5} g/L. Without temperature and pressure correction, the result would have erroneously been 10% higher.

Calculations using hood/chamber systems:

Example data is shown in table 1.
1. Calculate airflows: airflow = velocity (m s^{-1}) * cross sectional area (cm^2) * 1 L / 10 m-cm^2. Convert airflow reading to L/h.
2. Calculate the molar gas volume: volume (1 mole) = 22.414 * 101.3kPa / barometer reading (kPa) * 277K / (thermometer reading (C) + 273)
3. Calculate methane flux in L/h: Flux = (ppm outlet - ppm inlet) / 10^6 * airflow (L/h)
4. Calculate methane flux in g/h: Flux (g/h) = Flux (L/h) * mol wt / mol volume.
5. Calculate flux for the time interval, and/or per day.

Table 1: Example results for methane hood/chamber measurements.

Recorded data		Calculated data	
Exit duct diameter, cm	15	exit duct cross sectional area, cm2	176.6
Air velocity, M s-1	16	Airflow, L s-1	282.6
Inlet concentration, ppm	3.4	Airflow, L h-1	1.017E+06
Outlet concentration	21.5	Methane flux, L/h	18.41
Time elapsed, hrs	24	molar volume	24.7130
Barometer, kPa	100.5	methane flux, g/h	11.9
temperature, C	30	methane flux g/d	286.1

2. The SF_6 tracer technique.

The SF_6 tracer technique, first described by Johnson et al. (1994), has become prominent in recent experiments measuring methane from ruminant livestock. The primary advantages of the technique are that, 1. It allows the animals to go about normal activities without the restriction of hood or chamber systems, 2. It allows monitoring of individual animals, and 3. It is less costly than other systems for measuring methane on free ranging animals. However, measurement precision is lower than open circuit hoods, demanding a greater number of measurements to obtain the same results (Dr. Alan Fredeen, unpublished), shown in table 2. Boadi et al. (2002) observed similar precision between hood measurements and SF_6 tracer results for methane emission from beef heifers, but found the SF_6 tracer method overestimated CO_2 production by 20% and was considerably more variable than the hood method. Table 2 shows considerably higher ranges and standard errors for the SF_6 tracer method at NSAC. The number of observations is too small for definitive comparison of the results.

The SF_6 tracer method is least suited to applications for stall fed livestock where the concentrations of methane in background air vary widely and cannot be fully monitored. This does not preclude its use in this situation, but it limits the method’s precision.

Table 2. Comparison of results using open circuit respiration chambers or hoods versus the SF_6 tracer technique

Source	Method	mean CH4 flux, g cow^{-1} day^{-1}	Range	SE	# obs
Dr. A Fredeen and M. Main, NSAC, 2003 (unpublished) Mature lactating Holsteins	chamber	348	289 - 411	6.6	23
	SF_6	293	172 - 416	12.3	23
Boadi et al., 2002, yearling beef heifers	hood	87	72-97	2.7	36
	SF_6	91	60-111	2.7	36

Figure 6 shows a schematic of the SF_6 tracer technique. The method employs a tracer of sulfur hexafluoride gas emitted at a known fixed rate from a bolus placed in the rumen. The tracer gas mixes with rumen gasses and is eructed with the methane. The animal is equipped with a halter and an evacuated canister that slowly collects air samples from the vicinity of the nose of the animal, regulated by a length of capillary tubing, capturing a portion of the methane, CO_2 and SF_6 evolved. The methane emission is determined as the release rate of the SF_6 tracer multiplied by the ratio of methane to SF_6 concentration in the breath sample. Essentially, as more CH_4 is produced in the rumen, the SF_6 is more diluted relative to CH_4. A detailed guide to the method is available from Dr. Hal Westberg at Washington State University, USA.

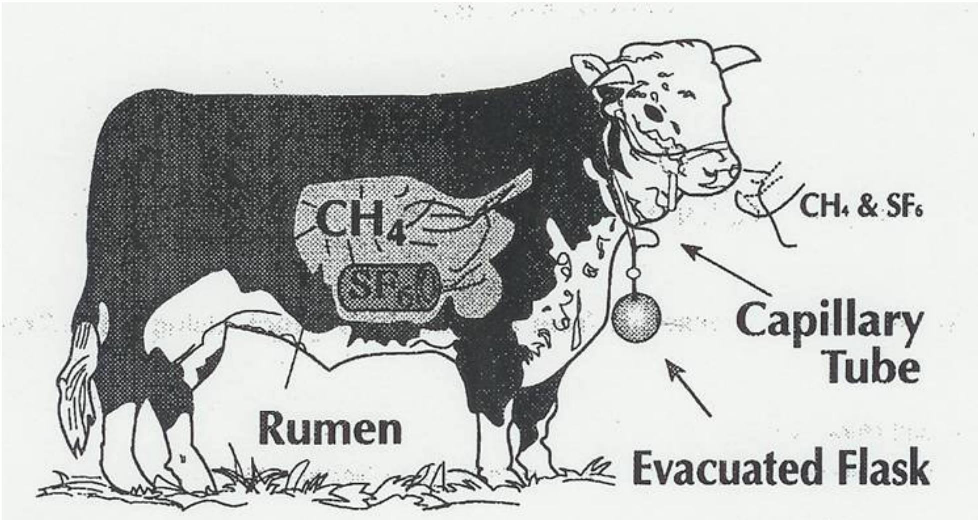

Figure 6. Diagram showing the SF_6 tracer method. (from Johnson et al, 1994)

Variations on the halter and bolus design are possible, but the key principles need to be respected, both in equipment design and experimental protocols.

Permeation tubes (the SF_6 emitting bolus) can be made from brass rod machined to accept a tubing nut, frit and permeable membrane, or made similarly with brass or stainless steel fittings. SF_6 in the tube is emitted at a slow fixed rate through a PTFE (*Teflon*) membrane into the rumen. The stainless steel permeation tubes used at NSAC are shown in figure 7.

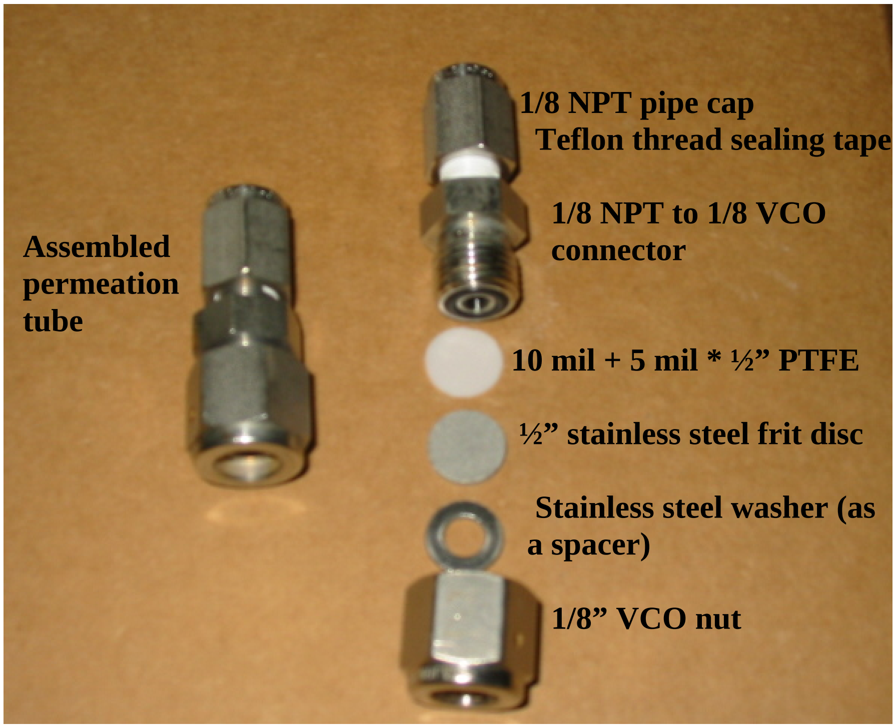

Figure 7: Assembled and exploded view of a permeation tube made from stainless steel fittings.

Permeation tubes must be prepared about 3 months in advance of the experiment in order to establish a known uniform emission rate. The method for loading SF_6 into the tubes is as follows:

1. All the parts for the tube as shown in figure 7 are assembled. The pipe cap is tightened securely, while other parts are loosely fastened. Each assembled tube is engraved top and bottom with an identification number. Each empty tube is dried and weighed to 4 decimals.
2. The tube is placed in liquid nitrogen until the N stops boiling, at which time it has reached -196C. It is then removed, inverted to pour out any LN inside the tube, and placed in a stand or in a shallow bath of LN to keep it chilled. Immediately, about 150 ml of pure SF_6 is injected into the tube. The SF_6 freezes as a flaky solid within the tube. The PTFE (Teflon) disc, frit, washer, and nut are tightened on immediately. 150 ml of SF_6 contains about 0.9 g, but usually there is some loss, resulting in about 0.8g retained in the tube. Injecting more than 1 g usually results in a non-linear, declining emission rate, whereas injecting too little shortens the lifespan of tubes.

3. The process results in frosty tubes that must warmed to room temperature and dried. This occurs over about ½ day in air. After drying, the filled tubes are weighed to 4 decimals.
4. Tubes are then incubated in a water bath at rumen temperature - 39C. The water bath should be equipped with a slow purge of dry N gas or clean air, or be agitated to purge SF_6 dissolved in the water.
5. Every 5-9 days, the tubes are removed from the water bath, blown dry with compressed air, dried for 6-8 hours in an incubator at 39C, and weighed to 4 decimals. Date and time are recorded at each weighing. For accuracy, balances need to be recalibrated at each weighing, or a standard weight should be weighed at each weighing, and any correction made for drift. The tubes should be weighed in triplicate if differences of more than 0.0002 grams between triplicate weighings are noted. (Every 0.0001g error results in an emission estimate error of about 0.5% of the true value.) The weighing procedure is repeated for 6-10 weeks until the weight loss rate is stable, and at least 5 reliable weighing intervals are available to calculate an average emission rate.
6. The emission rate is calculated as the weight loss divided by the elapsed time for each interval. Typically the calculated emission fluctuates about a mean value, due to slight errors in weighing or in the degree of dryness of the tubes. Often, the rate is higher for the first 2-3 weeks, but declines to a steady value thereafter. Some example data is shown in table 3. Note that final emission figures are converted to L/hr. This is essential in establishing the correct ratio of SF_6 to CH_4 concentration, since both are measured on a volumetric basis at the point of analysis, and the density of the 2 gasses are very different.

