MANAGING GREENHOUSE EMISSIONS FROM LIVESTOCK SYSTEMS

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ABSTRACT

Options for mitigation of enteric methane and other greenhouse gases from ruminant livestock systems are constrained by regional characteristics of the systems. In both developing and developed countries there are various non-greenhouse gas issues that also need to be considered when identifying effective and sustainable options for greenhouse gas mitigation, for example regional human food security and the need for poverty alleviation of farmers in developing countries. On a global basis, major cattle populations are located in grassland and mixed crop-livestock systems in developing countries. Successful global mitigation of enteric methane emissions from ruminant livestock systems can only be achieved if significant mitigation from these developing country systems is also achieved. Dramatic reductions in enteric methane gas production can be demonstrated in biological simulations on an individual animal basis. What is required, however, is that mitigation options need to be evaluated in the context of the livestock system before being promoted for adoption, because the consequences for the whole system along with the effects on emissions of nitrous oxide and carbon dioxide need to be understood. Approaches that may assist decision makers to identify options for greenhouse mitigation options from livestock systems are discussed.

CLASSES OF RUMINANT LIVESTOCK SYSTEMS

Opportunities for greenhouse gas mitigation from livestock systems through the adoption of various management interventions and technologies are often constrained by the characteristics of the system. Table 1 presents a classification of livestock production systems proposed by Sere *et al.* (1996). This classification system is based on the agro-ecological environment, level of integration of crop with livestock production and availability and type of land used for livestock production. Production intensity of a ruminant livestock system influences the sources and relative contributions of methane, nitrous oxide and carbon dioxide to total emissions from the system. For enteric methane gas from ruminant livestock, annual emission factors are influenced by bodyweight and level of productivity. Diet quality and level of feed intake are also major determinants of emission factors for different classes of livestock (Blaxter &

Clapperton 1965). Methane production (g per unit production) is generally higher for ruminant livestock in extensive grassland-based systems than in intensive systems where diets offered are typically higher quality. In contrast, methane production (g per day) is typically lower in grassland-based systems due to low levels of productivity.

Table 1. Classification of the world's livestock production systems (Sere *et al.* 1996) and indicative methane conversion factors.

Broad classes* of livestock systems	Methane conversion factor** (% gross energy intake)
Grassland based (livestock only)	6.5 – 7.5
Mixed crop-livestock, rain-fed	5.5 – 6.5
Mixed crop-livestock, irrigated	5.5 – 6.5
Industrial	3.5 – 4.5

* Within each broad class of livestock systems there are three agro-ecological sub-classes including temperate, humid/sub-humid and arid/semi-arid.

** Based on IPCC (1997) and EPA (2003) data.

Figure 1 illustrates percentages of the global non-dairy cattle population managed in grassland, mixed and landless livestock systems, and indicates that the largest non-dairy cattle populations are managed in mixed (crop-livestock) and grassland systems in developing countries. A prerequisite to achieving significant global mitigation of enteric methane emissions from non-dairy cattle sources is mitigation from mixed and grassland systems. Increased livestock production efficiency and reduced greenhouse gas production (g per unit animal production) are projected to occur in developing countries over the next decade in the absence of greenhouse gas mitigation policies, because increased efficiency will occur alongside the present trend of increased intensification of systems as greater areas of land are used for crop production. Examples of increased production efficiency and reduced methane production per unit milk production in developed countries have been demonstrated in dairy production systems over the last 20 years in the US (Environment Protection Agency 2003), Japan (Terada, 2002) and Australia (Howden & Reyenga 1999).

SOURCES OF GREENHOUSE GASES FROM LIVESTOCK SYSTEMS

Although methane emissions from livestock systems are the largest global source of methane, representing 20 to 25% of all sources of methane gas emissions in the 1990 inventory (Environment Protection Agency 1994), nitrous oxide and carbon dioxide are also produced by livestock systems. Sources of greenhouse gas from livestock systems include (i) methane from the digestive tract of cattle and livestock effluent management; (ii) nitrous oxide from agricultural soils, including nitrogen excreted in livestock faeces and urine, and nitrogen fertilizer application; (iii) carbon dioxide from agricultural soil management and forestry; and (iv) carbon dioxide from the combustion of fuels used in farm vehicles, tractors and pumps, and from fuel used to generate electricity consumed by the system (IPCC 1997).

