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Estimation of methane (CH_4) emission in the livestock from Costa Rica, 1990 and 1996.

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Introduction

Methane (CH_4) is a trace gas with greenhouse effect, aproximately 25 times more infrared sorbing capacity per molecule than CO_2. According to some researchers, it contributes with the 18% of the anthropogenic global warming, being only surpassed by the CO_2. Livestock activity contributes with 20% of the anthropogenic CH_4 emission. In Costa Rica, the livestock contributes with more than 80% of the methane emission.

Ruminants, as bovines, have an unique and unvalued digestive process that allow them to use a wide range of biomass rich in fiber and make it accessible for human consumption upon transforming it in milk or meat.

The CH_4 is generated largely in the fermentative digestion of feed by microbes in the rumen. However, the intake level and food characteristics, as quality, and the use of additives, have much importance in the amount of methane produced by the animal. Due to it, we can say that poor nutrition contributes to increase levels of methane emission.

In general terms, ruminants could lose 2% to 12% of the energy of the food by the CH_4 emission. Avoiding this loss, it would mean that the energy of diet could be used for growth or lactation. As a result, an increment in efficiency would benefit economically to farmers, since they would obtain better parameters of production, such as: higher percentages of calving and growth, better production of milk and healthier animals. This implies larger incomes and minor costs of production by unit of product (milk or meat). Besides, consumer would have two parallel benefits: one environmental, the reduction in the emission of a gas with greenhouse effect, and another economic, a possible decrease in prices of products of animal origin due to higher productivity of animals.

In tropical conditions, 90% of the feeding of bovine cattle is based on pastures (Pezo et al 1992) and between 80% to 85% of the energy of pastures is contained in structural carbohydrates in cellular wall constituents: cellulose, hemicellulose, pectin and lignin (Van Soest 1994). Therefore, it is of supreme importance to value the CH_4 emission based on the substratum in which microbial populations grow.

In another hand, although animals with high production have higher rates of methane emission than animals with low production, the first ones are more efficient in the use of energy, because the amount of emitted CH_4 by unit of obtained product is smaller. This means that with more efficient animals according to the use of foods, minor amount of animals is required in order to produce and satisfy the demand of products in the market.

According to the previous explanation, we can derive additional ecological benefits: the change of use of the soil (from degraded pastures to forest) and the improvement of pasture systems in soils suitable for livestock. Also, techniques, as the idea of associating grasses with legumes and silvopastoral systems, could contribute to the mitigation of the greenhouse effect through capture and retention of the carbon in the biomass and the organic matter of the soil.

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The present document contains the estimation of the CH_4 emission since 1990 up to 1996, carried out by the project "Options for the Reduction of CH_4, N_2O in the Costa Rican Agriculture".

Characterization of bovine production systems in Costa Rica.

In Costa Rica, livestock farms could be classified in three basic systems:

I. Dairy cattle
II. Beef cattle
III. Double purpose (milk and meat)

I. Dairy cattle.

This system is characterized by the use of european breeds, with high genetic potential in milk production. In this system, cows are milked without calf and with high degree of technology. Improved pastures and the employment of fertilizers prevail, rotational grazing systems, and a paddock every day are used.

Dairy cattle in Costa Rica is located in high zones with cold climates, especially in the Volcanic Central Mountain and in the Northern Huetar Region, which have a tropical humid climate less hot than other regions with life zone classified like Tropical Basal (Holdridge 1978).

Dairy cattle has achieved important importation of germoplasm from temperate countries, which have great subsidies and high fossil energy consumption for the production of cereals. Therefore, Costa Rica depends on the grain importation. Consequently, Costa Rica has efficient animals for milk production, but with genetic potential for the conversion of grain to milk, and not to transform forage to milk.

II. Beef cattle

Technology in this beef farm is low in relation with its potential. Beef cattle system presents poor parameters as: little reproduction, low weight gain, and stocking rate. This situation decreases the efficiency of the activity and it affects negatively the methane:meat ratio. In spite of this condition, beef cattle constitutes one of the activities more diffused and accepted between farmers.

