Report on emissions and emission reduction potential for cattle production in Cuba

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Summary

Due to numerous challenges, the production of milk and meat from cattle in Cuba has high greenhouse gas (GHG) emissions per unit of production. GHG intensities for the 2018 baseline conditions are more than twice as high as the average GHG intensities for milk and meat production for Latin America and the Caribbean region. Therefore, there is a large opportunity to reduce GHG emissions by improving efficiencies of cattle production in Cuba without compromising animal welfare or other environmental outcomes. Three different sets of practice improvements, represented by three scenarios (A, B, and C), were evaluated and compared with a base scenario that aligns generally with current national cattle management. The four (A, B, C, and base) scenarios had the same total area and each has 1000 cows. The practices involved improving diet quantity and quality through increased use of stored forages and better management of pastures. In the scenarios, the diet improvement, when combined with other practices to improve herd health, greatly improved animal performance, and reduced unintended animal mortality. Compared with the base scenario, the scenarios of improved production systems (A, B, and C) affect total productivity more than greenhouse gas emissions. Scenario A, with most modest improvement in practices, decreased total emissions by 27% but increases milk production by 250% and meat production by 21%. Scenario B, with more improvements in management and pastures, has total emissions 10% less than the base scenario but has three times the milk production and 52% higher meat production. Scenario C, with greatest improvement and most change in pastures including having some silvopastures, has 8% higher emission than the base scenario but about 4 times higher milk and 2 times higher meat production than the base scenario. The increased efficiency and productivity should improve rural livelihoods, animal welfare, and non-GHG environmental outcomes.

Implementing these practice improvements could reduce GHG intensities of milk production by about 73% for milk and 43% for meat without including the effect of changes in carbon stocks in above-and below-ground biomass. Including changes in carbon stocks significantly reduces the intensities for improved practices. Also including the potential for bioenergy from methane digesters using collected

cattle manure also provides further reductions when substituted for energy supplied by fossil fuels. In fact, for the practices that include silvopastoral systems on 20% of the land area used for cattle production, there is evidence that carbon negative milk and meat production with emission removals from carbon stock changes exceeds total GHG emissions, at least for the 20 years following establishment of the silvopastures. Without including the effects of changes of carbon stocks, different option of partial adoption of the improved practices for lonely a portion of the total Cuban cattle herd would have more positive benefits for milk and meat production than for reduction of GHG emissions. Therefore, the amount of potential reduction in national GHG emissions will depend both on the extent of adoption of improved practices for cattle production and the goals for total amount of milk and meat production. Increases in milk production of 50% are possible with partial adoption of improved practices with achievable reductions of total GHG emissions also about 50%.

Introduction

Cattle production is important to Cuba. For 2016, the Tercera Comunicación Nacional of Cuba (Ministerio de Ciencia Tecnología y Medio Ambiente 2020) reports that 2617 million hectares (Mha, 24% of the surface of Cuba) is natural pastures, primarily used for cattle production. In addition, there are about 0.5 Mha of improved (cultivated) pasture. Total emissions from agriculture are 10000 kt CO_2e - about one-fifth of total national greenhouse gas emissions. The Tercera Comunicación Nacional does not separate out greenhouse gas emissions for cattle production. However, by estimating enteric fermentation, some methane emissions from manure and some nitrous oxide emissions from manure applied to soil, about one-half of greenhouse emissions from agriculture can be attributed to cattle production. That means about 10% of total national emissions can be attributed to cattle production.

The Cuban cattle production system has many challenges including:

- Feeding systems with low quality natural grasses
- Low soil fertility (acidity, erosion, low organic matter, salinity, compaction, and drainage)
- Insufficient food production areas
- Requirements for dry matter, energy, protein, and minerals are not covered throughout the year
- Inadequate management in pasture and forage areas that affect persistence, availability, and quality, as well as the invasion of herbaceous and shrubby weeds
- Deficit of protein plants and quality food
- Little presence of trees in the pastures
- Water deficit for animal consumption and sanitation of facilities
- Low productive and reproductive indicators
- Livestock waste is not recycled in most production units (lack of culture or equipment)
- Due to the above factors, production of milk and meat from cattle has low efficiency and provides low incomes.

Implementing practices that overcome some of these challenges will improve efficiency and increase productivity of cattle production while reducing the intensity of greenhouse gas emission per unit of milk and meat produced.   The effect on absolute emissions depends on how the management interventions affect the balance between GHG efficiency, total national production of meat and milk, and the size of the national cattle herd. Large increases in national milk and meat production from cattle are possible with reduction in total national GHG emissions, particularly if the total increase in national production is reduced by reducing the national cattle herd.

In its Primera Contribución Nacionalmente Determinada (Actualizada) (Gobierno Cubano 2020), the Government of Cuba did not identify specific goals for cattle production. However, there was a general goal for agriculture to further build resilience and less carbon-intensive development. This goal is obviously relevant for cattle production. Another goal across the economy was to increase the use of renewable energy sources.   This goal is relevant where, for example, there are opportunities to collect cattle manure and use the manure in biodigesters to produce methane for energy.

Methods

Greenhouse Gas Mitigation Opportunities

The Cuban Project Team was made up of experts and leaders from the Estación Experimental de Pastos y Forrajes "Indio Hatuey". The Team, with solicited input of other Cuban experts in cattle production, developed a list of potential practices to reduce greenhouse gas emissions. These are listed in Table 1. They also developed a list of barriers to adoption (Table 2).

Through discussion with Cuban experts and leaders in the cattle industry, these were reduced to a small number of combinations of practices, termed scenarios. Originally, the discussions were to be conducted over two sets of workshops, the first to narrow the practice options and the second to discuss the adoptability and greenhouse gas benefits of the practice combinations. However, Covid-19 produced important restrictions on meetings and only allowed one set of workshops. Therefore, the initial reduction to a set of practices into several combinations, termed scenarios, was done through more limited consultation, led by the Cuban Project Team, within Cuba via email. Using those initial scenarios, preliminary estimates were calculated of how the greenhouse gas emissions changed and how the greenhouse gas emission intensities were affected. The practices, scenarios, and preliminary greenhouse gas results were shared with a broader set of stakeholders in Cuban cattle production at a workshop in late November 2020. As a result of this workshop, the scenarios were modified slightly including both modifications to expected practice adoption and to expected cattle performance with that expected adoption.