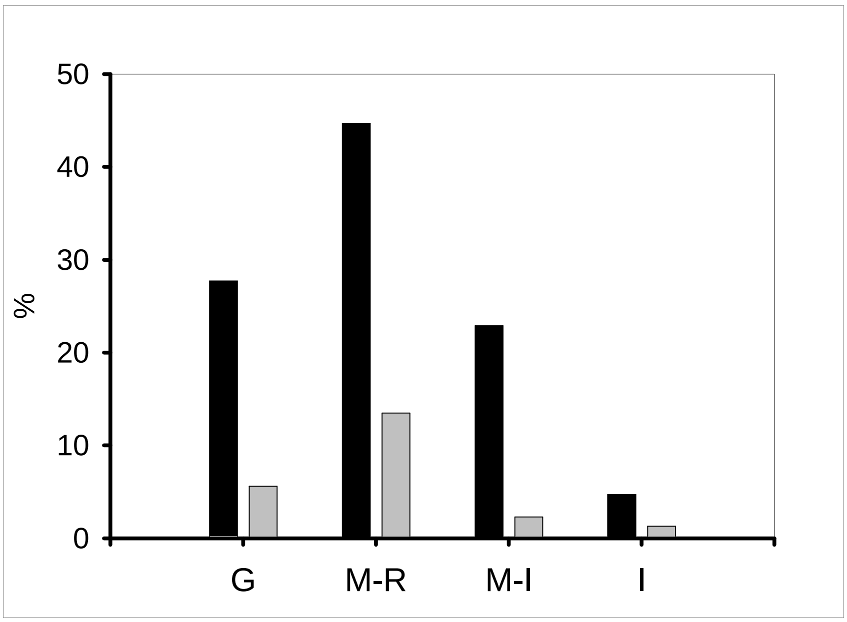

Figure 1. Proportions of the global non-dairy cattle population managed in grazing (G), Mixed (Crop-Livestock)-Rainfed (M-R), Mixed (Crop-Livestock)-Irrigated (M-I) and Industrial (I), in developing (black) and developed (grey) countries (Fernandez-Rivera *et al.*, 2001).

Greenhouse emissions from livestock systems are influenced by the degree of intensification of the system. Enteric methane emissions are presumed to be the principal greenhouse gas emitted from grassland-based based systems because there are relatively few other greenhouse gases emitted from these systems. For developing countries where land degradation and deforestation are prevalent, there are little published data available to quantify the relative contributions of all greenhouse gases (sources and sinks) for livestock systems, including the contribution made by agricultural soil management. There are published data for some livestock systems in developed countries. For example, a Californian dairy farming system with 98 milking cows, each producing 9000 kg per lactation, produces 1.2 kg CO_2-e per L milk (i.e. 1037 tonnes CO_2-e) and is comprised of 52% methane, 38% nitrous oxide and 9% carbon dioxide (Johnson *et al.* 2000).

COMMONLY USED INDICES OF GREENHOUSE GAS EMISSIONS

In the analysis of livestock populations aimed at identifying greenhouse mitigation options, comparisons are potentially required between different classes of livestock production such as industrial versus extensive, or temperate versus tropical systems. Below we list commonly used indices for greenhouse emissions from ruminant livestock systems. The choice of which index is used in a particular situation typically depends on the end use of the analysis. We have found that none of these indices alone are sufficiently comprehensive for comparing greenhouse gas emissions between different livestock systems because other regionally significant non-greenhouse issues, for example human food security and environmental sustainability, are not considered.

Per animal per unit time: This index is typically reported in kg/year by national governments and international agencies, which have responsibility to prepare inventories of greenhouse gas emissions from various sources (e.g. IPCC 1997, IPCC 1999). Values range from 30 to 70 kg per year for non-dairy cattle and 40 to 120 kg per year for dairy cattle (IPCC 1997).

Per unit of meat or milk production: These indices are commonly used by livestock producers to identify the effect of changes in livestock management. These indices do not represent the energetic efficiency of livestock, rather they report methane production rates relative to levels of animal production or human food production (i.e. meat, milk). In Australia, 0.6 to 1.3 kg methane per kg saleable beef yield is produced by tropical beef cattle (McCrabb *et al*. 1998). For Japanese dairy cows, Kurihara *et al.* (1997b) reported values ranging from 10 to 17 g methane per kg milk.

Per unit of feed intake: This index reports the amount of methane produced per unit of feed intake, and reflects the efficiency of conversion of dietary energy to animal production by reporting the proportion of digested energy lost as methane. This index is used to highlight dietary differences, but does not give any indication of methane production relative to the amount of meat or milk that an animal produces. Kurihara *et al.* (1997a) reported values of 33 - 75 g per kg digested organic matter intake for forage-based beef cattle in tropical Australia.

Per unit of Gross Domestic Product (GDP): This index is used by economists to compare between and within industry sectors (Howden & Reyenga, 1999). For Australia, Lenzen (1998) reported a national average of 0.7 kg CO_2-e per $GDP, compared to 7.7 kg CO_2-e per $GDP for thermal energy generation and 9.0 kg CO_2-e per $GDP for the Agriculture, Forestry and Fisheries sector.

Per capita: This index is typically used for comparison between countries in order to rank greenhouse gas emissions.