Table 3: An example of real permeation tube calibration data and calculations.

	empty	filled				
tube mass	62.2224	63.1349	63.1140	63.0943	63.0725	63.05549
day	0	0	7	14	22	28
hr of day	13.5	13.5	15.5	16.5	13.5	13.5
hrs in interval		0	170	169	189	144
mass SF6	0	0.9125	0.8916	0.8719	0.8501	0.8331

SF6 emitted, g	0.0209	0.0196	0.0219	0.0170
SF6 emitted, g/hr	0.000123021	0.000116	0.000116	0.000118
SF6 emitted, ug/min	2.050351316	1.935471	1.926956	1.967015
SF6 emitted, L/hr	2.17E-05	2.05E-05	2.04E-05	2.08E-05

7. The thickness of the Teflon determines the emission rate. A minimum of 12 mil is suggested, and up to 15 mil may be used. Teflon thinner than 12 mil results in high emission rates that tend to be non-linear. Teflon of different thicknesses can be layered, but single thicknesses are preferable if they are available. A 15 mil thickness (10+5mil) on the design of tubes shown in figure 7 resulted in emission rates between 1.2 and 2ug/minute for most tubes, but occasionally a tube produced much higher rates (Dr. Alan Fredeen, NSAC, unpublished). A 20-30% greater number of tubes than needed should be prepared, to ensure a sufficient number of tubes with emission rates within the desired range of 1-2 ug/min. Figure 7 show real permeation tube calibration data that shows 4 tubes within the desired range, and 1 tube with an unusually high emission rate.

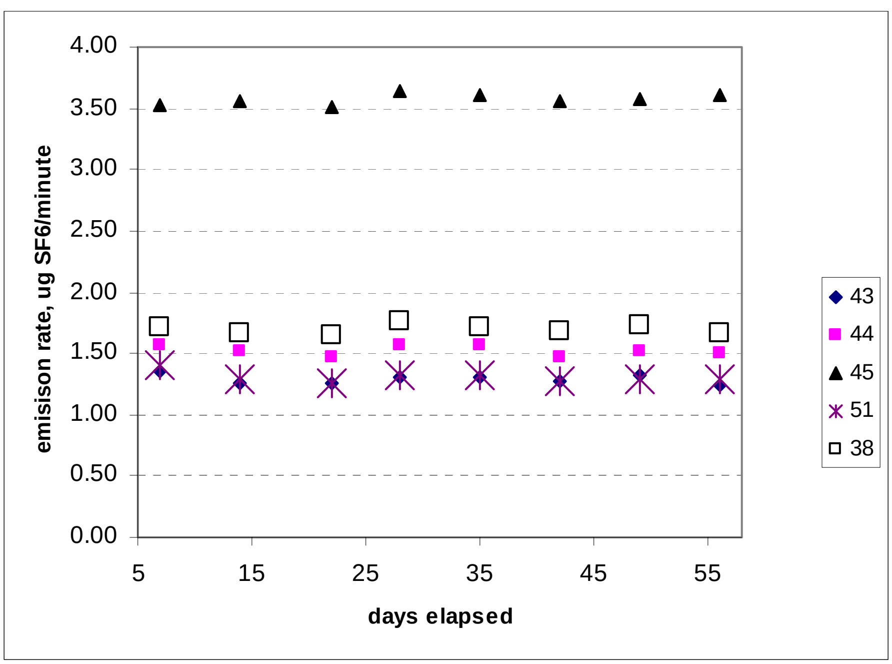

Figure 8: Example results for permeation tube incubations, NSAC, spring 2005.

The best design of sampling halter/canister depends on the handling and restraint system being used. The original design (Johnson et al., 1994) used a spherical stainless steel canister that dangled from the neck strap of the halter. Currently, many researchers use a collection canister using two pieces of 2″ PVC pipe and an elbow, bent into a yoke (an inverted V or U that fits over the cow's neck), rather than a canister below the neck. A sampling halter design used recently at the Nova Scotia Agricultural College is shown in Figure 9. This canister was constructed from 4″ PVC pipe and caps, drilled and threaded to receive a 1/8″ NPT fitting and sample line. This design worked well for cows both on pasture and when restrained in tie stalls. The same design was used successfully on cows in a free-stall barn. Velcro straps were used to attach canisters to halters. This was effective, and allowed easy attachment/removal.

Damage to equipment or clogging or leaking of sample lines can happen periodically, since equipment wears over time, and animals can sometimes break or tear components. Damage can be minimized by proper design and use of high quality components. The NSAC design has had very few failures due to damage, but occasional leaks or clogs have occurred, and are likely unavoidable. It can be noted from figure 9 that all lines are fastened and taped tightly onto the straps of the sampling halter, except for the blue line leading from the canister to the halter, where some flexibility is required. A tough but flexible polyurethane tubing was used in this case. The quick connects and other fittings are made from strong brass or stainless steel.

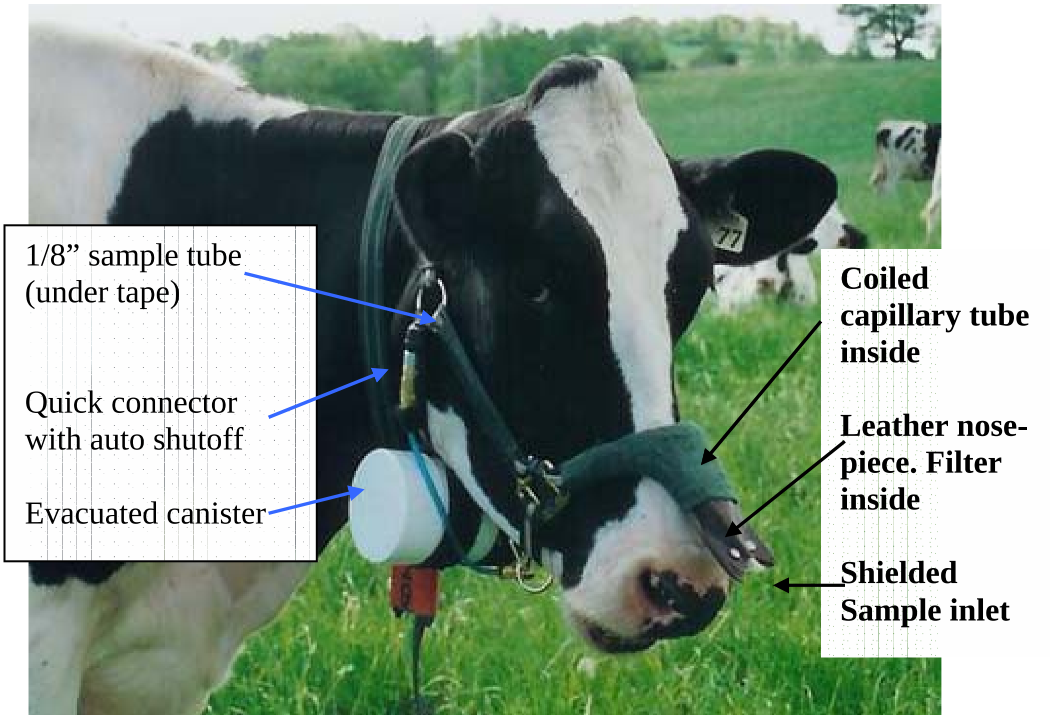

Figure 9. An example of the breath sampling apparatus used at the Nova Scotia Agricultural College, Canada.

The sampler structure, starting at the sample inlet, consists of a ¼″ or 3/8″ tube cut at an angle to shield the inlet from water. This is attached to a brass filter with an element of 60 um pore size or less, which is then connected to the capillary tube. This arrangement minimizes the opportunity for water droplets or dirt to enter the capillary tube. Even a tiny water droplet severely restricts flow. The capillary tube is coiled in the nose-piece (or it can be coiled and taped to the side of the halter if desired. This is then connected via a 1/16″ to 1/8″ compression fitting adapter to 1/8″ fluoropolymer semi-rigid tubing which connects to the quick connector at the side of the halter. This quick connect is wired tight to the halter to prevent tearing or stretching of the tubing when cows rub against posts, etc. This quick connect plugs onto the matching quick connect fitting on the canister. The quick connect on the canister needs to have an automatic shut-off valve. The canister can also be equipped with a separate shutoff valve, but this adds cost and opportunity for breakage. Stainless steel capillary tubing can be sourced from suppliers for HPLC, while high quality fittings can be sourced from Swagelok Inc. High quality fittings are essential since any leaks in the system result in complete failure of a sampling.

The canister and capillary tube must be sized so that the pressure in the canister at the end of the sampling period is about 0.5 atmospheres pressure. Equipment can be sized for 12 or 24 hr. sampling periods. Longer sampling periods are convenient, but increase the risk and seriousness of lost samples in the case of damage, leaks etc. Twenty four hour sampling can be obtained using a canister of 1.2 liters drawing air through a capillary tube of 0.004" id x 1.2M .

The equipment needed for method deployment includes permeation tubes, sampling halters and canisters, a high vacuum pump (capable of routinely reaching <0.1torr), a high vacuum gauge (electronic or mercury based "McLeod gauge", a vacuum/pressure gauge (preferably reading absolute pressure reading about 0-2atm), high purity compressed dry nitrogen, a gas regulator (capable of 0-20 psi delivery), and a properly equipped gas chromatograph.