Table 1. List potential practices to improve cattle production and its efficiency

Alternative	Practices or components
1-Improve pasture management	Adjustments of animal load according to production system Sowing improved pastures Smaller paddocks Electric fences Rotation of paddocks (rotational and / or rational grazing)

	Systematic weed control Use of bioproducts for the integrated control of pests and diseases Renovation (sowing and establishment according to the regionalization system of pastures and forages Grassland rehabilitation Promotion of multiple partnerships Management of grazing area (recovery of rational grazing) Manage forage and protein plant production areas Production of pasture, forage, and grain seeds Respect technologies and meet soil and crop requirements
2-Establishment of energy-protein forage banks	*Saccharum officinarum* L. (Sugar cane) *Pennisetum purpureum* Schumach (King grass) *Tithonia diversifolia* (Hemsl.) A. Gray (Tithonia) *Morus alba* L. (Mulberry) *Leucaena leucocephala* (Lam.) De Wit and other legumes *Moringa oleifera* Establishment of other forage species based on the edaphoclimatic conditions of the productive scenarios.
3-Agrosilvopastoral systems	Scattered trees in paddock Protein banks Live fences Tree association throughout the area Intensive silvopastoral systems (high density of trees) Planting timber species in paddocks, in low density, considering the edaphoclimatic conditions and the local flora
4- Conservation of pastures and forages	Preserved food in silage and hay forms (grasses, legumes, and other forage species) Use of different technologies for conservation depending on local conditions (bags, rings, sacks, or others), for the different production scenarios.
5-Efficient management of farm management with a gender perspective	Livestock control Efficient management of zootechnical flow Herd health management and control Reproductive and zoo-hygienic management of the herd Genetic improvement (participatory selection) Selection and disposal of unproductive livestock Proper management of the calf Water availability and quality Animal welfare
6-Infrastructure and equipment	Shade facilities Milking room and equipment. Milking routine and hygiene compliance Weights for determining the live weight of animals Equipment for measuring individual milk production Water supply and distribution system for the production system. Piers and traps for handling animals Equipment for food processing (choppers, mills, mixer, solar dryers, among others)
7-Sustainable soil management	Balance of system nutrients Manure management (vermiculture, composting, biodigesters, bioles) Fertilization (organic) Fertilization (chemical in case the soil requires this amendment) Adjustment of stocking according to soil quality

	Use of bioproducts Intercropping and use of green manures
8-Use of zootechnical additives and use of agro-industrial waste and by-products	Strategic and differentiated supplementation Mineral supplementation Food production in the scenarios taking into account local resources Uses of probiotics, prebiotics, and ruminal activators Food preservation (Silage, hay, and flour) Agro-industrial products and by-products (sugarcane and its by-products, residual from livestock exploitation) Activators of animal fermentation Zootechnical additives Food produced by biotechnological routes
9- Socio-economic management	Efficient financial economic system Financial mechanisms Environmental policies Training of human resources and training Regulatory aspects

The Cuban Team also developed a list of the potential barriers to adoption. These are listed in Table 2.

Cuadro 2. Barreras para la adopción.

Technical Barriers
• Limitations in the agroproductivity of soils and progressive loss of their fertility. • There is no defined strategy at the national and local level for the production of grass, forage and grain seeds. • Increasing decrease in areas of improved pasture and forage. • Restriction of grazing time (night grazing is not carried out). • Invasion of spiny woody and idle areas. • Poor food base to meet the requirements. • Little application of the technologies available for the sector. • Interruption of the zootechnical flow and structure of the deficient herds to guarantee the productive end. • Unproductive cattle in the herd. Genetic policy not consistent with existing production systems • Lack of a local extension and innovation system. • Insufficient use of renewable energy sources. • Insufficient machinery and implements. • Lack of technological discipline. • Lack of a systemic approach throughout the cycle of the production chain. • Lack of a coherent policy for agroecological management of the agroecosystem. • Totally vertical, rigid and centralized organizational structures. • Lack of production chains and chains approach.
Economic Barriers
• Insufficient economic incentives to stimulate productive efficiency • Job instability. • Lack of a coherent policy for payment for environmental services. • Limitation of material and financial resources. • Lack of quantification and penalization for economic losses. • Little efficient organizational and accounting-financial systems. • Ignorance of the value of the land and the depreciation of infrastructure and machinery, • Almost zero presence of foreign investment, • Centralized administrative scheme for the allocation of resources to producers in the absence of an internal market for livestock inputs. • There is no effective recognition of the importance of the diversified market.

Greenhouse gas emissions estimation

The greenhouse gas emissions for cattle production were estimated by Viresco Solutions using the Agriculture and Land Use National Greenhouse Gas Inventory Software, based on Methodologies in the 2006 IPCC Guidelines (https://www.nrel.colostate.edu/projects/alusoftware/home/), henceforth referred to as ALU2006. The ALU2006 software was developed by Colorado State University and is freely available (https://www.nrel.colostate.edu/projects/alusoftware/download-software.php). ALU2006 was specifically developed to assist non-Annex 1 countries, such as those in Latin America and the Caribbean, to produce national inventories. This software provides rigorous internal checking for data consistency. Inputs are collated and organized into an Access database. Output results from ALU2006 are provided in Excel worksheets. Unfortunately, the current version of ALU2006 is only available in English (note, some earlier ALU versions that are not currently supported or operational were in Spanish).

ALU2006 was specifically used to implement Tier 2 methodologies for enteric emissions from cattle available in the IPCC 2006 Guidelines. The Tier 2 methodology enables calculation of the effects on greenhouse gas emissions from changes to cattle diet quality and herd performance characteristics including rates of pregnancy, lactation, live weights, and daily weight gains. This was important because changes to both diet quality and herd performance characteristics were important to the improved management scenarios. The alternative was to use Tier 1 methodologies which use fixed emissions for each type of animal with no regard to diet quality or livestock performance characteristics. Where 2019 Refinement to 2006 IPCC Guidelines had significant updates to factors and values, these updates were used. Updated values that were used include emission factors from biodigesters for producing methane, required for one of the scenarios of improved management, and soil carbon stock estimates that affected all the scenarios of improved management.

Although the changes in biomass and soil carbon stocks could be done using ALU2006, these changes were calculated in separate spreadsheet for simplicity (ALU2006 would require a full matrix of land uses to be included and that complexity was not needed for this analysis). These calculations were based on the 2006 IPCC Guidelines.

