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GREENHOUSE GAS EMISSIONS BALANCE ESTIMATE OF THE CHACO SUSTENTABLE PROJECT, PARAGUAY

INITIATIVE ON CLIMATE AND AGRICULTURE VALUE CHAIN

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ABSTRACT

This study presents the greenhouse gas (GHG) emissions estimates calculated during the implementation of the Chaco Sustentable Project, led by Solidaridad in the Chaco region. The project consists of farmer capacity building on sustainable intensification of dairy production based on the progressive recovery of degraded pasturelands and adoption of integrated farm management. By 2027, the Project has the average potential for reducing GHG emissions in farms taking part in the Chaco Sustentable Project of 92% per hectare and 97% per liter of milk produced, with a 33% increase in milk productivity compared with the begin-ning of the program. In year one, the project already achieved an increase of almost 17% in milk productivity and has reduced GHG emissions by 29% per hectare of pasture and by 63% per liter of milk produced. These results were achieved by a strategy designed to recover about 4 ha of the pasture area using fencing

and planting Algarrobo trees on the farms taking part in the project initially. Those recovered areas represent from 1 to 17% of the pasture of the farm types covered by the program. Additionally, this strategy introduces and improves practices such as rotational grazing, animal supplementation (sorghum silage), health and breeding techniques, and management systems to ensure the sustainability of the farms as a whole. The assessment carried out shows that the strategy adopted by the Chaco Sustentable Project has reduced GHG emission levels of the participating farms to levels similar to the best levels recorded worldwide which, if scaled up these practices, could contribute close to 4% of the entire Paraguay commitment to the Paris Agreement. This paper also shows the potential and capacity of dairy farming in the Paraguayan Chaco region to reduce its GHG emis-sions and increase production. At the same time, it can also help decision-makers, consumers, and other actors in the Dairy and Meat value chain to realize the import-ant role played by large-scale sustainable production in preventing climate change and meeting food demands.

INTRODUCTION

The Chaco region is one of the major wooded grassland areas in central South America, encompassing parts of four countries (Bolivia, Brazil, Paraguay & Argentina).

The Chaco region is one of the major wooded grassland areas in South America, encompassing parts of four countries (Argentina, Bolivia, Brazil, & Paraguay). Specifically, in Paraguay, the Chaco is known as the western or occidental region (Buol, 2007).

The Chaco accounts for about 60% of the Paraguayan territory but less than 2% of the population live there. Livestock farming is the main economic activity, primarily dedicated to meat and dairy production.

However, at least a third of the Chaco has been converted to grassland to feed half of Paraguay's cattle herd. For this reason, land use change, agriculture and livestock production are the main sources of greenhouse gas (GHG) emissions in Paraguay. In 2017 the country emitted 193 $MtCO_2e$, of which the agriculture sector accounted for 16% (FAO-Stat).

The Paris Agreement, adopted at the 21st session of the Conference of the Parties (COP 21) to the United Nations Framework Convention on Climate Change (UNFCCC), aims to maintain global average temperatures to below 2 °C of pre-industrial levels. The signatory countries stipulate their Nationally Determined Contributions (NDCs), which are the main commitments and contributions of the respective coun-tries to the fulfillment of the agreement (UNFCCC, 2015a).

The Paraguayan NDC proposes to reduce the 2030 GHG emissions projection (416 $MtCO_2e$) by 20% or 83 $MtCO_2e$ (UNFCCC, 2015b). Despite most GHG emissions from Paraguay are coming from land use change, there is an entire livestock sector involved in this land-use that may contribute to reducing GHG emissions impacts and meeting future food demands if well managed.

The dairy cattle herd, for instance, represents around 2% of the total national agricultural sector emissions (FAO-Stat), but also plays an important role in Chacos' land use and agriculture production.

In Paraguay, close to 40% of the national dairy production comes from the Chaco region, of which cooperatives are the main agents, responsible for industrialized milk production, processing and sales. In 2014, 525.000 t of milk were produced. More than one thousand farms, totalizing about 200,000 hectares, are involved in dairy production in the region (Solidaridad). Furthermore, future projections show that milk production is increasing by 40% in the next decade in Paraguay (OECD-FAO, 2018).