An example of deployment protocol is as follows:

1. Evacuate canisters to <0.1 torr, and mount to halters, but do not connect the fittings.
2. Connect the fitting, and immediately place the halter on the cow.
3. After the specified sampling period, remove the halter, and disconnect the canister. (Usually it is immediately replaced by another halter/canister for the next sampling period.)
4. Remove the canister from the halter, and record the canister pressure.
5. Fill the canister to about 1.2 ATM pressure using dry N. Record this pressure, so that the dilution can be calculated.
6. Store samples for analysis within 2 days for CH_4 and SF_6. (CO_2 can also be analyzed.
7. At analysis, plug canisters directly onto a line that feeds a sample loop on the GC. (This requires equipping the GC line with a quick connect fitting.)
8. Calculate GC results and calculate emission rates.
9. For every deployment for a group of cows, at least 2 background samples need to be collected in order to

establish background concentrations of methane. This can be accomplished by placing a sampling halter/canister in the general vicinity of the cow herd, where it collects background air.

The analysis of gasses by gas chromatography requires a flame ionization detector for methane and an electron capture detector for SF_6. Methane separates well on a variety of porous polymer (e.g. *Hayesep or Poropak*) packed columns (Hayesep T, 1/8″ x 1m works well), while SF_6 may be separated on Hayesep QS, or Molecular Sieve 5 angstrom, 1/8″: x 2 M in either case. Pure N_2 carrier gas is used for SF_6, while helium is preferred for CH_4. The molecular sieve provides sharper peaks than Hayesep for SF_6, but the Molecular sieve will retain water under operational conditions, and needs to be conditioned at higher temperatures (>110C) daily to drive out moisture. Use of a machine equipped with backflush columns largely eliminates moisture and contamination issues, but causes slight broadening of peaks. Without backflush, water comes off a 2 M Hayesep after about 10 minutes, while SF_6 comes off in about 2 minutes. This necessitates longer run times when backflush is not used. Hence, run times can vary from about 2.5 minutes to about 12 minutes, depending on equipment configuration. Column oven conditions may range from 50 to 80 C isothermal. Ideally, the GC will be equipped with 2 sample loops and valves so that loops can be filled at the same time and run concurrently on 2 channels. To allow direct loading of samples on the GC, the line feeding the sample loop(s) must be equipped with a quick connect fitting corresponding to the collection canisters.

Typical concentrations of diluted samples range from 1 to 100 ppm methane, and 20 to 500 ppt (parts per trillion) SF_6 (v/v). Three standards reflecting this range of concentrations should be run to create a standard curve, and then the middle standard run every 10th sample or so. Because of the very low SF_6 concentrations, the samples may need to be run in triplicate to gain precision on that analysis. Using Hayesep columns with backflush, triplicate samples are needed for precise analysis of any sample containing less than 50 ppt SF_6. Methane can be analyzed precisely at all concentrations encountered in this type of work.

Calculating gas fluxes is straightforward once quantities are converted to the correct units:

g CH_4/d = SF_6 emission rate (L/h) * (ppm CH_4 sample/df - ppm CH_4 background)/df) / (ppm SF_6/df) * 24 h/d * 16 g CH_4 / mol CH_4 * 1 mol / 24L/mol., where df is the dilution factor of samples or background samples. A table of data with sequential calculations is shown in table 4. The 4 columns of data demonstrate how changes in the basic data on methane or SF_6 concentrations, or permeation tube emission rates, affects results.

Table 4: Example data and calculations using the SF_6 tracer technique.

Line	parameter	S1	S2	S3	S3
a	Permeation tube emission rate, L/hr	0.000020	0.000020	0.000020	0.000024
b	Sample Pressure after sampling, psi abs.	7.4	7.4	7.4	7.4
c	Sample pressure after dilution, psi absolute	19.5	19.5	19.5	19.5
d	Sample dilution factor (c/b)	2.6351	2.6351	2.6351	2.6351
e	Sample ppm methane	56.1	74	56.1	56.1
f	sample ppb SF_6	57.7	57.7	69.5	57.7
g	sample ppm SF_6 (f * 100000)	5.77E-05	5.77E-05	6.95E-05	5.77E-05
h	background pressure after sampling, psi abs	7.9	7.9	7.9	7.9
i	background pressure after dilution, psi abs.	19.5	19.5	19.5	19.5
j	background dilution factor (i/h)	2.4684	2.4684	2.4684	2.4684
k	background ppm CH_4	1.9	1.9	1.9	1.9
l	mean atmospheric pressure, kPa	100	100	100	100
m	mean temperature, C	25	25	25	25
n	molar gas volume at STP, L	22.414	22.414	22.414	22.414
o	molar gas volume at typical conditions, liters (n*(273+m)/277 * 101.3kPa/l)	24.427	24.427	24.427	24.427
p	molecular mass of methane, g	16	16	16	16
q	gas density at typical conditions, g/L (p/o)	0.655	0.655	0.655	0.655
r	sample methane concentration (e*d)	147.83	195.00	147.83	147.83
s	background methane concentration (k*j)	4.690	4.690	4.690	4.690
t	sample SF_6 concentration (g*d)	1.52E-04	1.52E-04	1.83E-04	1.52E-04
u	corrected sample methane concentration (r-s)	143.14	190.31	143.14	143.14
v	ratio, CH_4/ SF_6 (u/t)	9.41E+05	1.25E+06	7.82E+05	9.41E+05
w	emission rate of CH_4, L/hr (a*v)	18.83	25.03	15.63	22.59
x	emission rate, g/h (w*q)	12.33	16.40	10.24	14.80
y	emission rate, g/d (x*24)	296.0	393.5	245.7	355.2

C. Other methods for methane monitoring in livestock

The only proven methods for methane monitoring from individual animals are the open circuit chamber and hood methods, and the SF_6 tracer technique. Other methods apply to groups of animals. These will be discussed only briefly.

An existing barn can be converted into a whole barn chamber if the barn is entirely enclosed by walls and roof, and uses fan forced ventilation. Airflows in the barn are controlled so that air enters the facility at known locations and exits entirely at one location. The barn then becomes like a large open circuit chamber, and methane emission by a herd can be estimated using the same principles that are applied to single cow chambers or hoods. This method may employ a tracer dilution approach to better establish airflows, using SF_6 tracer. (Jackson et al., 1993).

Kaharabata and Schepp (2000) report an open air sampling method using SF_6 tracer that allows determination of methane emissions from barns or open lots by downwind sampling. The dilution of the tracer is used to establish the methane emissions. These systems demand strategically located sampling points, and need to be uniquely designed for each location. It is also very challenging to establish sufficient sampling points and wind monitoring to obtain quality results under all wind and weather conditions.

Other more elaborate methods that have been employed include large greenhouse type chambers used over grazing sheep, mass balance methods based on upwind and downwind air sampling around paddocks, and open atmosphere mass gradient methods using very costly wind measurement devices (sonic anemometers) and fast response lasers. The latter systems require particular site and weather conditions to meet all assumptions of the models used to assess methane emissions. For large scale assessments over livestock producing regions, at scales > $1km^2$, aircraft based methods based on atmospheric gradients in gas concentrations are useful, but very costly for flight time and instrumentation. All open air methods require extensive micrometeorological expertise, as results are based on particular models of gas diffusion and convection, and usually employ complex and costly instrumentation.

D. Methods of monitoring N_2O emissions from soils.

N_2O emission can be monitored by a number of methods, ranging from quite labor intensive small chamber methods with low equipment cost, to more automated but highly costly micrometeorological or automated chamber methods. Static chambers are the standard for monitoring of N_2O, and the only practical approach for comparing a number of treatments statistically.

Static chambers consist of a base ring that is permanently placed into the soil. A bottle-cap shaped cover is then placed over the ring for up to 1 hour. A closed-cell foam seal is placed between the cover and base. Examples of 60 cm diameter chambers used at the NSAC dairy pastures are shown in figure 10. Gas samples are taken before covering and 3-4 times during deployment, and samples are analyzed for N_2O. N_2O emission for that deployment is calculated based as the slope of the increase in N_2O concentration, multiplied by the chamber volume, divided by the chamber height. The covers are applied and measurements taken once every 1 to 7 days - more frequently after excrements are applied and after rainfall (when emissions are more active), and less frequently after prolonged dry periods. Between measurements, the covers are removed and the crop is left to grow and be harvested as per normal. Measurements should continue periodically for about 1 year, and the total N_2O emission is estimated by integrating measurements over the year.

Figure 10: 60 cm chamber base rings and covers at the NSAC dairy pasture.

Static chambers are a simple concept, but a considerable literature has accumulated as to proper design and deployment (E.g., Rayment, 2000, Hutchinson and Livingstone, 2001). In summary:

- 2 piece chambers are preferred to older 1 piece designs in order to minimize soil disturbance.
- Chambers must be equipped with septa or sampling valves for easy gas sampling.
- Volume of samples must be small relative to chamber volume to avoid significant air exchange due to sampling. Sample volume should not represent more than 2% of chamber volume.
- Chambers must be well sealed at the interface between base and cover. The base must be inserted sufficiently deeply in soil to avoid leaks under the chamber base ring. Usually 10 cm deep is adequate, except in very coarse soils.
- Chambers must be insulated to maintain near steady temperature during deployment. Excessive temperature changes affect the gas exchange process, and also may abnormally affect plant growth.
- Chambers must be vented using a specially sized vent tube that allows normal fluctuations in atmospheric pressure to be transmitted inside the chamber while preventing diffusion of gas out the vent. A vent tube consists of a long tube connecting the outside atmosphere tom the chamber interior. Formulae for sizing vent tubes are found in Hutchinson and Mosier (1981).
- The exterior outlet a vent tube should be pointing downward near the ground to avoid excessive wind passing over the end of the vent, as this can generate a small suction by the “Venturi effect”, leading to higher than accurate N_2O concentrations in the chamber.
- Deployment time is usually less than 1 hour. Deployment should avoid accumulation of high N_2O concentrations in the chambers, as this increases tendency of leakage of N_2O from the chamber, and decreases the diffusion rate of N_2O from the soil to the chamber, leading to non-

linear accumulation patterns. Shorter deployments can be used at times of high emissions, and slightly longer deployments when emissions are lower.