The amount of change in soil organic carbon stocks was estimated using default values from the 2019 Refinements to IPCC Greenhouse Gas Inventory Guidelines and factors from the 2006. We assume that the 47 ha of land that was improved pasture in base scenario was converted to forage in scenarios A, B, and C. We assume that the pasture area was moderately degraded pasture («pastizal moderadamente degradado») due to high grazing intensity relative to the pasture production in the base scenario. For scenarios of improved rotations, rotational and rational grazing caused the pasture to move to a non degraded state.

Baseline greenhouse gas emissions

The Cuban Team provided the values (cattle number, herd characteristics) for cattle production in 2018 from official government data. These are listed in Table 3.

Greenhouse gas emission intensities

The greenhouse gas emission intensities were calculated as the total of net emissions divided by the number of cows, amount of annual milk production, and amount of carcass weight of animals for meat. Total emissions were the sum of methane (CH_4) from enteric fermentation, CH_4 from manure, and indirect and direct emissions of nitrous oxide (N_2O) from manure applied to soils. Where applicable, changes in biomass carbon stocks were included. The emission were converted to carbon dioxide equivalents (CO_2e) using global warming potentials from the IPCC Fourth Assessment Report (IPCC 2007), i.e. 1 kg CH_4=25 kg CO_2e, 1 kg N_2O=298 kg CO_2e.

The carcass weight was estimated as the live weight multiplied by 50% as the factor for Latin America and the Caribbean (FAO. 2019). The milk production for the baseline was increased by 30% to include the milk fed to calves (García Trujillo 1991) which was not included in initial baseline milk production statistics.

For the scenarios, the live weight of meat was the calculated by multiplying the head of mature animals harvested by their average mature body weight. The number of head harvested was set equal to the number of replacement animals that enter the subcategories of bulls for finishing (toros de ceba) and cows (vacas).

Table 3. Animal characteristics for 2018 baseline (see glossary for English terms).

Ganado		Peso Vivo		Edad			Hembras		Producción			proteína	retención
		comienzo	final	comienzo	final	Ganancia	embarazadas	lactantes	de leche	gestión de	Digestibilidad	bruta	de N
tipo	cabezas	(kg)		(meses)		(kg/dia)	(%)	(%)	(kg/dia)	estiércol	(%)	(%)	(%)
Terneros	361000	30	105	0	12	0.2	0	0	0	pasture	55	4.8	47
añojos	226400	105	180	12	24	0.2	0	0	0	pasture	55	4.8	47
Toretes	198900	180	255	24	36	0.2	0	0	0	pasture	55	4.8	47
Toros de ceba	275900	255	340	36	54	0.2	0	0	0	pasture	55	4.8	47
Bueyes	195700	340	500	36	96	0.2	0	0	0	pasture	55	4.8	47
Sementales	14900	255	450	36	96	0.2	0	0	0	stall (dry)	67.5	4.8	47
Terneras	372000	30	105	0	12	0.2	0	0	0	pasture	55	4.8	47
añojas	244600	105	180	12	24	0.2	0	0	0	pasture	55	4.8	47
Novillas	749900	180	290	24	42	0.2	50	0	0	pasture	55	4.8	47
Vacas	1169100	290	370	42	144	0.2	50	50	4.6	pasture	55	4.8	47

Results

Final scenarios for improved production practices

Through consultation and workshop, four scenarios of cattle production for comparable herds were developed based on 1000 cows. One scenario was a base scenario corresponding to conventional management. This scenario generally aligns with 2018 national baseline but is a simplification that does not have the complexity of the 2018 baseline that includes the entire cattle production of Cuba. The other three scenarios were all improved production scenarios with different combination of practices. These scenarios are described in Table 4 to 7.   Table 8, 9, 10, and 11 summarize the inputs for scenarios base, A, B, and C, respectively.

Table 4. Description of Base Scenario

Scenario	Component	Productivity
Base Scenario. Feeding system with natural pastures, the manure is not managed, it is deposited in the pasture, two or three large paddocks greater than 2 ha. Feeding system with predominance of low-quality pastures and forages with high invasion of undesirable plants, inadequate management systems with low intensity of genetic selection, insufficient availability and quality of water for consumption and sanitation of the units, together with an inadequate management of residuals. Insufficient public policies and socio-economic and financial mechanisms that encourage productivity and job stability.	Low soil fertility (acidity, erosion, OM, salinity, compaction and drainage) Predominance of low-quality natural grasses Insufficient food production areas The requirements of DM, energy, protein and minerals are not covered. Low productive and reproductive indicators Insufficient use of RES Inadequate management of the artificial calf rearing system Bulky feed deficit for livestock throughout the year with a predominance of low-quality natural pastures Low soil fertility (acidity, erosion, OM, salinity, compaction and drainage) Low productive indicators No seed banks are available to guarantee new plantings Water deficit for animal consumption and sanitation of facilities Deficit of protein plants and quality food Inadequate management in pasture and forage areas that affect their persistence, availability and quality, as well as the invasion of herbaceous and shrubby weeds Little presence of trees in the pastures Insufficient boxing in units No forage or food balance is carried out Insufficient use of renewable energy sources Livestock waste is not recycled in most production units (lack of culture or equipment)	33.1 kg / milking cow / day. 50% birth rate 50% in milking Improvement of the load to 0.9 AUM / ha Mortality of 20% in the lower categories and 12% in adult animals[a] Animal requirements covered at 80% Live weight: 370 kg 100% natural grass GMD: Less than 200 g / animal / day in all categories Slaughter weight: less than 350 kg Limiting soil: - 45% of soils are low in OM - Find data on salinity, acidity and compaction Rations of 1.9 Mcal / kg DM and 8% CP.

[a] The initial estimated mortality was 30 and 20% for young and old animals, but these were reduced to have enough replacement females to have a sustained population of 1000 cows.

Cuadro 5. Description of Scenario A.

Scenario	Component	Productivity
Scenarioio A. Improvement of the herd management of the productive entity in addition to pasture management. In the second instance, after better pasture management, a forage area is sown with organic fertilization for its fresh use and to promote food conservation and the use of living fences will be promoted.	Animal load adjustments according to production system Smaller paddocks Electric fence Rotation of paddocks (rotational grazing) Systematic weed control Use of bioproducts Improving the water supply for the herd Sowing forage areas Preparation of preserved foods Soil improvement and management Organic fertilization Live fences	Milk production: 6 kg Birth rate: 55% Percentage of cows in milking: 55% Standby time: 65-70 days Load: 1,5 UGM / ha Mortality in calf categories: 15% Mortality in adult animals: 10% Percentage of diet that is forage: 30% Live weight of cows: 390 kg Cows at first calving: 36 months Birth-Birth intervals: 480 days Replacement percentage: 30% Nitrogen retention with diet: 45-50% Live weight of cattle fattened at slaughter: 370 kg Earnings per category: up to 400g Slaughter age: 30 months Manure management: Organic fertilizers

Table 6. Description of Scenario B.