This system is divided in two main subsystems: breeding and fatten. Fatten, in some cases, is subdivided in development and finishing cattle. The breed subsystem is constituted by reproducer animal, its replacement and the calves in lactation and "post-weaning" period. Its function is the production of calves for fatten and replace mature animals, especially females for sacrifice. This group presents the larger number of animals inside the national herd; although it, in the last years has decreased strongly; it is due to the increment of the local demand of meat, crisis of prices, lack of organization of the involved sectors, and little technological improvement.

The fatten subsystem begins when "post-weaning" period concludes and it finishes with the animal sold for the sacrifice. Although variations between regions and types of farmers, the objective of this subsystem is to put the animal on a nutritious regime in order to reach the sacrificed weight in the minor possible time.

On the other hand, the fact that the commercialization of animals of meat in Costa Rica be expedite and simple, it stimulates participation of a great amount of intermediaries, which opens the way to fraction more the fatten subsystem. In some cases, farmers that develop cattle are those who buy "post-weaning" calves, and

fatten them up to 300-350 Kg., and then sell them to others who take charge of them until they be finishing animals.

III. Double purpose

In Costa Rica, the double purpose system represents approximately 30% of the national herd. The main characteristic of this system is to milk with calf, to which farmers use several techniques of suckling, depending on the regional culture, size, technological level and scale of the farm. Other general characteristics of the system are: sale of calf at weaning and short lactation period with milk production to sell between 6.0 to 10.0 Kg/cow/day (Efdé et al, 1996).

The feeding is based on pastures, with continuous or alternating grazing systems. The grasses have low nutritional quality and yield. In most of the farms, during the period of lactation, cows are supplemented in order to improve the efficiency of ruminal fermentation. In general, these foods are high in soluble energy and non protein nitrogen, by-products as molasses of cane, green banana, poultry production, and forages.

These farms are located in zones far from the metropolitan area, in regions with sub-humid and humid climates. The sub-humid region have a period of scarce precipitation, and farms present a seasonal production of milk, which increases with the rains and it falls significantly in the dry period. The liveweight gain in pre-weaning period in the double purpose system is inferior to them observed for animals of the beef cattle. However, it is the production system of calves more sustainable, in economic and technician terms, and the more accepted social and culturally for the small and medium farmers of the warm and low regions from the country.

Although, we could consider that animals that compose this system have low productions of milk and low weight at weaning, upon uniting the two products, milk and meat (each component represents 50% of the total production), this system improves its indexes of efficiency.

Methodology

Different regression equations to predict methane emission in cattle were identified, especially those models that adjusted to the tropical conditions. The identified models were the proposals by Bratzler and Forbes (1940), Blaxter and Clapperton (1965), Moe and Tyrrel (1979), Shibata *et al* (1993) and the validated models by Wilkerson et al (1995). The Moe and Tyrrel (1979) model was selected, due to it uses a division of the several energy sources. This model separates the no structural carbohydrates fraction of the structural carbohydrates fraction. The SC are responsible of the larger methane emission in ruminants.

Like second step, we were considered the intake of food of the animals, and we used the system of equations of the National Research Council (1989). In order to determine the quality of the main forages from Costa Rica, we were carried out analysis of carbohydrates, crude protein, cellulose, hemicellulose, ash and ethereal extract, according to the methodology of the AOAC (1970) and Van Soest et al (1991).

The information about the animal population was taken from the estimates carried out by Montenegro and Abarca (1997).

With available data was calculated for each physiologic state and for each production system, the methane emission in function of the intake of food, the quality of diet, live weight, gain of weight, milk production, growth and animal population of each animal category in the country.

The efficiency of production with regard to the emission of methane, in the double purpose system was considered as 50% to each one (milk and calves).

Results

I. Dairy Cattle

The dairy cattle population has stayed relatively constant in the last years. However, the number of cows in production decreased 18% for 1996 (Table 1). This reduction is due to increase of meat demand, which has increased significantly in last years. It is possible that happens a recovery of the number of cows in production in the medium term.