- At least 3, and preferably 4 or 5 samples should be taken in sequence throughout each deployment. This improves accuracy of the flux estimate and will make any non-linear accumulation patterns readily apparent.
- For GC analysis, 20 ml samples can be injected into evacuated 12 ml screw topped exetainers vials (Labco Ltd., UK) with thin Teflon/silicon septa added in addition to the original butyl rubber septa. The second septum increases the lifespan of gas storage. A few grains of magnesium perchlorate added to vials are recommended to desiccate the sample. This avoids the possibility of condensation containing dissolved N_2O.
- Air samples should be analyzed as soon as possible after sampling, preferably within a few days. In all cases, 2-3 samples of a standard gas mix should be injected into evacuated vials of the same type used for the samples, and stored along with the samples, to be used to make correction for any gas loss. Using this approach, it is possible to store vials of gas for up to 3 months – but usually there is some loss of samples due to slightly imperfect sealing of some vials. This is exacerbated by long storage times.
- Air samples are usually analyzed by Gas chromatography. N_2O separates well on a number of porous polymer columns (*Hayesep Q* or *Poropak*), and is detected on an electron capture detector. The carrier gas usually consists of 10% methane in Argon, as the differential in background to sample signal is much improved relative to N_2 carrier gas. As an alternative, FTIR equipped with a multi-path gas cell and chemometric software can give excellent precision while doing simultaneous analysis of several components, but the expertise and technology is usually less widely available or automated, and somewhat larger samples are required than for GC, demanding that only large chambers are used, or that corrections are made for air exchange during sampling. Calibration procedures for FTIR may be more complex than IR because of overlapping infrared absorbances that can only be resolved by

chemometrics (multivariate statistical analysis applied to IR spectrographs and similar applications.) For IR analysis, desiccating the sample improves precision by removing the many heavy absorbance bands associated with water.

E. Methods of monitoring GHG emissions from manures.

Simple chamber methods, similar to soil chambers, can be used to monitor gas emissions from solid manure heaps. On liquid manure pits, floating steady state (constant airflow) chambers have been employed, as well as a suit of micrometeorological methods using very costly equipment. Simple chamber methods provide reasonable accuracy as a first approach.

F. Modeling techniques

Modeling has been applied to every aspect of GHG emissions from livestock systems. Benchaar et al. (1998) review the effectiveness of a selection or empirical and mechanistic models of ruminal methane production. They observed that the mechanistic models have superior predictive capacity. However, the mechanistic models require detailed animal and feed information, and applicability to livestock systems other than intensively fed Holstein cattle are not well established. The models of IPCC (1996) and IPCC (2001) offer a rough approximation of emissions based on a broad database for use in national inventories, and offer a choice of the simple tier I or more detailed tier II methodologies, according to the level of feed and animal information available. The IPCC also recognizes alternate models when supported by sufficient data for a Country.

Modeling of N_2O emissions from soils has received much attention, but has proven very challenging in light of the extreme variability. Prominent examples include models described by Li and Frolking (1992) and Parton et al. (1997). These models are typically very complex, and require involvement of advanced modelers. They often require some re-calibration for application in regions where they were not previously applied. IPCC (1996) methodologies are more practical and may be nearly as accurate for estimates over a wider scale.

Life cycle assessment (LCA) models are very useful for evaluation overall system GHG emissions. These models consist of empirical modeling protocols that assess the environmental impacts of a product or process. The LCA approach accounts for not only direct impacts, but the impacts generated by provision of the necessary resources that run the process, for the entire life cycle of the process or product. Existing LCA models account for GHG emissions along with other impacts. For example, for a farm using fertilizer, the LCA examines the energy consumption and pollution used in manufacturing the fertilizer, and adds this to the total impact of growing the crop. While developed for industrial products and processes, it is increasingly being applied to agricultural systems (E.g. Casey and Holden, 2005, Haas et al., 2001, Cederberg and Mattson, 2000). The IPCC (1996) methodologies do not tie emissions due to energy use uniquely to the agricultural sector, and are hence less useful for evaluating the overall impact of the livestock system.

Some modeling of the system is important to lend context to the study of specific emissions within the system from the various sources. This is recommended for examination of GHG emissions from livestock systems in South Asia, to examine the relative impact of the different sources, and particularly to incorporate estimates of energy use. This may impact directions for development and avoid mimicking the high energy input systems used in the Western world that have yielded some short term success, but cannot be sustained. Ideal development will increase productivity and efficiency with minimum increases in costs and inputs, such that the system is sustainable. A life cycle systems analysis approach to GHGs from livestock systems will help meet this goal.

Conclusions

Over the past 2 decades, new methods for monitoring GHG emissions from agricultural systems have proliferated. However, simple tried and true methods remain the basis for most measurements because they can be executed within limited project budgets.

Methane constitutes the most prominent GHG emission from ruminant livestock systems. For measurements on stall fed livestock, open circuit hoods are recommended as the most accurate system within limited budgets. The SF_6 method is recommended if grazing livestock are to be monitored, but is a second choice for stall fed livestock. Developing capacity in both these methods is desirable, but the method of choice will depend on the management systems to which measurements are applied.

Monitoring N_2O is relevant to livestock systems, as N_2O is generated from soils used to grow feedstuffs, and is generated when manure is applied to fields, and it is affected by climatic conditions. The classic static chamber remains the basis of most measurements because it is adequately accurate, cost effective within limited budgets, and does not require electrical supply, mechanical devices, or instrumentation at the field. Static chamber methods are highly recommended for small scale monitoring where some treatment and site effects are expected.

Simple chamber methods are the most practical means of monitoring CH_4 and N_2O emissions from solid manure heaps, and may be recommended for most applications in South Asia.

Modeling is useful adjunct to field studies as a means of giving context to the results, increasing the useful information that can be generated, and estimating indirect emissions. System models based on a life cycle approach enhance the value of the research in working toward improved national GHG inventories and, potentially, GHG credits as improved technologies are identified and applied.

The importance of developing a stronger basis of expertise and infrastructure for GHG monitoring in South Asia cannot be overemphasized. The data generated to date is quite limited and reflects a lack of investment. Funding agencies should be encouraged to invest more heavily in this neglected research field.

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Presented at Impact of global change on the availability of forage and performance of livestock in South Asia, December 15, 16, 2005, Lahore, Pakistan

Sustainable development of livestock production system and global changes

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Introduction

Evolution of livestock production systems is a function of agro-ecological conditions, human population density, cultural norms, availability and use of natural resources and marketing. In fact there are several natural (physical and biological) and socio-economic (endogenous and exogenous) factors that determine a farming system. To understand the dynamics of the farming systems, at the minimum, an in intuitive knowledge of interacting factor is essential. Due to great variation across the regions in the above factors, there has been many classification of livestock production systems. Nestel (1984) classified the livestock systems on regional basis. Wilson (1995) used farming system approach to classify crop-animal system. Seré and Steinfeld (1996) used the agro-ecological zones approach and broadly classified livestock system in to three groups; (i) Industrial or landless system (ii) mixed crop-livestock system (iii) grassland-based, pastoralism and ranching. Livestock systems compete with other agricultural systems for natural resources such as land and water. In order to sustain a livestock production system, it should be complementary with minimum competition in using the available resources and less damaging to the environment. Sustainable development is thus a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional changes are all in harmony or equilibrium and enhance both the current need and future potential to meet the human needs (Willem, 1990). Generally, natural resources are shrinking at a great speed and at the same time there is a rising demand for food by explosive increase in human population. Sustainability of any system that depend on natural resource utilization such as livestock systems is therefore is a major challenge today for those involved in the development processes. It is much easier to produce today's needs at the expense of the environment than in a sustainable way, in many cases not easier only but the sustainable option hardly even exists. For example in smallholders system with the meager resource base, the farmer does not have means at his disposal to obtain a minimum level of income and at the same time conserve the sources of his income. Most of his energy is spent for the former and little is left for the later. This would mean that farmers need assistance for external inputs to supplement the resource base. But to pay for the inputs he must produce surplus. In the commercial or industrial livestock systems, high production from animals is associated with large resource use and production of more biological waste that may be damaging environment. Intensification of livestock sector has created disconnection between the location of local land and feed resources and location of animal production units resulting in imports of inputs. Since intensive livestock production systems are disconnected from land it create major geographical imbalance (Slengenbergh et al. 2003)

South Asia including Pakistan is densely populated with very limited land resources per person depending on agriculture. Much of the land area is arid or semi arid and considerable proportion of crop land is also irrigated. Thus most of the livestock production system is of mixed farming system, either irrigated or rainfed. South Asia together with East and South East Asian countries have the world largest agricultural population of about 1800 million and at the same time due to limited agricultural land have the minimum average land per agriculture worker (<2 ha Vs. 33 ha/worker in Industrialized countries). Thus agricultural land will continue limiting factor in sustainable farming and increasing land productivity will be a key concern to both food security and to reduce poverty in Asian countries. This shall require increasing grains for human and feed for animals in a combined way per unit of land. The livestock share to agriculture production is 32% in Asian countries as against 54% share from industrialized countries. This is mainly due to large population of livestock with accelerated growth and low productivity. Decreasing the number of unproductive or less productive animals with improved feed resources, better management and health cover will add to the sustainability of livestock system especially of rural smallholding.

This paper describe features of major livestock production systems in South Asia with a focus on situation in Pakistan and attempt to identify various constraints and make suggestions for sustainability of the farming systems. Two most important farming systems; landless/ urban, peri-urban and mixed crop-livestock farming that mainly contribute to both milk and meat supply and play vital role in livelihood improvement , will be discussed.

1. Landless Livestock Production System

Sere and Steinfled (1996) defined landless systems as those where less than 10 percent dry matter consumed is produced in the farm where the animals are located and where annual average stocking rates are above 10 livestock units per hectare of agricultural land. The author further distinguished landless monogastrics and landless ruminants systems. More recently, Devendra et al (2005) considered the above threshold of 10 livestock units per hectare as too rigid as these exclude landless livestock keepers in rural areas. In South Asia including Pakistan and India, a landless farmer often keep one or a few buffaloes, cows or goats. Two main types of landless livestock system are discussed below.