Scenario	Component	Productivity
Scenario B. Improvement of the farm herd management in addition to pasture management. In the second instance, after better pasture management, an area of fertilized forage (organic) is sown for the use of preserved food. In addition, the health and reproductive behavior of the herd is improved. Supplementation with minerals and preserved forage is carried out. Manure is also handled.	Animal load adjustments according to production system Sowing improved pastures Smaller paddocks Electric fence Rotation of paddocks (rotational and rational grazing) Systematic weed control Use of bioproducts Improving the water supply for the herd Sowing forage areas Preparation of preserved foods Improved soil management Organic fertilization Live fences Livestock control Breastfeeding and / or artificial rearing techniques Herd health management and control Reproductive management Genetic improvement (participatory selection) Selection and culling of cattle Manure management Strategic and differentiated supplementation Mineral supplementation Cost management	Animal load adjustments according to production system Sowing improved pastures Smaller paddocks Electric fence Rotation of paddocks (rotational and rational grazing) Systematic weed control Use of bioproducts Improving the water supply for the herd Sowing forage areas Preparation of preserved foods Milk production: 7.0 liters Birth rate: 60 Percentage of cows in milking: 60% Standby time: 30 in rain and 60 in dry Load: 1.5 UGM / ha Mortality in calf categories: 15% Mortality in adult animals: 8% Percentage of diet that is forage: 25% Live weight of cows: 400 kg Age at first calving: 30 months Birth-Birth intervals: 410 days Replacement percentage: 20% Nitrogen retention with diet: 45-50% Live weight of fattening cattle at slaughter: 400 kg Daily gain by category: Calves up to 400 g / d Yearlings up to 700 g Young bulls up to 600 g Bulls up to 500 g Slaughter age: 28-30 months Manure management: 30% is managed for the manufacture of Compost, Bioles and others

Table 7. Description of Scenario C.

Scenario	Component	Productivity
Scenario C. Feeding system with predominance of pastures, improved quality forages and variants of silvopastoral systems that are managed in a rational way and the requirements of water, DM, energy, protein and minerals are guaranteed with a sufficient number of supplements and supplements from agro-industrial resources. and natural that together with good practices of genetic selection, reproduction and health allow sustainable productions per unit of area with reduction of GHG emissions / Kg of milk and meat produced as a contribution to food and nutritional sovereignty.	Smaller paddocks Electric fence Rotation of paddocks (rotational grazing) Systematic weed control Use of bioproducts Improving the water supply for the herd Sowing forage areas Preparation of preserved foods Use of zootechnical additives Improved soil management Ring silo (grasses, tree meal, sorghum and legumes Planting grasses and trees throughout the area.	Milk production: 8.0 liters Birth rate: 70 Percentage of cows in milking: 70% Standby time: 30 in rain and 60 in dry Load: 1.5-1.6 UGM / ha Mortality in calf categories: 10% Mortality in adult animals: 5% Percentage of diet that is forage: 15-20% Live weight of cows: 400 kg Age at first calving: 30 months Birth-Birth intervals: 410 days Replacement percentage: 20% Nitrogen retention with diet: 45-50% Live weight of fattening cattle at slaughter: 420 kg Earnings by category: Calves up to 500g Yearlings up to 700g Tortoise up to 600g Bulls up to 600g Slaughter age: 30 months Manure management: 30% is managed by renewable energy sources

Cuadro 8. Caracteristicas animales para el escenario base (see glossary for English terms).

Ganado		Peso Vivo		Edad			Hembras		Producción		Dieta		
tipo	cabezas	comienzo (kg)	final	comienzo (meses)	final	Ganancia (kg/dia)	embarazadas (%)	lactantes (%)	de leche (kg/dia)	gestión de estiércol	Digestibilidad (%)	proteína bruta (%)	retención animal de N (%)
Terneros	250	30	100	0	12	0.192	--	--	--	pastos	55	4.8	47
añojos	220	100	170	12	24	0.192	--	--	--	pastos	55	4.8	47
Toretes	194	170	240	24	36	0.192				pastos	55	4.8	
Toros de ceba	170	240	340	36	42	0.100	--	--	--	pastos	55	4.8	47
Bueyes		340	500	36	144	0.03	--	--	--	pastos	55	4.8	47
Terneras	250	30	100	0	12	0.192	--	--	--	pastos	55	4.8	47
añojas	220	100	170	12	24	0.192	--	--	--	pastos	55	4.8	47
Novillas	194	170	280	24	42	0.192	50	--	--	pastos	55	4.8	47
Vacas	1000	240	370	42	168	0.100	50	50	6	pastos	55	4.8	47

Cuadro 9. Caracteristicas animales para el escenario A (see glossary for English terms).

											Dieta		
		Peso Vivo		Edad			Hembras		Producción			proteína	retención animal de N
Ganado		comienzo	final	comienzo	final	Ganancia	embarazadas	lactantes	de leche	gestión de	Digestibilidad	bruta	
tipo	cabezas	(kg)		(meses)		(kg/dia)	(%)	(%)	(kg/dia)	estiércol	(%)	(%)	(%)
Terneros	275	30	117	0	12	0.238	--	--	--	pastos	60	4.75	47
añojos	234	100	265	12	24	0.405	--	--	--	pastos	60	4.75	47
Toros de ceba	210	265	370	24	36	0.404	--	--	--	pastos	60	4.75	47
Bueyes	2	370	500	36	96	0.030	--	--	--	pastos pastos	60	4.75	47
Terneras	275	30	117	0	12	0.238	--	--	--	pastos	60	4.75	47
añojas	234	117	265	12	24	0.405	--	--	--	pastos	60	4.75	47
Novillas	210	265	390	24	36	0.342	55	--	--	pastos	60	4.75	47
Vacas	1000	390	390	36	132	0.100	55	55	6	pastos	60	4.75	47

Cuadro 10. Caracteristicas animales para el escenario B (see glossary for English terms).