DIFFERENCES BETWEEN DEVELOPED AND DEVELOPING COUNTRIES

Ruminant livestock populations: Ruminant livestock populations in developing countries have been increasing at rates of 3% per year over the last 2 decades, and are projected to continue increasing until at least 2020 (Delgado *et al.* 1999). This increase is being driven by an increasing demand for meat and milk in the developing world. In contrast, ruminant livestock populations in developed countries are stable or declining (Delgado *et al.* 1999). The projected increases in ruminant livestock populations in the developing world will make an absolute reduction in enteric methane gas emissions difficult to achieve.

Evolving production systems: Along with increasing global ruminant livestock populations there are changes occurring in production efficiency, leading to reduced greenhouse gas emissions in the absence of regulating policies. In developed countries livestock production systems are relatively efficient, with only minor improvements in production efficiency possible. In developing countries, however, ruminant production systems are becoming more intensified as the area of agricultural land used for crop production expands (Fernandez *et al.* 2001), and in these populations there is potential for large-scale improvement in production efficiency. The associated dietary changes alongside this increased production intensity of livestock systems are lower methane conversion rates (Table 1) and reduced greenhouse gas emissions per unit of livestock product.

Management boundaries of livestock systems: In developed countries management decisions are typically made within distinct farm boundaries by individual farm managers. This contrasts to the situation in many developing countries where some resources including animal feed are common property of the community. In these situations grazing land is communally used and not owned by individual livestock farmers. Farmers frequently manage the cultivated land individually during the crop growing season. After grain harvest, cropping land along with at least part of the residues also becomes a common resource available to the farming community.

Reasons for keeping livestock: Livestock are kept for a variety of reasons including production of meat, milk, fibre and hide which are either sold for income or consumed by family members, land cultivation, transport (i.e. animal draft power), social status, storage of wealth and other religious or recreational reasons (International Livestock Research Institute 2002). Noteworthy is the fact that animals are kept for non-productive reason in both developing and developed countries. The purpose for which livestock are kept have a significant impact on the policy options available.

Regional and country priorities: National priorities differ between developing and developed countries. Various issues such as food security, poverty, health care, environmental management, are important considerations for poor farmers in developing countries (International Livestock Research Institute 2002). The commonly used indices for greenhouse gas emissions noted earlier do not easily accommodate such issues, however in a realistic analysis of livestock populations such issues need to be considered.

INDIVIDUAL LIVESTOCK VERSUS LIVESTOCK SYSTEMS

Enteric methane emissions are a key consideration in the process of identifying mitigation options for livestock systems because methane is the principal gas produced by the system. The Environment Protection Agency (2003) recommends the following analyses be conducted when evaluating greenhouse emissions from ruminant systems: analysis of livestock population, livestock production, feed and forage, methane emissions, other greenhouse gases and financial impact.

Table 2 reports the results of simulations of the effect of growth rate for beef cattle on maintenance energy requirements and lifetime methane production. These data indicate that when liveweight gain for an individual animal increases from 100 to 365 kg/year, maintenance energy requirement is reduced by up to 40% and lifetime methane production is reduced by up to 80%. The next step for such a potential mitigation option is to translate these differences to livestock production systems, however this is not a simple task because the management of livestock systems is often complex. For example, modifying liveweight gain will affect other components of the system, such as the number of breeding animals required to replace slaughtered animals that leave the system with other livestock (i.e. new methane generators). Clearly the challenge is to incorporate all interacting factors into analyses, including the effects on the whole system and the consequences for all greenhouse gas emissions and sinks.

Table 2. Estimated energy requirements and methane production by steers slaughtered at 550 kg liveweight (Hunter & McCrabb 1998).

Annual liveweight gain (kg)	Age at slaughter (years)	Lifetime energy requirements (MJ x 10^3)	% total energy requirements as maintenance	Lifetime methane production (kg)
100	5.3	83	80	301
200	3.5	61	76	217
300	2.5	49	68	167
365	1.5	40	48	60

CONCLUDING REMARK

An approach for decision makers to identifying options for greenhouse gas mitigation from ruminant livestock is to rank the efficiency of livestock systems on a scale between “efficient” and “inefficient”. With such information a livestock population can be analysed to identify production systems that are inefficient and associated with high greenhouse gas emissions. Based on such rankings, policies could be developed to encourage (i) the inefficient systems to be improved or (ii) a reduction in the number of livestock managed in inefficient systems. The difficulty with this approach comes during the initial stages when identification of a simple index of efficiency is required to categorize the efficiency of livestock systems. We conclude that the most appropriate approach for identifying opportunities for significant mitigation from ruminant livestock systems is to identify relatively inefficient systems through regional population analysis. Cost effective mitigation options need to be identified in analyses for different classes of livestock systems (e.g. extensive, intensive). These options should also be associated with improved energetic efficiency of livestock production, without adversely impacting on other non-greenhouse issues. A range of considerations including farmer acceptability, human food security, environmental sustainability, and sustained greenhouse gas mitigation need to be integrated into the decision making process. These issues are presently being addressed in an Environment Protection Agency project that has been established by the International Livestock Research Institute.

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