Table 1. Dairy cattle population, in Costa Rica.

ANIMALS	1990	1996	DIFFERENCE *
Total	278.867	260.657	-18.210
Growth	147.017	152.777	+5.760
Mature cows	131.850	107.880	-23.790

* Differences refers to the change with regard to the population of 1990.

Source: Montenegro and Abarca, 1997.

In spite of the fact that dairy cattle population diminished from 1990 to 1996, the production of milk increased in 5.8% (Table 2). This is a consequence of the genetic improvement and of the management in farms. Therefore, the milk production by cow obtained has increased.

In Costa Rica due to the productive improvement of the dairy production, the methane emission by kilogram of milk has diminished (Table 3). This implies that the production systems of milk at the moment are more efficient and less pollutants, since the mature heard diminished 18%, the milk production increased in 21.9 million of kilograms, and the methane emission decreased in 858 tons.

Table 2. Comparison of productive parameters in the dairy cattle, in Costa Rica, 1997.

PARAMETER	UNITS	1990	1996	DIFFERENCE*
Milk production	Mill. ton $year^{-1}$	377,1	399	+21,9
Lactation	Days	277,7	277,7	0
Milk production	kg $lactation^{-1}$	2.860	3.694	+834
Milk production	kg day^{-1}	10,3	13,31	+3,01
Live weight	kg	330	343	+13
Live weight gain	g day^{-1}	300	324	+24

* Differences refers to the change with regard to 1990.

Source: Montenegro and Abarca, 1997.

Table 3. Methane production and efficiency in dairy cattle in Costa Rica, 1997.

VARIABLE	UNITS	1990	1996	DIFFERENCE*
CH_4, cow lactation day^{-1}	g	225	249	+24
CH_4, cow $year^{-1}$	kg	78	85	+7
CH_4, cows in lactation	ton	10.023	9.165	-858
Efficiency	g CH_4 kg^{-1} milk	22	19	-3
CH_4, growth animals	ton	6.919	7.439	+520
Efficiency	g CH_4 kg^{-1}LW	430	412	-18
CH_4, total in dairy cattle	ton	17.002	16.604	-398
Efficiency	g CH_4 kg^{-1} milk	45	41	-4

* Differences refers to the change with regard to 1990.

Although the total reduction of the methane emission was not proportional to the decrease of the number of animals, the efficiency (g CH_4/ Kg milk) improved in 13.6% in cows in production and in 8.9% when the total heard of milk was considered.

II. Beef cattle

All animal categories in the beef cattle heard in Costa Rica presents rates of negative growth and in consequence the total population decreased 25.7% in last years (Table 4).

Some of the possible causes of the drastic reduction of the animal population were the increment of the internal demand of meat products, few stimulus to the bovine production, crisis of prices in the national and international markets, low indexes of some productive parameters and organization problems of the sector of the meat (Table 5).

Table 4. Beef cattle population in two different years, in Costa Rica.

ANIMALS	1990	1996	DIFFERENCE*
Total	1.309.948	972.774	-337.174
Growth females	346.367	310.510	-35.857
Males 0 > 2 years	429.362	208.314	-221.048
Cows in maintenance	227.349	175.759	-51.590
Cows with calf	246.295	219.205	-27.090
Bulls and oxen	60.575	58.986	-1.589

* Differences refers to the change with regard to the population of 1990.

Source: Montenegro and Abarca, 1997.

Table 5. Comparison of some parameter in the beef cattle in Costa Rica.

PARAMETER	UNITS	1990	1996	DIFFERENCE*
Sacrified females	Animals	196.363	230.170	+33.807
Sacrified males	Animals	198.955	179.264	-19.691
Meat in channel, intern intake	ton /years	56.931	44.423	-12.570
Meat in channel, exportation	ton/year	26.787	26.787	--
Growth	Animals/year	--	-59.155	--
Reproduction	Percentage	52	55	+3
Mortality animals < 1 year	Percentage	6,0	6,0	0
Live weight gain	g/days	277,5	309	+31,5

* Differences refers to the change with regard to 1990.