Ganado		Peso Vivo		Edad		Ganancia	Hembras		Producción de leche	gestión de estiércol	Dieta		
tipo	cabezas	comienzo (kg)	final	comienzo (meses)	final	(kg/dia)	embarazadas (%)	lactantes (%)	(kg/dia)		Digestibilidad (%)	proteína bruta (%)	retención animal de N (%)
Terneros	300	30	120	0	12	0.247	--	--	--	Pastos 70%, Compost 30%	67.5	5.5	47
añojos	255	120	330	12	24	0.575	--	--	--	Pastos 70%, Compost 30%	67.5	5.5	47
Toros de ceba	235	330	400	24	28	0.574	--	--	--	Pastos 70%, Compost 30%	67.5	5.5	47
Bueyes	2	400	500	36	96	0.030	--	--	--	Pastos 70%, Compost 30%	67.5	5.5	47
Terneras	300	30	120	0	12	0.247	--	--	--	Pastos 70%, Compost 30%	67.5	5.5	47
añojas	255	120	310	12	24	0.521	--	--	--	Pastos 70%, Compost 30%	67.5	5.5	47
Novillas	235	310	400	24	30	0.495	60	--	--	Pastos 70%, Compost 30%	67.5	5.5	47
Vacas	1000	390	400	30	108	0.100	60	60	7.2	Pastos 70%, Compost 30%	67.5	5.5	47

Cuadro 11. Caracteristicas animales para el escenario C (see glossary for English terms).

Ganado tipo	cabezas	Peso Vivo comienzo (kg)	final	Edad comienzo (meses)	final	Ganancia (kg/dia)	Hembras embarazadas (%)	lactantes (%)	Producción de leche (kg/dia)	gestión de estiércol	Dieta Digestibilidad (%)	proteína bruta (%)	retención animal de N (%)
Terneros	350	30	120	0	12	0.247	--	--	--	70% pastos, 30% biogás	67.5	5.5	47
añojos	315	120	320	12	24	0.548	--	--	--	70% pastos, 30% biogás	67.5	5.5	47
Toros de ceba	299	320	420	24	30	0.549	--	--	--	70% pastos, 30% biogás	67.5	5.5	47
Bueyes	2	420	500	30	96	0.030	--	--	--	70% pastos, 30% biogás	67.5	5.5	47
Terneras	350	30	120	0	12	0.247	--	--	--	70% pastos, 30% biogás	67.5	5.5	47
añojas	315	120	310	12	24	0.521	--	--	--	70% pastos, 30% biogás	67.5	5.5	47
Novillas	299	310	400	24	30	0.495	70	--	--	70% pastos, 30% biogás	67.5	5.5	47
Vacas	1000	400	400	30	84	0.100	70	70	8.2	70% pastos, 30% biogás	67.5	5.5	47

Change in carbon stocks

Table 12 summarizes the land areas used in the four scenarios. All scenarios were set to have the same total area of land (1438 ha). However, the amount of feed provided by that land area increased from the base scenario to scenario C. Table 13 provides the estimated soil carbon (C) stocks within the four scenarios. Table 14 summarizes the changes in carbon stocks of the soil with implementation of scenarios A, B, and C.

Scenario C involved the establishment of a silvopastoral system of some of the land used for production. This will produce increases in woody biomass in addition to changes in soil carbon. Based on updated rates from the 2019 Refinement to the 2006 IPCC Guidelines, the rate of accumulation of above ground biomass for tropical silvopastures was 2.91 t C/ha/yr and below ground biomass was 0.79 t C/ha/yr. The total rate of change of C stocks in biomass was 3.7 t C/ha/yr.

Cuadro 12. Área y usos de la tierra (see glossary for English terms).

	Área (ha)				
Escenario	Total	Pastos naturales	Pastos del King grass fertilizados	Pastos cultivados y fertilizados	Sistemas silvopastoriles
Base	1438	1438	0	0	0
A	1438	1338	100	0	0
B	1438	331	100	1007	0
C	1438	0	100	1050	288

Cuadro 13 Existencias y cambios estimados de carbono en el suelo durante 20 años (see glossary for English terms).

Uso y gestión de la tierra	Referencia por defecto (de existencias de C orgánico para suelo (t/ha)	Factor del uso de la tierra	Factor de gestión	Factor de las entradas	Las existencias de carbono después de 20 años (t/ha)
Pastos naturales moderadamente degradado	40	1.0	0.90[b]	1.0	36.0
Pastos naturales con pastoreo rotacional y racional	40	1.0	1.0	1.0	40
Pasto del King grass fertilizado	40	1.0	1.17[c]	1.11[d]	51.9
Pastos cultivados y fertilizados	40	1.0	1.17[c]	1.11[d]	51.9
Sistemas silvopastoriles	40	1.0	1.0	1.0	40.0

[a] tropical, húmedo, suelos HAC (Referencia por defecto de existencias de C orgánico suelos minerales (de refinamientos de 2019 del IPCC)

[b] Pastizal moderadamente degradado de pastoreo de alta intensidad (de refinamientos de 2019 del IPCC)

[c] Pastos mejarados (de refinamientos de 2019 del IPCC)

[d] entradas-alto (de refinamientos de 2019 del IPCC)

Cuadro 14. Existencias y cambios estimados de carbono del suelo para los escenarios (see glossary for English terms).

Escenario	Área (ha)	Gestion de la tierra: Previa (base)	Gestion de la tierra: Final (escenario)	Las existencias de carbono: Previas (t/ha)	Las existencias de carbono: Finales (t/ha)	Las existencias de carbono: Cambio (t/ha/a)
A	100	Pastos naturales moderadamente degradado	Pastos del King grass fertilizados	36	51.9	0.80
	1338	Pastos naturales moderadamente degradado	Pastos naturales no degradados	36	40	0.20
	1438	Tierra total		36	40.8	0.24
B	331	Pastos naturales moderadamente degradado	Pastos naturales no degradados	36	40	0.20
	100	Pastos naturales moderadamente degradado	Pastos del King grass fertilizados	36	51.9	0.80
	1007	Pastos naturales moderadamente degradado	pastos cultivados y fertilizados	36	51.9	0.80
	1438	Tierra total		37.2	49.2	0.66
C	288	Pastos naturales moderadamente degradado	Sistemas silvopastoriles	36	40	0.20
	1050	Pastos naturales moderadamente degradado	pastos cultivados y fertilizados	36	51.9	0.80
	100	Pastos naturales moderadamente degradado	Pastos del King grass fertilizados	36	51.9	0.80
	1438	Tierra total		36	49.5	0.68

The summary of emissions and emission intensity for the baseline and the four scenarios are listed in Table 15.

Scenario C also produces methane for energy using a biodigester. The total estimated annual methane production for energy could be 40 tonnes of methane per year with an energy equivalent of 60,000 L of diesel fuel. This was not included in the emission reductions because it depends how much it substitutes for other energy sources and the emissions from those substituted sources.