Rural Landless Livestock Production System

Landless rural livestock keepers include those who do not own agricultural land nor practice cultivating agricultural crops on leased land. They are generally in public or private service, business men or off farm labours. Species of livestock kept by landless farmer in rural area depend on traditional food preferences. In Pakistan and India mostly buffalo is preferred. There is also rising interest for keeping cows, especially cross bred cows by rural landless farmers because of more milk yield and high price of the offsprings. The number of animals per household is seldom higher than two. Milk is household consumed and the surplus if any is seldom sold and mostly converted to butter. The farmers prefer rearing calf for sale and also practice regular breeding of buffalo/cow because pregnant animal fetch high price when sold on completion of lactation period. Because of feed problem, dry cow is no longer kept and replaced by an advanced pregnant or newly calved cow. The animals are stall fed all the time with purchased feed and in some case grazed on marginal land. Field of standing fodder crop is purchased for daily harvesting in the season. Women at home are mainly responsible for the management of the animals.

Fluctuating supply of fodder and high cost of concentrates constrain animal production. Selling of milk at home is not liked by many of these livestock keepers. Organized marketing that collect milk from household will ensure income and increase investment for inputs to enhance animal productivity. For resource poor landless livestock keeper in rural area, rearing milking goat instead of large ruminant is more relevant because goat consume less feed (about 1-2 kg DM/day) and may produce 1-2 liter milk/day with good reproductive efficiency. Rearing of milking goats by landless farmers in many rural areas of Pakistan and other developing countries was found helpful in reducing poverty.

Urban and Peri-urban Landless Livestock Production System

In Pakistan and other Asian countries, urban and peri urban livestock farming is well established and their number has considerably increased over the last two decades in association with rapid urbanization and improved economic status of urban population. These are mostly specialized dairy farms located inside or near the big cities. This system has average stocking rate greater than 10 animals of one or two species and in some farms it may exceed 300 heads. In Pakistan and India, buffalo is a dominant species in such system. The high demand for milk in cities is the driving force for establishment of urban and peri urban dairying. The system is highly labour and capital intensive with high input cost to match out put. Animals are kept on zero grazing especially in urban location. Feed (fodder and concentrates) are purchased with well established city market. Farmers are profit motivated and fresh milk is sold directly to consumers, middle man or processing plants. Market opportunities through involvement of strong private participation have increased the intensity of urban and peri urban dairying. A number of elite and civil servants in addition to poor are increasingly involved in urban livestock farming.

Because of the limited space and high cost of feed and management, dry animals are never retained on the farm and valuable buffaloes when get dry are disposed for slaughtering at a price nearly half of that purchased. As a traditional practice, breeding of the buffaloes after calving is either delayed or never bred due to fear of milk reduction or quick drying. Similarly, calves with in first few days after birth are also disposed and sold to butchers.

Issues

Intensification of urban and peri urban livestock farms has created several problems of environment and public health concern in the cities. Space problem is on peak in many big cities of Pakistan due to rapid urbanization. Associated with livestock farms in cities are nuisance (odour, noise, and manure accumulation), clogging of sewage system, traffic congestion and contamination of water sources. More severe are the transmission of several zoonotic diseases from animals to human such as tuberculosis, salmonellosis, brucellosis etc. Farmers are ignorant and also animal testing facilities against communicable diseases are absent and animals when do not respond to initial treatment therapy, are slaughtered for meat. Thus further endanger the human health.

Manure is generally dumped at the farm or on agricultural land in the vicinity. This cause contamination of underground and surface water through nitrification and denitrification of the nitrogen excreted in urine and feaces. Excretion of large quantity of nitrogen and phosphorus from the animals is associated with feeding of excessive amount of home made conventional concentrates that are imbalanced in Ca/P ratio and rich in soluble nitrogen (Habib, 2005). Considerable emission of methane also occurs from enteric fermentation and decomposition of improperly stored manure. As a result of these contaminants associated with intensive livestock farming, health problems in human living on or in vicinity of the farm are increasingly reported.

Slaughtering of dried buffaloes is causing great loss of genetic pool of valued animals and is further aggravated with disposal of calves in early age that otherwise serve as herd replacer . This has added to the vulnerability of the intensive urban, peri urban livestock production system in Pakistan and other Asian countries with similar situation.

Future Perspectives

In view of the projected rapid urbanization in Pakistan and other Asian countries, the commercial livestock production system will continue expand further and will play important role in meeting the rising demand for milk and meat. In recent years such system grew globally at twice the rate of mixed farming system and more than six times the rate of grassland based system.

The associated environmental, human health, and living problems with intensive farming in the cities has provoked public consensus for shifting these farms out of the cities to a common place " buffalo/ cattle colony" equipped with facilities for proper disposal of manure and animal health institution for producing safe food.

Development of low cost feed packages that minimize nutrients losses and emission of greenhouse gases from animals will add to sustainability of the system. As the agricultural land is shrinking with the expansion of cities, fodder supply will suffer most in the future. Technology that ensure use of alternate untapped local feed resources will evolve with the passage of time. The increasing involvement of elite and educated persons in commercial livestock farming will make the acceptance of technological innovations easy for development of the system.

Provision of on-farm breeding facilities or establishment of breeding centers for recycling of dry buffaloes/cows is important for sustainability of the urban, peri urban livestock production system. Equally important is the saving of calves through rearing for fattening and herd replacement. Establishment of modern abattoir linked with these farms for supply of animals will encourage calf rearing as a source of income that will further add to diversification of the farming system.

Evidence show that world oil production has peaked or will soon be so. The high oil prices have seriously affected the economic development all over the world. The use of alternate energy sources such as biogas has high relevancy to intensive livestock system and can effectively overcome the energy crises at farm level. This has been successfully demonstrated by intensive animal farming in several developing countries and can be used as a model.

2. Mixed Crop - Livestock Production System

Mixed farming where crop and livestock are integrated form the backbone of the smallholder agriculture throughout the Asia and developing countries in other regions. In global term this system provides 50% output of meat and share 90% to the milk supply. About 57% of the 678 million poor livestock keepers are engaged in crop-based livestock system (Devendra et al. 2005). In South Asia, 95 percent of the total population of large and small ruminants is reared under this system dominated in both irrigated and non-irrigated areas and significantly contribute to the livelihood of the resource poor farmers. Mixed crop-livestock system is associated with marked complementary in the use of local resources with strong interdependence of other relevant sectors. However, these interactions have not yet fully exploited to meet the growing challenges in food security, environment and farm economics for sustainability of the system. Unlike past, globally the discussion is more empirical than philosophical on the socio-economic aspects of the mixed system. However, in Pakistan such modified approach is yet to be seen and the system is often underestimated. Some of the important features of the mixed crop-livestock production system are given below;

- Low capital input and less profit oriented
- Low level of economic efficiency and living on the threshold between subsistence and poverty
- Higher dependency on farm produced crop-based feed resources and natural common property resources
- Labour intensive with dominant share of women in livestock management
- Keep large number of livestock of multiple species (cow, buffalo, sheep, goat and poultry)
- Animal productivity is low and tailored to meet the requirements of household.
- Lack of organized marketing on local level for the animals and animal products
- Farmers are less informed of new technologies, are less innovative and strict to traditional farm practices.

Examples of different types of mixed crop-livestock farming in Asian region outlined by Devendra et al. (2005) are given below;

i. Combining livestock with annual or perrineal crops. In these systems livestock mainly graze native grasses and weeds on communal land and fallow land. Crop residues and byproducts of main feed constitute most of the feed for stall feeding with intensive cropping

   Rice/wheat/cattle/buffaloes/sheep/goats in Pakistan and India
   Maize/wheat/cattle/buffaloes/sheep/goats in Pakistan and India
   Rice/goats/ducks/fish in Indonesia
   Rice/buffaloes/pigs/ducks/fish in Philippines
   Rice/vegetable/pigs/ducks/fish in Thailand

ii. Combining livestock with integrated perrineal tree crop annual system;

   Rubber plantation/sheep in Indonesia
   Oil palm/cattle in Malaysia and Columbia
   Coconut/sheep/goat in Philippines
   Coconut/fruit/cattle/goat in Sri Lanka
   Multipurpose trees (fodder trees)/cattle/buffaloes/goats/sheep in Pakistan and India

Issues

The problems of mixed farming system are different in irrigated, arid and hilly areas. But these are common with respect to efficiency of resource utilization. Also the crop-animal interactions are almost similar in all mixed farming systems but the extent and implication vary in different agro-ecological zones. Existing land utilization pattern associated with high population pressure do not spare more cultivable land for fodder cultivation. This together with sub optimum fodder yield per unit of land with the use of unimproved seeds and traditional agronomic practices has led to fodder inadequacy. The quality of grazing land that is mostly of common property source is progressively deteriorating and has seriously affected by the recurrent droughts in the near past. As a result, ruminant livestock mainly thrive on crop residues for most part of the year.

Farmers of mixed system often invest their saving to increase the animal her size. Household with more persons often prefer increase animal number than those with small household members. One reason of keeping more number of animal is that because of high risk of animal diseases and secondly that because of unreliable weather and other conditions, their farm fluctuate enormously from one year to year. Therefore, part of the income made in good years is saved in the form easily cashable asset “liquid asset” so that at bad time it can be used to buy essential items for the family. Banking services are always not well developed in rural area and investment in livestock is the next alternative.

In mixed farming, keeping animals of relevant breed is very important. The desire for high milk production has changed the farmers preference for keeping cross bred cows. This has not always yielded expected results rather in most cases has caused negative impact. In irrigated areas where feed and fodder situation and institutional artificial insemination services are better, cross breeding of local cow with exotic such as Holstein Friesian is successful. In arid and hilly areas animals are mostly grazed and feed inadequacy is a common problem. There the cross bred cows and other high input breeds, that require good feeding and management is not relevant. Experience has shown that under stress conditions cross bred cows suffer more than the indigenous breed. Not only production is reduced but the high input breeds suffer from several reproductive and health problems causing great economic loss to farmers. Up-gradation of indigenous breeds through selective breeding may be the choice strategy in mixed farming system of arid areas.