Another factor that caused the decrease in the animal population was the environmentalist campaign against the production of bovine meat in tropical pastures. This campaign was carried out without offering alternative for a rational change to systems of production more sustainable, and (without thinking in peasants and farmers who were carried to poverty), that they avoid taking to peasants and farmers to the poverty, that years before had been encouraged in order to change the forest for pastures.

The methane emission in the reproducer herd of beef cattle has decreased significantly (Table 6) which is, in first instance, due to the strong reduction in the number of animals that they compose the breeding subsystem (Table 4). The breeding subsystem contributes with 11.4% of the decrease of the CH_4 emission. In second instance, the decrease of the emission is due to a light increment in the index of reproduction (Table 5). The reproduction improved the efficiency in terms of emited CH_4 per calf born in 14%. This improvement in the rate of reproduction produced a global reduction of 2.7% in the CH_4 emission. Therefore, the reduction of the total methane emission of 1996 with regard to 1990 was 16%.

Table 6. Methane emission and efficiency of production in the breeding herd, in Costa Rica.

VARIABLE	UNITS	1990	1996	DIFFERENCE*
CH_4/cow/day	g	233	235	+2
CH_4/cow/year	kg	85,2	85,8	+0,6
Efficiency	g CH_4/calf	191	161	30
CH_4, total cows	ton	40.376	33.894	-6.482
CH_4, bulls and oxen	ton	6.766	6.589	-177
CH_4, total breeding cattle	ton	47.142	40.483	-6.659

* Differences refers to the change with regard to 1990.

It is important to point out that with an improvement of approximately 3% in the reproduction, the amount of CH_4 fell 180 ton., it meant a reduction of 60 ton. for each one percent of increment in the reproduction.

As consequence of the minor amount of capable cows for the reproduction, the animal population in growing also experienced a strong reduction (Table 4), the amount of emitted methane diminished 10.3% for females in growing, and 51.5% for the male animals in fatten (Table 7). The percentile variation of the methane emission for both animal categories in growing, heifer and steer, between 1990 and 1996 was on the average -5.6% annual.

Table 7. Methane emission of the animals in growth, heifer for breeding and steer for fatten, in Costa Rica.

VARIABLE	UNITS	1990	1996	DIFFERENCE*
CH_4 growth males	ton	28.444	13.800	-14.644
Efficiency	g CH_4 kg^{-1} LW	0,59	0,59	0
CH_4 growth females	ton	22.031	19.751	-2.280
Efficiency	g CH_4 kg^{-1} LW	0,71	0,71	0
CH_4 growth animals total	ton	50.475	33.551	-16.924

* Differences refers to the change with regard to the population of 1990.

In general, the reduction of the CH_4 emission for enteric fermentation in the beef cattle herd was 24.2% for the period 1990-1996 (Table 8). This reduction is explained mainly for the decrease in the cattle inventory of the country, and not for increment in the efficiency of production. Therefore, the trend toward the reduction of the methane emission will continue if the population of the national herd also continues diminishing.

Table 8. Methane emission and efficiency of production in the beef cattle herd, in Costa Rica.

VARIABLE	UNITS	1990	1996	DIFFERENCE*
CH_4 beef cattle	ton	97.617	74.034	-23.583

In summary, the quality and availability of the forage consumed by the cattle influences significantly in the methane emission. Also, the low productive parameter in the beef cattle reduces the efficiency of this activity and affects negatively the relationship amount of methane emitted: amount of produced meat.

III. Double purpose.

The number of animals of double purpose in Costa Rica have been constant in the last years, it forms the 25% of the total bovine herd (Table 9).

Table 9. Population of double purpose cattle in Costa Rica.

ANIMALS	1990	1996	DIFFERENCE*
Total	469.209	437.238	-31.971
Growth females	178.587	157.662	-20.925
Growth males	102.606	105.911	+3.305
Cows	188.016	173.665	-14.351

* Differences refers to the change with regard to the population of 1990.