Cuadro 15. Emisiones e intensidades de emisión para la línea base y los escenarios de producción (see glossary for English terms).

Fuente	2018 linea de base	Escenario Base	A	B	C
Emisiones de metano a partir de la fermentación entérica (t CO_2e/a)	6781468	3823	2672	2938	3406
Emisiones de metano producidas por la gestión del estiércol (t CO_2e/a)	41314	25	12	19	118
Emisiones de N_2O de los suelos gestionados y de los estiércoles (t CO_2e/a)	493076	328	246	666	830
Cambio en las existencias de carbono de los suelos (t CO_2e/a)	0	0	-1274	-3347	-3586
Cambio en las existencias de carbono de la biomasa de las silvopasturas (t CO_2e/a)	0	0	0	0	-3911
Total (sin cambio en las existencias de carbono) (t CO_2e/a)	7315858	4176	2930	3623	4354
Total (con cambio en las existencias de carbono) (t CO_2e/a)	7315858	4176	1656	276	-3124
Leche (incluye la producción de las nodrizas), (t/a)	824143	511	1277	1577	2095
Carne, producción del peso de la canal, (t/a)	81128	61	74	91	120
Emisiones por unidad de producción (kg CO_2e/kg)					
Sin cambio en existencias de carbono					
Producción de leche	8.9	8.2	2.3	2.3	2.1
Producción del peso de la canal	90.2	69.0	39.6	40.0	36.4
Con cambio en existencias de carbono					
Producción de leche	8.9	8.2	1.33	0.2	-1.5
Producción del peso de la canal	90.2	69.0	22.4	3.0	-26.1

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Discussion

Greenhouse gas emissions

The GHG emissions for the baseline are unexpectedly large. The emissions for enteric fermentation from cattle are nearly 70% larger than the national total reported for this source in the Tercera Comunicación Nacionals (Gobierno Cubano 2020). The latter total also includes emissions from other livestock types including other ruminants, such as goats, plus some enteric fermentation emissions from monogastrics including pigs and horses. Unfortunately, the national communications do not give the cattle population used for calculation so it is not known if that is a cause of discrepancy. If the input diet quality for this study is much lower than that used in national communication, that would also explain some of the discrepancy.

Total emissions for the base scenario were lower than the baseline when expressed on intensity for producing milk and meat.

Total emissions for scenario A are lower than the base scenario due to reduction of enteric fermentation emissions that result from improvement in diet quality through better management of the natural pastures and increased supply of forage. Emissions are also lower because less feed is needed resulting in lower N excretion and lower N_2O emissions. Emissions from enteric fermentation (CH_4) increase from scenario A to B due to increasing numbers of cattle and greater feed intake to support the greater milk production and faster weight gains. For these same reasons, emissions from scenario C are greater than scenario B.

The biodigesters used in scenario C leak some biogas – the installation is assumed to be relatively simple without technologically advanced sealing. The assumed leakage of biogas from the biodigester increases methane emissions from manure management compared to the other scenarios. The use of the biogas produced in scenario C determines how that biogas affects net GHG emissions. If the methane provides additional energy so that it does not displace other fuels, then it will not cause any reduction in emissions. If the methane displaces energy produced by other sources, then it causes a reduction in net GHG equivalent to the emissions that would have been produced by the displaced energy. The greatest reduction will occur if the methane entirely displaces energy derived from fossil fuel. In this analysis, the reduction in net GHG emissions from use of the biogas was not included because of the uncertainty of the avoided emissions from any displaced energy sources.

The N_2O emission decrease from the base scenario to scenario A is a result of more efficient use of N for scenario A. The N_2O emission increase from scenario A to B and from scenario B to C is because of increasing application of N to the soil in organic fertilizers. The amount of N-fertilized land goes from 0 ha in the base scenario, to 100 ha in scenario A, to 1107 ha in scenario B, and to 1150 ha in scenario C. With this fertilization, and increased feed intake by the cattle, there is also an increase in manure N deposited for scenario B compared with scenario A and for scenario C compared with scenario B. Because of these greater N inputs to the soil from both organic amendments and manure, the N_2O emissions increase from the base scenario to scenario C.

The net GHG emissions for scenarios A, B, and C are significantly affected by the change in C stocks from the changes in use and management of the land. The effect of the GHG removals is greatest for scenario C since it has C sinks from soils on 1150 ha plus from trees for 288 ha of silvopastures. In fact, with carbon stock changes included, the scenario C is carbon-negative with net emission less than zero due to removals exceeding emissions. Under IPCC methodology, the GHG removals occur for 20 years after the land use and management changes. However, if the trees in the silvopasture are harvested, new tree growth on that land can continue acting as a C sink. The harvested trees can be used to avoid other emissions, for example, using the trees as an energy source to avoid GHG emissions associated with using fossil fuels as an energy source.

Productivity

Compared with the base scenario, the scenarios of improved production systems (A, B, and C) affect total productivity more than greenhouse gas emissions. Scenario A decreases total emissions by 27% but increases milk production by 250% and meat production by 21%. Scenario B has total emissions 10% less than the base scenario but has three times the milk production and 52% higher meat production. Scenario C has 8% higher emission than the base scenario but about 4 times higher milk and 2 times higher meat production than the base scenario.

The productivity gains are from a combination of more mature animals produced per cow, higher milk production per cow, and faster rates of weight gain. This combination results from the system of practices in the scenarios rather than just one practice. The increase in mature animals per cow results from decreased mortality, reduction in age of first calving, and increased fecundity. Faster rates of weight gain come about from better diet in terms of quality and quantity. However, to realize the increase in mature animals per cow and faster weight gains also requires better herd health and access to sufficient quality and quantity of drinking water. The improved diet quality comes from using forages to supplement grazing and improved pasture management that improves quality of the grazed vegetation. The large herd health improvements come with better prevention and treatment of cattle pests, infections and diseases when combined with a good diet and good drinking water supply. The cooling from shade by trees in the silvopastural systems in scenario C also contributes to higher productivity per animal.

Greenhouse gas intensity of production

The average global GHG intensity of grassland-based milk production is 3.7 kg CO_2e /kg (Opio et al. 2013). For Latin America and the Caribbean (LAC), the average GHG intensity of milk is about 3.8 kg CO_2e/kg. The baseline and base scenario have GHG intensity more than twice these averages. The baseline and base scenario have GHG emission intensity more similar to sub-Saharan Africa (9.0 kg CO_2e/kg). The challenges that Cuba faces mean that the dietary needs of the cattle are not adequately met throughout the year. The inadequate diet for Cuban cattle, which compounds the other challenges of achieving good cattle herd health, explains the high GHG intensities.