Past research on mixed crop-livestock system in Pakistan and other Asian countries has not addressed the issues of integrated system judiciously. Crop scientists and animal scientists have been working in isolation with no involvement of social scientists. Such isolated approaches has no doubt generated data for the purpose of publication but has not benefited the system. Agricultural education and training in Pakistan put more emphasis on specialization than on integration. Institutions have separate focus on crop and animal production at all levels (extensionists, researchers and decision makers), and the two groups ignore each other and struggle separately for power and budgets. They develop separate projects instead of cooperating with each other and exploiting the benefits of integration.

Future Perspectives

The consumption of milk and meat in rural areas is increasing due to change in socio economic status. Land fragmentation has been caused by rapid growth in human population. Therefore, farming system will need to be more efficient. Devendra et al (2005) speculated that crop-livestock system will see important growth and will be dominant system in Asia and will be a main avenue for intensification and specialization in food production. According to Thornton et al. (2002), the area of mixed farming system in close proximity to landless system could change to the latter by 2050 due to increased crop-animal intensification, through spatial integration, increased market integration, increased income diversification and greater opportunities for off farm income generation. However, Devendra et al. (2005) showed their concern that this shift is yet to be seen and will be constrained by available feed resources, high capital investment and strong private sector partnership.

In the mixed crop-livestock system, production enhancement in livestock is achieved through increasing crop-based feed supply and this with the limited crop land can be obtained through cultivation of dual crops and or integrating fodder crops with grain crops. The possibility of integrating fodder production with annual crops through combination of traditional and improved practices has been demonstrated in several developing countries through companion, alley, relay and related cropping systems (Nitis, 1999). For example in the Northern Areas of Pakistan with limited land holdings, companion/intercropping cereals with fodder was successfully implemented on farmer fields (FAO, 2002). The Three Strata Forage System (TFST) in Indonesia showed that forage production was increased, attracted high stocking rate with annual weight gain of 375 kg Vs 122 kg/ha and resulted in 57% less soil erosion and 31% more income and ensured 64% self sufficiency in household fuel wood requirements (Nitis, 1999). Development of dual purpose crops such as dual purpose sorghum and groundnut in India has increased drymatter digestibility of the plant by 10-15% with an increase in feed consumption and improved milk yield by cow and an increase of 25-29% in net return of the farmer. In Africa attack of stem borers and striga in maize crop was controlled by cultivating Napier grass or Desmodium around the field that increased both maize yield and fodder production and also improved soil fertility. These examples demonstrate that how research on crop diseases can benefit livestock production in the mixed crop-livestock system. Genotype selection of cereals that combine both high grain yield and better quality straw as animal feed is another approach that benefits livestock. Habib et al. (1995) screened 15 local cultivars of wheat in Pakistan and identified varieties that resulted in high grain yield and straw with high dry matter digestibility. The authors explained that selection for better quality straw exclude the need for expensive and labour intensive urea treatment of straw.

Studies on nutrient management among soil, crop and animals will help devising management strategies that employ animals to collect, concentrate & convert nutrients leading to better soil, human & animal nutrition. Similarly management of manure shall be required to minimize nutrient losses and use for generation of energy. Due to high prices of oil, promotion of biogas and restoration animal draught power for agriculture will considerably contribute to economic of the integrated system.

The above discussion emphasize that the crop-livestock system should be looked as a one integrated system to enhance the output. The importance of marketing system need not be ignored. Effective marketing systems that ensure economic returns to farmers encourage inputs for productivity enhancement on sustainable basis in both crops and livestock. In future designing and implementation of community development projects must foresee agriculture & livestock as strongly interlinked integrated systems – in fact just one system, especially in smallholder farming.

Conclusions

Asian livestock production systems will continue to evolve. The commercial urban/peri urban dairy production system will continue expand to capitalize on the well established marketing system and the increasing demand for milk and meat products. The integrated crop-livestock system will also continue to be the main system in rural areas with enormous potential for improving livelihood of resource poor farmers and in future this integrated system will get more intensive, diversified and specialized. However, the future efforts will require understanding the implication of crop-livestock system holistically with inclusion of socio-economic issues. Multidisciplinary approach with joint working of the crop, animal and social scientists shall be required the future research and development programs.

As the demographic pressure is increasing rapidly, new priorities are emerging such as food security, sustainable management of resources, environment safety and use of alternative energy sources. This emphasizes integration within production systems.

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Interactions between greenhouse gas emissions from dairy livestock, climate change, and feed quality.

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There are many ways to produce a litre of milk. Evolution in dairy production systems over the last century has occurred largely without consideration of total environmental impact. Under current economic conditions, intensive, confinement dairy farm systems use fossil fuel to support high milk yields per cow. This type of system is rapidly gaining popularity in the Canadian dairy industry as well as other OECD nations. Unfortunately, this type of system has served as a model for the world. Higher efficiency of milk production is assumed in these systems, but the method of measuring efficiency has a tremendous impact on how systems are ranked. Certainly intensive systems are less efficient energetically. Worldwide the trend to intensify is associated with a shift from seasonal grazing to year- round feeding of silage in total mixed rations (TMR). The most ecological system of milk production capitalizes on natural swings in forage availability. Seasonal dairying, with lowest reliance on fossil fuel, however, has long been disallowed in Canada by its system of supply management, which evens out the annual production of milk.

Higher milk yield per cow and smaller acreages devoted to forage crops are characteristic of production systems currently evolving in the dairy industry. While the need for high quality forage is well understood, high milk yields are increasingly a result of feeding proportionately less forage, more grain.

The environmental impact of agriculture extends well beyond the visible. Greenhouse gas (GHG) is the latest pollutant to gain attention because of its potential to change global climate. Enteric methane emission from ruminants is a main point of interest. Two main options exist for nations to estimate this value (IPCC, 2000); The Tier I approach is least accurate. It bases estimates on the total number of animals in each species and class, and uses an average values for CH_4 emission. The Tier II approach uses more specific data. Livestock are enumerated by species and class, and associated production practises and feeding regimen that may affect CH_4 emission are considered. Different emission factors are used for each production sub-category using general equations improved by research where possible, and is based on digestible energy (DE) intake.

Five years ago, Canada envisioned a plan to identify agricultural sources and sinks of CO_2 equivalent to help it meet its commitment to reduce by 5% its 1996 emission of GHG by 2015. Following an initial broad investigation, which identified key areas for further study, funding was committed to specific research projects. We had identified the potential role of pasture in C sequestration. Our role was to research the environmental impact of dairying. The results presented herein have accrued from that experience.

Impact of dairy system

Emission of methane (CH_4)/L) milk from intensive systems is widely assumed to be lower than that of pasture systems. First, diets contain a higher proportion of grain and less land is needed to produce forage. Fewer high-yielding cows are needed to produce a given quantity of milk (cows/ t milk), finally, a diet containing more grain (i.e. lower forage: grain ratio), is assumed to be less methanogenic. Regarding total GHG emission, increasing intensity in the dairy industry is thought widely to be beneficial. However, pasture systems are comparatively more profitable and more sustainable. The environmental impact of a shift away from grazing in the dairy industry on total GHG emission had not been made. Furthermore, at the time of our initial research, no new data existed on CH_4 emission from grazing, lactating, dairy cows.

The major GHGs associated with milk production arise from many sources (Figure 1); therefore, measurement of total GHG emission in agriculture requires a broad systems approach. Sources of GHG include fossil fuel use, soil C sequestration, and resultant CO_2 emission, of nitrous oxide (N_2O) emission from microbial cycles in soil and manure, as well as enteric CH_4 emission from anaerobic microbes in cows and manure.

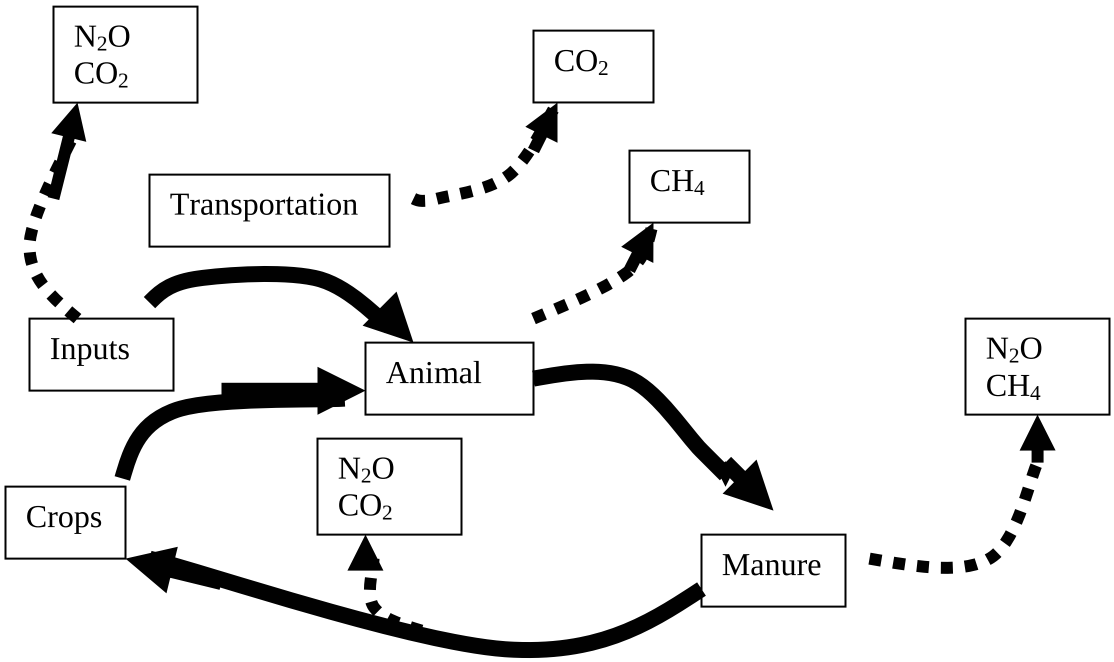

Figure 1. Points of greenhouse gas emission in a dairy system

We observed that milk yield was not much different between cows consuming diets used in pasture and confinement systems (Table 1), neither was total emission of CH_4. The differences were that cows on pasture need less grain because forage quality is higher, and CH_4/ kg milk produced from the forage (forage milk) is less on pasture, indicating a less methanogenic forage and higher forage milk production on pasture. Although we didn't measure it in this study, associated system level emissions of other GHGs would be higher for confinement systems.