To support Chaco dairy farms, Solidaridad began an initiative called Project Chaco Sustentable in 2017, aimed at improving dairy production and food security in the region. Since then, 40 farmers, selected as pilot farms to showcase mitigation potential of milk production, have taken part in capacity building and training on new production methods, pasture recovery, animal feeding and breeding improvements, as well as farm management. So far, the project has increased milk production by an average of 17% and recovered degraded pastures by implementing silvo-pastoral systems on more than 160 ha. In addition, Solidaridad is working on a 10-year business plan for the farmers, targeting transformational change in dairy production in the Paraguayan Chaco.

Therefore, the Chaco Sustentable Project appears to be in line with Paraguayan efforts for meeting climate and production targets. **In this context, the objective of this study is to estimate the GHG emissions balance of the Chaco Sustentable Project carried out by Solidaridad in Paraguay.**

MATERIALS AND METHODS

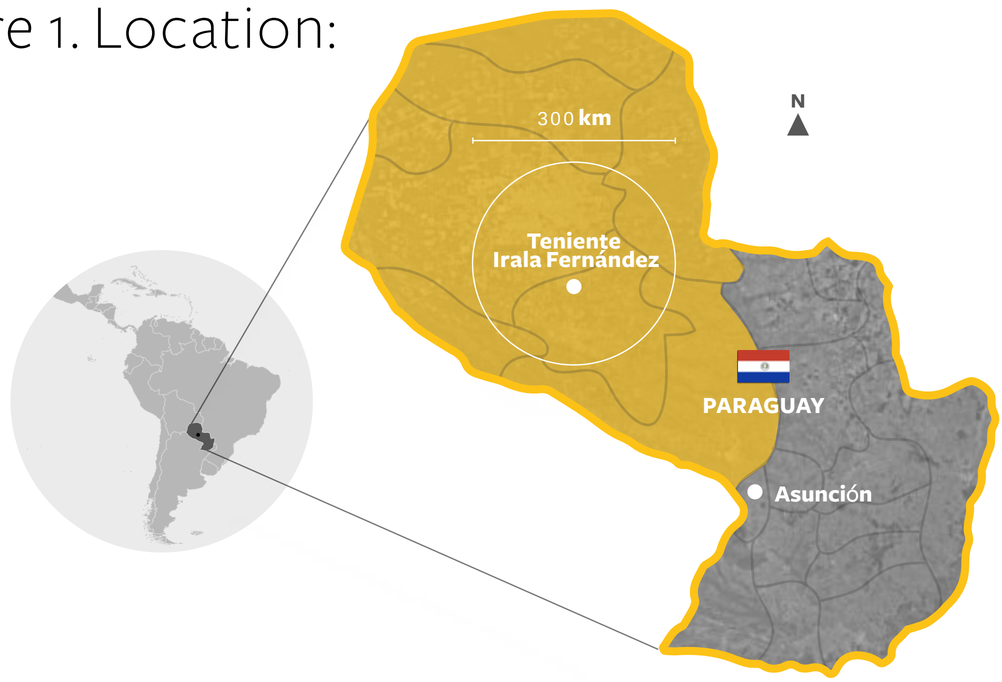
Joint farms have been gradually introducing improved practices to enhance the capacity of managing pastures and animals.

Solidaridad

SYSTEMS ANALYZED

The present study focuses on the scope of the Chaco Sustentable Project, an initiative of Solidaridad to promote the implementation of best management practices in dairy production on farms in the Paraguayan Chaco located in the District of Teniente 1° Manuel Irala Fernández (Figure 1).

Figure 1. Location:



The climate in this region is humid subtropical with dry winters and hot summers, classified as Cwa (Köppen classification). The temperature reaches 44 °C in summer and drops to 0 °C in winter; the average temperature is 26 °C. The average amount of precipitation is between 900 and 1,200 millimeters annually.

The farms are typical dairy ranches established in the region after converting native Chaco vegetation in the 1980s. Since then, these farms have failed to adopt adequate livestock management practices, such as soil correction, rotational grazing, and reproductive control of the herd. Thus, the pastureland established on once fertile soil of the Chaco has begun to degrade, and the dairy farms have faced a decline in milk production, to levels that could jeopardize the economic feasibility of this activity.