All the scenarios with improved practices (A, B and C) have 72 to 74% lower emission intensities for milk than the base scenario and 40 to 45% less than the average for LAC. The GHG intensities for improved management scenarios are similar to those for east and south-east Asia (2.3 kg CO_2e/kg) but are higher than North America (1.7 kg CO_2e/kg) or Europe (1.5 kg CO_2e/kg)(Opio et al. 2013). The low GHG intensities for North America and Europe are not practical for Cuba because they require a very high level of inputs to produce very high quality feed plus expensive housing and milk handling equipment. In addition, they require efficient cattle breeds that are poorly suited to Cuban climate.

The average global GHG intensity of grassland-based production of cattle meat (expressed in carcass weight) in humid climate globally is about 50 kg CO_2e/kg (Opio et al. 2013). For LAC the average intensity is 48 kg CO_2e/kg when excluding the effects of land-use change from expanding pasture area (Opio et al. 2013). The base scenario has nearly twice the GHG intensity for meat production than many other countries in the LAC. Including the effects of land-use change from expanding pasture area in LAC increases average emission intensity in those regions to about 72 kg CO_2e/kg. Such land use change to expand pasture area is not significant in Cuba. Thus, the GHG intensity for Cuban beef is about the same as for LAC when including average LUC in that region outside of Cuba. The base scenario has slightly lower GHG intensity than the average GHG intensity than sub-Saharan Africa (71 kg CO_2e/kg) or south Asia (75 kg CO_2e/kg). The higher intensity for meat for baseline than the base scenario may be due to losses of mature animals before they can be harvested for meat. As was the case for milk, the inadequate diet of Cuban cattle would explain the high GHG intensities for meat production.

All the scenarios with improved practices (A,B and C) have 40 to 45% lower emission intensities for meat than the base scenario. The GHG intensities for improved management scenarios are all higher than North America (29 kg CO_2e/kg) or Europe (14-18 kg CO_2e/kg)(Opio et al. 2013). Similar as the case for milk, the low intensities for North America and Europe are not practical for Cuba because the require considerable grain in the diet plus productive cattle breeds that are not well suited to the Cuban climate.

Including the GHG removal from increase in C stocks of soil and trees, the emission intensities are dramatically reduced for both milk and meat. These improved lower intensities with soil carbon sequestration would not continue indefinitely but only until a new equilibrium soil carbon is obtained. The new equilibrium would occur in 20 years based on IPCC methods after which it would no longer lower GHG intensity.

Other non-GHG outcomes

Animal welfare is obviously improved by better herd health for the scenarios of improved cattle management systems.

All the land management improvements, rotational grazing of grassland, seeded forages, seeded pasture, and silvopasture all would increase soil organic carbon and thereby help reverse past soil degradation. Overall, the improved vegetation and soil health should benefit biodiversity (Russell and Bisinger, 2015) Consequently, the improvements will have good environmental outcomes beyond GHG.

The large improvements productivity from the same number of cows and land area with improved practices will substantially increase returns from milk and meat per cow or per unit of land. There will be more employment required for the improved management systems than the conventional systems for the increased handling and care of cattle and for building and maintaining the increased physical infrastructure involved in cattle production. It is beyond the scope of this study to evaluate how employment and livelihoods will be specifically affected.

The national greenhouse gas implications for potential implementation of the practice combinations from the scenarios

Estimating the feasibility of implementation of the practice combinations in the three scenarios of improved management are beyond the scope of this study. Nevertheless, we can comment on some GHG implications from adoption.

Scenarios B and C require most of the area used for cattle production to have substantial amounts of organic fertilizers to supply the increased N (90 kg N/ha/yr). Organic fertilizers are generally costly to transport so depend on nearby sources. Expensive imported mineral N fertilizers are less costly to transport long distances but their cost affects the economics of their use. Further, these scenarios are also most suitable where soils will be responsive and thereby productive to the substantial vegetation and management interventions. Therefore, the application of the suite of production practices for scenarios B and C will probably be limited to a small portion of cattle production area where conditions are suitable. The interventions for scenario A require fewer fundamental changes to the land vegetation and required soil fertility inputs so will probably be suitable to a larger portion of the cattle production area.

Compared to the base scenario, we calculated the change in milk, meat, and net GHG emissions for different options of adoption of the suite of practices in the scenarios of improved practices (Table 16). The adoption options included were based on 15% to 35% of the total head of cows in Cuba (the number of other types of cattle would be in the ratio to the cows as described for the scenarios). Without including the changes in carbon stocks, the reduction in total GHG were modest (8% or less) for the adoption options investigated. When including the changes in carbon stocks, the reductions in GHG emissions are larger (11-42%) for the adoption options investigated. The reduction in GHG emissions with changes in carbon stocks included were greatest for options with larger adoption of practices in scenario C that contains silvopastoral systems. The increases in milk production were significant (27-85%) for all the investigated options of adoption of improved practices (Figure 1). The increases in meat production were also relatively greater (5-26%) than that of total GHG reduction without including changes in carbon stocks for all the options.

Cuadro 16. Efecto de la cantidad de adopción de prácticas para los escenarios A, B y C en la producción de leche y carne y en las emisiones netas de gases de efecto invernadero (see glossary for English terms)

Adopción de las prácticas de los escenarios	Emisiónes netas de gases de efecto invernadero	
	sin cambio en las	con cambio en las

Base	A	B	C	Producción de leche	Producción de carne	existencias de carbono	existencias de carbono
(% del total de cabezas de vacas en Cuba)				(% del total con solo las prácticas del escenario base)			
100	0	0	0	100	100	100	100
85	5	5	5	133	109	98	84
85	11	2	2	127	106	97	88
85	7	1	7	134	110	98	83
85	7	7	1	128	107	97	87
70	10	10	10	167	118	96	67
70	20	5	5	155	112	94	75
70	15	15	0	153	112	94	77
70	15	0	15	169	119	96	65
70	5	0	25	185	126	100	53
70	26	2	2	149	109	92	79
65	20	10	5	166	115	93	70
65	10	10	15	183	122	96	58