Table 1. Impact of diet on cow performance and methane emission

Variable	Pasture	TMR
milk yield	23.9	24.7
forage milk	14.1	11.6
Grain, kg/ kg milk	0.28*	0.39
CH_4, g/ d	369	396
CH_4 , g/ kg milk	16.6	17.0
CH_4, g/ kg forage milk[1]	30.2*	36.6

* P<0.05.

[1] forage milk is milk produced from the forage component of the diet.

Climate change and forage quality

The effects of climate on forage, the ecological base of sustainable ruminant production may be due largely to drought, which will reduce availability of fresh forage, and higher temperatures during the growing season, which will increase lignification and reduce digestibility (Van Soest 1982). Both possibilities threaten to simultaneously increase methanogenicity of the diet and reduce milk produced per unit of intake. The net effect is a multiplication of the impact indicator used in Canada, CH_4 / L milk (Figure 2).

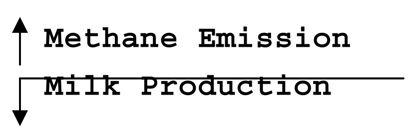

Figure 2. Negative impact of climate change on the methane indicator ratio

We examined the effect of climate on forage quality and methane emission indirectly in 2001 and 2002 comparing forages from the same field in spring when temperature is mild and precipitation plentiful, and fall, when drought is common and temperature exceed 30°C. Forage was obtained from pasture managed using a Management Intensive Grazing (MIG) strategy aimed at keeping forages at a vegetative growth stage all summer. Twenty mid-lactation Holstein cows were cycled through two respiration chambers in three crossover studies. Cows were supplemented with a concentrate (containing 75% grain in addition to protein, mineral and vitamin) twice daily at milking at the rate of 0.25% of milk yield. Methane collected from chambers was analyzed using FTIR spectroscopy equipped with a long-path gas cell and MCT detector.

As predicted, cell wall (NDF) content of forages was higher under warmer, drier conditions of fall (Table 2). Digestibility of the cell wall was also diminished in fall as indicated indirectly by higher ADF (cellulose + lignin fraction) content.

Table 2. Effect of climate on composition of pasture under managed grazing and predicted intake and energy content

	Spring	Fall
%NDF	28.55	34.10
%ADF	18.67	22.03
Intake[1], kg/ d	26	22
Energy content[2], Mcal/ kg	1.9	1.8

[1]assuming maximum intake at 1.5% of body weight (325 kg)
[2]assuming NE_1 = 1.0876- 0.0127 x ADF%

The impact of differences in fiber content shown in Table 2 were related to changes in methane emission Table 3.). Expressed as g CH_4 kg^{-1} milk, fall pasture values were higher. While there are likely other climate factors not fully reflected by the seasonal influences studied here, this study did indicate the potential for both lower animal productivity and higher methane emissions under hot, dry growing conditions.

Table 3. Effect of climate on CH_4 emission of grazing cows

	Spring	Fall
CH_4, g/ kg DMI	18.11	19.41
CH_4, g/ kg NDF	63.75	57.29

CH_4, g/ kg ADF	97.12	89.08
CH_4, g/ kg milk	10.37	14.77
CH_4, g/ kg grain	48.06	64.53

SF_6 method of methane quantification

In 2004 we employed the SF_6 method using a balanced design employing 20 cows on a commercial dairy farm to compare emissions of CH_4 from free- ranging cows grazing a MIG pasture or confined in loose housing and fed TMR. Gas was analysed using gas chromatography.

Table 4. Use of SF_6 method on grazing and confined cows

	Pasture	Confined
Milk, kg/ d	34.4	30.2
CH_4 , g/ d	442*	384
CH_4 , g/ kg milk	13.5	11.5
Estimated CO_2 equivalent/ kg milk	1.02	1.17

*Pasture was managed using Management Intensive Grazing (MIG) strategies. All cows received a Total Mixed Ration (TMR)

Average CH_4 emission was significantly higher from grazing cows compared with those in confinement, although differences were not significant per L milk (Table 4). These results conflict with our previous observation that pasture may reduce total CH_4 emission. In the previous research, chambers were used. Pasture was cut and taken to the cows and grain was fed twice daily. In this study, pasture cows were allowed to graze freely and exercise selective grazing. They were also supplemented with TMR, which contains forage as well as grain. With the higher DE content of pasture, cows on MIG pasture required 40% less concentrate (0.16 vs.

0.41 kg kg^{-1}), and this resulted in overall lower emission of GHG from pasture.

Mitigation of methane emission

While it is important to mitigate emission of methane in agriculture, only those mitigation strategies that work toward sustainable food security will result in real benefits. Before researching alternatives, some hard thinking is needed.

Reducing the number of ruminant livestock is always the first approach to mitigating emissions. Number of cows in the Canadian dairy industry has been shrinking annually, and with it, total CH_4 production/ kg milk because milk production per cow is increasing, and just enough milk is produced to meet domestic requirement. The amount of milk produced and consumed on farm is outside this system is low. However if the increase in cow yield is due to practices that themselves that increase production of other GHGs, Its benefit is suspect. In other countries where on farm consumption and local marketing are common, reducing ruminant number also affects food security to a greater degree. In contrast to its regulated dairy industry, Trade in beef is unregulated, and the GHG emission from this sector has been increasing steadily.

> A second approach to mitigation is to increase feed efficiency of ruminant animals. This is attained partly by genetic selection, partly by management and partly by improving forage quality. Unless the total number of animals is regulated, gains in GHG reduction obtained through higher efficiency could be offset by increased number of animals.

Some research has shown that legumes reduce emission through a direct impact on methanogenesis. Legumes also improve animal efficiency and productivity so there is a potential win/win in this mitigation strategy.

Additives such as certain oils both improve efficiency of animal performance and reduce methanogen population in the rumen. Boadi et al. (2004) and Moss et al. (2000) review these and other potential strategies to reduce CH_4 emission from ruminants. Undoubtedly there are other native compounds that suppresse methane emission and could be obtained cheaply.

Nitrous oxide emission

Lush pasture often contains a surfeit of rumen-degradable N that is related to higher excretion of urea in urine and could result in high N_2O emission. Emission of N_2O is perhaps of greater importance than that of CH_4, therefore, in 2003, we conducted a crossover trial to examine the effects of dietary crude protein (CP) level, 11.6 (low) vs. 20.6 (high)(dry matter basis; 72% of N estimated degradable) on enteric CH_4 emission and soil N_2O emission from urine affected patches on pasture were measured. Two respiration chambers and 10 cows were used to evaluate the impact of dietary CP level on CH_4 emission.

Urine obtained by total collection from 2 cows on each treatment was applied to grass pasture (<15% legume by botanical separation), that had received no chemical N fertilization for 8 y previously, but, at times had carried a higher legume component (25-40%). N_2O emissions were monitored using 24 vented static chambers (60 cm diameter) replicated over pasture plus or minus urine from cows fed either high or low protein diets. Chambers were deployed 2-4 times per week over the grazing season, using a protocol of 3 gas samples taken over 40 min. Samples were analyzed for N_2O by gas chromatography.

Milk yield averaged 31.3 kg d^{-1} and was not affected by diet. Similarly, CH_4 emission was not affected by treatment, averaging 383 g cow^{-1} day^{-1}, or 16.8 g CH_4 kg^{-1} milk. These effects are particularly interesting considering that cows fed the TMR consumed nearly 40% more concentrate (0.39 vs. 0.28 kg kg^{-1} milk).

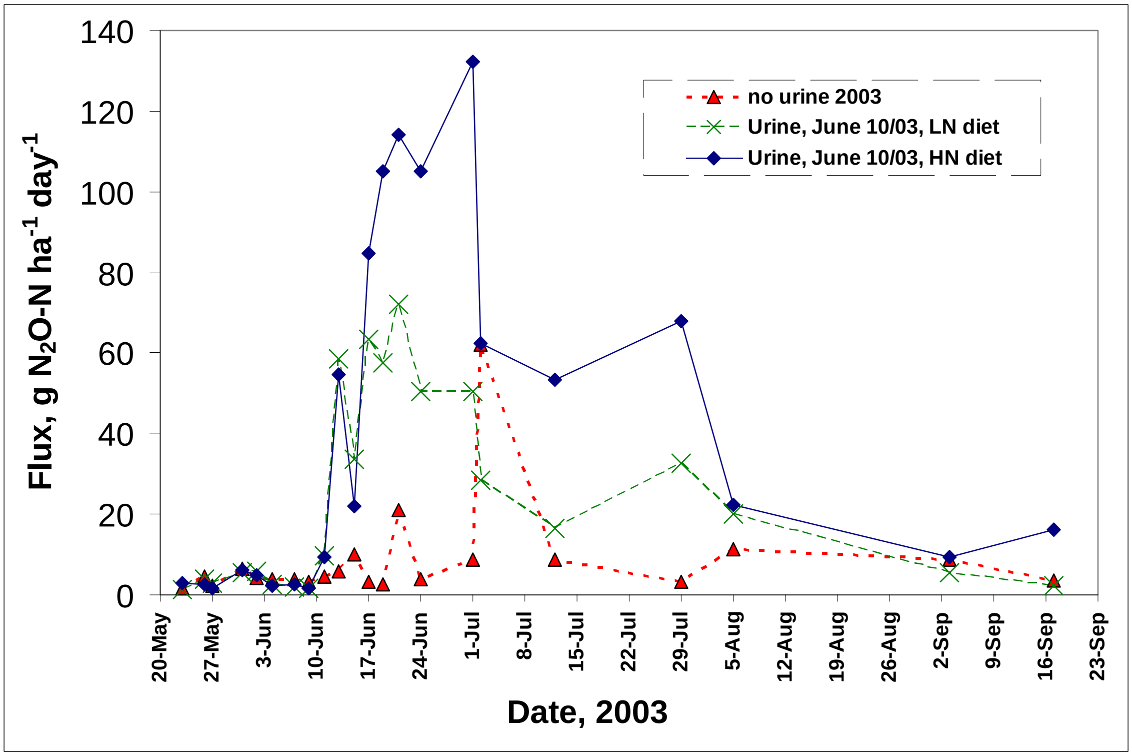

Figure 3. Effect of the dietary N level of cows on Nitrous oxide emissions

Nitrous oxide emissions are shown in Figure 3. No carry- over effect was seen from urine applied the previous summer. From 0.26 to 0.61% of urinary N was emitted as N_2O during the 3-month period following early summer application of urine from cows fed either low or high protein diets, respectively.