The stable population animal that conforms the double purpose cattle, in connection with the national herd show the elasticity of the system, in front the changes of price and stimulus that farmers receive, on perspectives of the milk and meat market. This indicates that the double purpose cattle is an activity more sustainable than the dairy and beef cattle activities in Costa Rica.

The double purpose cattle has not varied their productive level (Table 10). This suggests that it could exist scarce offer and generation of technology for this system, different to another cattle production systems, it is autochthonous of the Latin American region, and it have not suffered strong changes, product of the introduction of technologies of other latitudes.

Table 10. Comparison of some parameters in the double purpose cattle in Costa Rica.

PARAMETER	UNITS	1990	1996
Sulckling period	days	210	210
Milk per lactation	kg	1.470	1.470
Intake of milk per calf	kg/day	3	3
Milk to sell	kg/day	4	4
Total milk	kg/day	7	7
Reproduction	%	62	65
Mortality animals < 1 year	%	6,0	6,0
Live weight gain	g/day	301	301

The CH_4 emission in the cows of double purpose fell 14.0% in 1996 with regard to 1990 (Table 11). The possible causes of this reduction would be the decrease in mature cows (7,6%), and the improvement of a 3.0% in the index of reproduction. Reproduction is an important parameter to improve the efficiency expressed as amount of CH_4/amount of product.

Table 11. Methane emission of mature animals in the double purpose cattle in Costa Rica.

VARIABLE	UNITS	1990	1990	DIFFERENCE*
CH_4/cow/day	g	252	234	-18
CH_4/cow/year	kg	92	86	-6
CH_4/year	ton	17.287	14.878	-2.409
Efficience[2]				
Calves	kg CH_4/calf	82,1	69,4	-12,7
Milk	g CH_4/kg milk	50,0	31,0	-19,0

* Differences refers to the change with regard to the population of 1990.

Although double purpose cattle has low levels of production, double purpose cows emit amounts of methane similar to the esteemed for breeding cows, and inferior to those of dairy cows. Nevertheless the above-mentioned, if we considered that half of the production is constituted by calves and the other half by milk, the relationship *CH_4 emitted: product* is significantly minor that the breeding and dairy cattle.

In Costa Rica's conditions, a dairy cow of 400 kg of live weight in Maintenance emits 180 g CH_4/day, a breeding cow of 450 kg of live weight in a similar condition emits 210 g CH_4/day. This is equivalent to 390 g of CH_4/day. But both cows emit 439 g CH_4/day, one to produce a calf and the other to produce 4 kg of milk/day. While a double purpose cow emits 234 Kg in Maintenance, and 248 g CH_4/day for producing a calf and 4,0 kg of milk. Therefore, the no emission or reduction of methane is 39% and 44% for Maintenance and production respectively.

The double purpose cattle produces to the alimentary security from Costa Rica annually 448,056 kg of milk and 112,000 calves. Carrying out the respective equivalencies, in order to supply the milk and the calves before mentioned, the amount of cows additional necessary would be of 26.000 dairy cows and 173,000 breeding cows, for a total of 199,000 additional cows in the national herd, while with 173,000 cows of double purpose the same production is obtained. Requiring 13% less animals with a double purpose system.

Table 12. Methane emission of growth animals in the double purpose cattle of Costa Rica.

VARIABLE	UNITS	1990	1996	DIFFERENCE*
CH_4, growth males	ton/year	7.199	7.431	+232
Efficiency	g CH_4/kg peso vivo	0,532	0,532	0
CH_4, growth females	ton/year	7.485	6.608	-877
Efficiency	g CH_4/kg peso vivo	0,476	0,476	0
CH_4, growth animals total	ton/year	14.684	14.039	-645
CH_4 double purpose cattle	**ton/year**	**31.971**	**28.917**	**-3.054**

* Differences refers to the change with regard to the population of 1990.

In general form, the methane emission in the double purpose cattle between 1990 and 1996 decreased in 9,5%, as a result of the decrease of the herd, and to a light increment in the reproduction rate.

Total emission of CH_4 by enteric fermentation of the national herd.