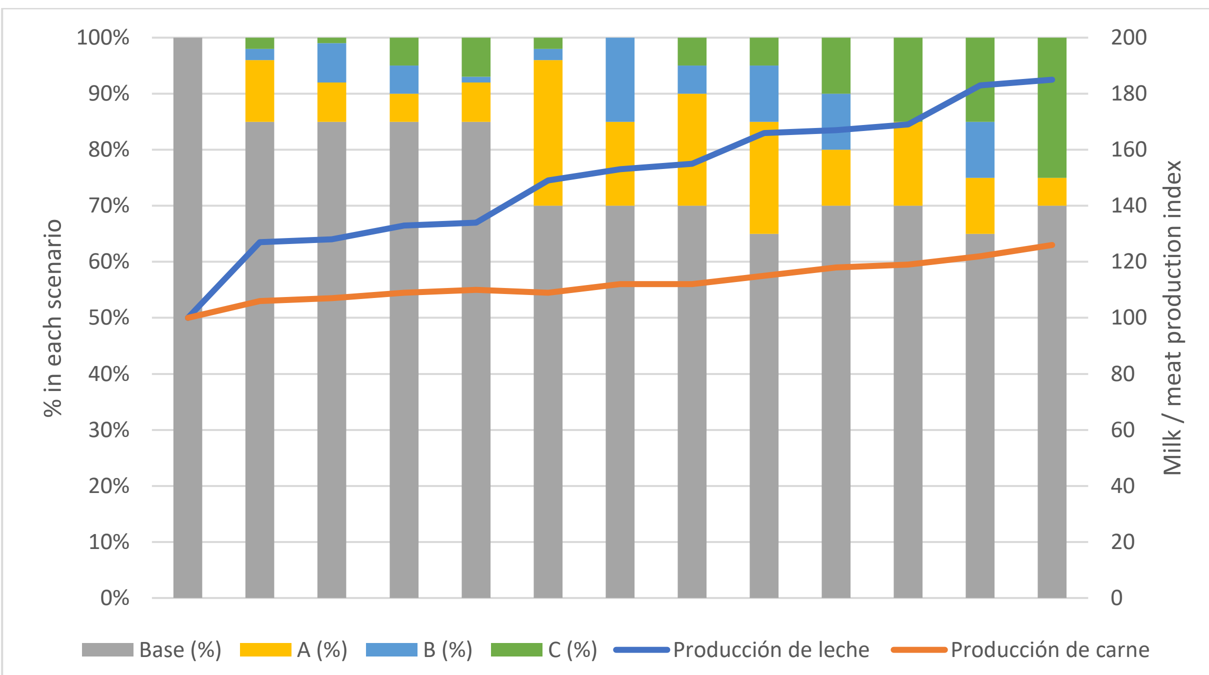

Figure 1. The increase in relative milk and meat production with different mixes of the production systems described in scenarios A, B, and C.

If the demand for milk or meat is not available to use the production increases in milk and meat, then it may be sensible to only increase milk and meat production to the limit of economic demand. The potential larger production can be reduced by decreasing the total cattle population and the area devoted to cattle production. These decreases in herd and area required for cattle production will cause absolute emission reductions beyond what is shown in each adoption option. For example, for the option of 5% adoption of scenario A practices, 5% adoption of scenario B practices, and 5% adoption of scenario C practices would produce the same amount of milk as the base scenario practices with 75% (i.e., 1/133%) of the cows required for base scenario practices. Total GHG emissions for that amount of milk production would then be 74% of those for the base scenario practices without changes in carbon stocks included and 67% with changes in carbon stocks included.

Cuba plans to increase forest area to cover 33% of the country under its Primera contribución nacionalmente determinada (actualizada) (Gobierno Cubano 2020). The land that could be potentially released from cattle production while meeting modest increases in milk and meat demand with improved practices could become some of the land planted to forests to meet this plan.

Conclusions

Due to numerous challenges, the production of milk and meat from cattle in Cuba is highly greenhouse gas intensive – it produces a lot of GHG emissions per unit of production. The GHG intensities are greater than the averages for milk and meat production in most other parts of the world including about twice as high as average for Latin America and the Caribbean. Therefore, there are large opportunities to reduce GHG emissions from cattle production in Cuba while improving animal welfare and other non-GHG environmental benefits. Improved practices that increase use of stored forages and improve management of pastures would improve diet quantity and quality the diet improvement, when combined with other practices to improve herd health, would greatly improve animal performance, and reduce unintended animal mortality. Implementing these practice improvements could reduce GHG intensities of milk production by about 73% for milk and 43% for meat without including the effect of changes in carbon stocks. Including changes in carbon stocks significantly reduces the intensities for improved practices. In fact, for the practices that include silvopastoral systems on 20% of the land area used for cattle production achieve carbon negative milk and meat production with emission removals from carbon stock changes exceeding total GHG emissions. Without including the effects of changes of carbon stocks, that would be the relevant emission reductions over more than two decades, different option of partial adoption of the improved practices would have more positive benefits for milk and meat production than for reduction of GHG emissions. Therefore, the amount of potential reduction in national GHG emissions will depend both on the amount of adoption of improved practices for cattle production and the goals for total amount of milk and meat production. Increases in milk production of 50% are possible with partial adoption of improved practices with reductions of total GHG emissions also being 50%.

Glossary of Spanish Terms

Spanish	English
añojas	Female yearlings
añojos	Male yearlings (intact)
bruta	crude

Bueyes	oxen
cambio	change
comienzo	starting
cabezas	head
carne	meat
con cambio en las existencias de carbono	With change in carbon stocks
cuadro	Table
de los suelos gestionados y de los estiércoles	From the managed soils and the manure
Edad	age
Existencias y cambios estimados de carbono en el suelo durante 20 años	Stocks and estimated change of soil carbon over 20 years
embarazadas	pregnant
gestión de estiércol	Management of manure
ganacia	Gain (weight)
ganado	cattle
gases de efecto invernadero	Greenhouse gas
hembras	females
incluye la producción de las nodrizas	Including the production from nurse cows
lactantes	lactating
leche	milk
linea de base	baseline
Novillas	heifers
pastos	pastures
Pastos naturales moderadamente degradado	Moderately degraded natural pastures
Pastos naturales con pastoreo rotacional y racional	Natural pastures with rational and rotational grazing
Peso Vivo	Live weight
Peso de la canal	Carcass weight
previas	previous
Sementales	Breeding bulls
sin cambio en las existencias de carbono	Without change in carbon stocks
Terneras	Female calves
terneros	Male calves
Toretes	Young bulls
Toros de ceba	Finishing bulls
tierra	land
tipo	type
Vacas	cows

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