Aggregated over the year, N_2O from urine patches represented approximately 1 to 3% of the total GHG impact of milk production. Results suggest that N_2O emission from MIG pasture, that had received no chemical N fertilizer, makes a small contribution to total GHG emission of a dairy farm.

Lifecycle Assessment of efficiency of energy use

Based on predicted life-cycle fossil fuel use, MIG and TMR systems emitted 1.02 and 1.17 kg CO_2 equivalents kg^{-1} milk, respectively. We concluded that pasture- based milk production reduces GHG impact compared with that of high-grain confinement systems, at least in herds producing 9 to 10,000 kg milk cow^{-1}. Minimizing CH_4 emission per unit of

Table 5 shows a comparison of life cycle energy efficiency between pasture and confinement systems from previous studies. Overall it shows that while pasture systems may return more energy than they use, confinement systems use 20 to 50% more, clearly not sustainable, and clearly revealing a hidden source of CO_2 emission.

milk yield in the dairy industry is therefore a false indicator of progress towards reducing total GHG emission from the sector. Feeding more grain to achieve higher milk yield may not reduce CH_4 emission and is accompanied by higher life- cycle emissions of GHG. A better indicator of progress in the industry related to its GHG emission is likely based on unit of milk produced from forages.

Table 5. Life cycle assessment of dairy systems (MJ fossil energy in/ MJ gross food energy out, farm gate).

Country	Pasture	Intensive	Source
Denmark	0.83-1.00	1.11-1.40	Refsgaard et. al. 1998
North America	0.94	1.92-2.38	Pimentel et. al. 1983 Southwell & Rothwell, 1977, Main, 2001
Sweden	0.92	1.07	De Boer 2003
Netherlands	1.50	1.42	
Germany	0.46	1.04	
Average	0.9	1.2- 1.5	
Corn, US	0.14	0.22	Pimentel et. al. 1983

CONCLUSIONS

Benefits of reducing GHG emission in the dairy industry include the following:

- reduced environmental impact
- improved animal efficiency
- the potential for agriculture to obtain Carbon

Credits that could be sold at some point.

There is benefit in identifying best management practises that create win/ win opportunities for overall sustainability and GHG reduction both. Obtaining good estimates of GHG emissions from these systems, as well as identifying sustainable mitigation strategies and their impact on GHG emission will accrue the most benefit.

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ACKNOWLEDGEMENTS

Appreciation is extended to the following funding agencies that supported this research: Dairy Farmers of Canada, NSERC, AAFC the Climate Change Fund Initiative of Canada and the Canadian Agricultural Research Council.

Presented at Impact of global change on the availability of forage and performance of livestock in South Asia, December 15, 16, 2005, Lahore, Pakistan

Modifications / suggestions proposed in the proposal entitled " "in the light of the Scoping workshop held on 15th-16th December, 2005:

After thorough discussion on different aspects of global changes and its interactions with livestock and fodder production, a number of comments and modifications to the original proposal are suggested here:

1. This research is highly needed and timely.

In light of the international efforts to reduce greenhouse gas emissions, and the serious impact the global warming can have on livestock production in South Asia, and the heavy populations of both people and livestock in South Asia, there is a dire need to commence this research. The research effort on this subject in the India, Pakistan and Bangladesh triad has been sparse. There is a need to not only generate data, but more fundamentally to develop a stronger regional base of equipment and research expertise on this important research subject. Sufficient data may allow adjustment of national GHG inventories too.

2. The relevance of the different greenhouse gasses (GHG).

The Intergovernmental Panel on Climate Change (IPCC) estimates that CH_4 and N_2O have 21 and 310x the global warming potential (GWP) of CO_2 (IPCC, 1996). While CH_4 constitutes the dominant emission from *ruminant livestock*, N_2O is usually the largest emission from *agricultural systems overall* coming primarily from nitrification and denitrification in soils. Quality of fodder impacts both methane emissions and quantities of N excreted from livestock. Excreted N may increase N_2O emissions. Data on both N_2O and CH_4 emissions from the Indian sub-continent are lacking. The importance of CO_2 emission from agriculture is related to fossil energy use, and can be estimated using life cycle assessment.

3. Some details of experimental design of feeding trials are suggested.

The original proposal lacked detail in this aspect. Because of the scale of the funding proposed, and the need for large quantities of fodder for livestock feeding trials, fodder cannot easily be grown in replicated field plots. But, about 5 grass species, combined (+ or -) with legumes, resulting in 10 combinations are proposed. From this can be selected 3 grass fodders and 2 grass-legume combination fodders for livestock feeding trials, from among the more successful stands, according to perceived desirable traits of certain combinations. The selected fodder mix should also include one fairly standard fodder as a control. Harvest dates and management should be such as to optimize both forage quality within the constraints of the harvest systems and accepted practice. The proposed numbers are a compromise between desire for maximum information and available funding.

For the livestock feeding trials considered, blocked experimental designs such as crossovers or latin square are highly recommended. These remove the effect of variation among animals that otherwise obscure treatment effects. Latin square designs with 5 treatments and periods are suggested. This is a compromise between the desire to evaluate many treatments and the restrictions of limited funding. A minimum data set requires 4-5 days measurement on each animal per period, limiting the size of a latin square. ANCOVA (ANOVA with covariates such as animal age, parity, lactation time and feed intake) to add statistical sensitivity. Some regression and correlation techniques will also be useful to discern relationships between climatic parameters and animal performance and physiological state.

At least one forage sample per treatment-period is required, to be analyzed for ADF, NDF, and fibre degradation in the rumen. Fibre degradation using the *in sacco* method will require canulating a number of cows (preferably 3 at each site), and at least 3 fibre analysis in series of forage samples incubated in the rumen (*in sacco* methods). The fibre component of forages has a prominent effect on methane emissions, and needs to be carefully monitored, in order to better model methane emissions. Feces and urine form cows on treatment will be collected, sampled for N analysis, and applied to field plots where N_2O measurements will be conducted, as per notes under point 6. Feed intakes and production parameters (milk yield and/or weight change) will be monitored at each site. If time, money, or further funding can be acquired, these experiments can be extended across multiple species and feed sources.

4. Legumes should be included in the forage mixes.

As noted in recommendations under point 3, legumes should be included in the fodder crop mixes. Legumes have potential to sustainably boost yields through self-fertilizing with N, and usually have enhanced protein and energy content relative to grass forages. Also, flavenoids, condensed tannins, and other substances that are known to occur in significant concentrations in legumes have potential to enhance efficiency of N use, reduce parasite loads, and reduce methane emissions. Selection of grass and legume fodders and mixes should be based on potential for yield, feed quality, and desirable probiotic traits.

5. Methods of methane estimation and design of hoods.

The SF_6 tracer technique, first described by Johnson et al. (1994), has become prominent in recent experiments measuring methane from ruminant livestock. The method allows animals to be managed under normal conditions while allowing methane monitoring on individual animals. However, the SF_6 method is not well suited to stall-fed livestock.

A simple system of open circuit respiration hoods is recommended. These will provide accurate data at fairly low cost for stall fed livestock. A hood system consists of a structure that covers the cow’s head, through which air is drawn at a fixed rate and sampled for gas concentrations. Details of hood design, as provided in the workshop presentations, are provided separately for inclusion by PI in the final proposal.

The open circuit hood is an excellent base for methane monitoring capacity that can be established with limited funding. In future proposals, if adequate funding can be secured, capacity to monitor free ranging livestock using the SF_6 tracer technique should be established.

6. Recommendations on N_2O monitoring

Total global warming potential of whole livestock systems should be considered. This avoids errors of reducing methane emission while GHG emissions in other sectors of the system (feed production, manure management). Most importantly, this includes

N_2O emissions from soils, especially those fertilized with livestock wastes. While it is not feasible to do complete study in this area, some monitoring in association with methane monitoring is recommended. Similar monitoring for CH_4 and N_2O on stored manure is also recommended, as this can be incorporated at a small scale at low cost.

N_2O emission can be monitored using a number of methods, ranging from labour intensive small chamber methods with low equipment cost, to more automated but highly costly micrometeorological or automated chamber methods. The small chamber method is recommended for this proposal, because it is an effective, recognized method that can be deployed at fairly low cost. Details are provided separately.

7. Modelling should address a number of issues.

It is recommended that model analysis be used to estimate total GHG emissions from the livestock system using the internationally recognized IPCC methodologies. It would be desirable to integrate energy use estimates and the consequent CO_2 emissions, to give a complete life-cycle analysis of system GHG emissions. This will provide context to specific results of methane emissions, and their relevance in light of total emissions.

Model analysis can also bolster information on the impact of climate on fodder production and livestock health. Models should be kept a simple as possible, while incorporating key elements that describe how the systems react to the environment. Detailed data will be limited, and the level of funding does not support the staffing and time needed for in-depth modelling. Nonetheless, basic empirical models will provide context for the experiments, and allows other available data and expertise to be incorporated into the analysis.