In the table 13 is observed the total CH_4 emission for enteric fermentation of the cattle from Costa Rica, where a reduction of 18.4 % is observed between 1990 and 1996. The decrease annual average for the period is of 4,506 ton., which corresponds to 112,650 ton equiv CO_2.

Table 13. Methane emission by enteric fermentation in the cattle herd from Costa Rica.

CATTLE	1990	1996	DIFFERENCE*
	ton.		
Dairy	17.002	16.604	-398
Beef	97.617	74.034	-23.583
Double purpose	31.971	28.917	-3.054
Total	**146.590**	**119.555**	**-27.035**

* Differences refers to the change with regard to the population of 1990.

The three systems of production have experienced a reduction in the CH_4 emission. However, the 87% of the reduction of the emission correspond to the beef cattle, which presented a strong decreased of the inventory in the last years. The double purpose and dairy cattle contributed with 11% and 2%, respectively, in the reduction of the CH_4 emission. Although there was a reduction in the national inventory, the internal demand of meat and milk was still satisfied, which imply that the emission *per capita* of CH_4 by consumption of milk and meat in Costa Rica has decreased.

In general terms, the CH_4 reduction in the bovine cattle has contributed with the *no emission* or economy of 675,875 ton CO_2 equivalent/year in the period 1990-1996, and has avoided the emission to the atmosphere of 3,564.3 Gcal of lazy energy in a lapse of 5 years. This amount of CO_2 equivalent is equal to reforest 15,000 ha. to a horizon of crop of 15 years, or to sow 3,000 ha. of land in agroforestal systems with 100 trees/ha. Likewise, the no emission referred to a well-known aspect as the production of CO_2 by vehicles (6,5 ton/vehíc/year) is similar to Maintenance 22,000 light vehicles outside of circulation for five years.

Other environmental benefits derived of the reduction of the national herd and of the increment of the efficiency of the bovine, are: the regeneration of 230,000 ha. of land in several successional stadiums, the increment of the turnover rate of the carbon, product of the use of grasses and legumes with high biomass production. Therefore, if we analyzed the livestock activity in Costa Rica, it is one of the anthropogenic activities that more has contributed with the environmental improvement.

Conclusions

It is evident that dairy cattle has been able to improve the efficiency of the diet, which is consequence of a better management, and genetic improvement of the animals used in these systems. This demonstrates that potential exists in order to make investigation to improve the efficiency in the production of milk and to reduce more the rates of methane emit. In consequence, in 1996 Costa Rica produced 21.9 million kilograms of milk more than in 1990, with 858 tons less than CH_4.

Also Costa Rica reduced the methane emission for enteric fermentation in the beef cattle significantly. It is important consider that this reduction is due to a strong decreasing of the national bovine herd. It is product of the increment of the internal demand of meat, crisis of prices, low productive parameters, as well as environmentalist pressures, lacking of stimulus and sustained support to the production.

Costa Rica has been able to satisfy the demand of meat, although it consequently decreased the herd in the studied period. The decreased of CH4 emitted was 48% in the rate "amount of methane emitted:Kg of meat produced in channel". From this point of view is convenient to improve the beef cattle systems in order to guarantee, not only the supply of this important food with a minimum of animals, if not also to have more efficient animals. This way, we could be contributed to maintenance or diminish the emission of CH_4 *per capita*,and by kilogram of produced meat.

The emission of gases with greenhouse is a problem that transcends the town or the country where gases are emitted. Therefore, if the internal demand of meat continues increasing, independently of their origin (national or imported) the CH_4 emission will increase too, and if the supplying country is not efficient (low productive parameter), bigger will be the emission *per capita* of methane for meat production.

Nevertheless the lower productions observed in double purpose cattle, in comparison with dairy and beef cattle, in terms of the emitted methane:product ratio, is the most efficient group of the three analyzed. The globalization process that could affect to dairy cattle, characterized by the strong dependence in the importation of grains, and the reduction beef cattle, could make the double purpose cattle the system more economically sustainable.

The technological improvement in double purpose cattle could be a big impact in the increment of the efficiency (emitted methane:product ratio) between systems of cattle in Costa Rica.

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