Since 2017, the farms that joined the Chaco Sustentable Project began to gradually introduce improved practices proposed by Solidaridad to enhance their capacity to manage pastures and animals. Solidaridad has worked with 48 farms in the Chaco region, which were categorized into 5 types according to the size of their farms, ranging from 24 to 327 ha (Figure 2). The types of farm model analyzed during the study were defined taking into account the average size of the farms (has) in the district of Tte. Irala Fernández and the farms associated with the cooperatives. The pilot farms are small and medium producers and the cat-egorization took in account the level of management of the herd, the infrastructure and the economic resources in order to tailor a detailed plan of actions suitable for each category.

In spite of dairy being the main farm activity, it is important to mention that other land uses are also present, such as native pasture, forests and cropping systems (Solidaridad).

Figure 2. Description of the five dairy farm types involved in the Project:

FARM TYPE 1

= 10ha = 5 animals

Average livestock areas of **24 ha**

Average quantity of **25 animals**

LIVESTOCK

		BL	Y1	Y5	Y10
Cows - Dry	head	6	5	7	6
Cows - Producing		9	13	13	12
Heifers - 1 year old		7	2	2	2
Heifers - 2 years old		3	6	2	2
Calves		8	2	3	3
Bulls		1	0	0	0
Total		34	27	26	25

PASTURE

		BL	Y1	Y5	Y10
Area	ha	24	24	24	24
Degradated	%	20	10	0	0
Nominal		80	73	20	0
Improved		0	17	80	100
Animal stocking rate	head /ha	1.42	1.14	1.09	1.02
Use of fossil fuel	liter /ha	0	16	16	16
Silvipastoral trees	tree /ha	0	120	130	144

MILK

	BL	Y1	Y5	Y10
L/head/day	5.5	6.4	7.3	7.3
L/ha/year	11.8k	19.6k	22.4k	21.6k

⚠ 83% increase on milk productivity by hectare

MILK

06/40 farms fit this profile (15% of total)

FARM TYPE 2

= 10ha = 5 animals

Average livestock areas of **34 ha**

Average quantity of **32 animals**

LIVESTOCK

		BL	Y1	Y5	Y10
Cows - Dry	head	6	5	8	8
Cows - Producing		10	15	16	16
Heifers - 1 year old		10	1	2	2
Heifers - 2 years old		5	9	3	2
Calves		10	2	3	3
Bulls		1	0	0	0
Total		42	33	32	32

PASTURE

		BL	Y1	Y5	Y10
Area	ha	34	34	34	34
Degraded	%	20	10	0	0
Nominal		80	78	20	0
Improved		0	12	80	100
Animal stocking rate	head/ha	1.22	0.96	0.95	0.93
Use of fossil fuel	liter/ha	0	16	16	16
Silvipastoral trees	tree/ha	0	120	130	144

MILK

	BL	Y1	Y5	Y10
L/head/day	7.3	8.5	9.7	9.7
L/ha/year	17.8**k**	30.3**k**	36.6**k**	37.5**k**

⚠

110% increase on milk productivity by hectare

MILK

19/40 farms fit this profile (47,5% of total)

FARM TYPE 3

= 10ha = 5 animals

Average livestock areas of **53 ha**

Average quantity of **39 animals**

LIVESTOCK

		BL	Y1	Y5	Y10
Cows - Dry	head	11	6	9	10
Cows - Producing		11	21	20	19
Heifers - 1 year old		11	3	3	3
Heifers - 2 years old		5	10	3	3
Calves		14	4	4	4
Bulls		2	1	1	1
Total		54	44	41	39

PASTURE

		BL	Y1	Y5	Y10
Area	ha	53	53	53	53
Degraded	%	20	10	0	0
Nominal		80	82	20	0
Improved		0	8	80	100
Animal stocking rate	head/ha	1.02	0.84	0.77	0.74
Use of fossil fuel	liter/ha	0	16	16	16
Silvipastoral trees	tree/ha	0	120	130	144

MILK

	BL	Y1	Y5	Y10
L/head/day	8,2	9,5	10,9	10,9
L/ha/year	21.6**k**	47.1**k**	52.3**k**	50.5**k**

⚠

134% increase on milk productivity by hectare

MILK

08/40 farms fit this profile (20% of total)

FARM TYPE 4

= 10ha = 5 animals

Average livestock areas of **50 ha**

Average quantity of **42 animals**

LIVESTOCK		BL	Y1	Y5	Y10
Cows - Dry	head	8	7	11	11
Cows - Producing		13	25	23	21
Heifers - 1 year old		14	2	3	3
Heifers - 2 years old		11	13	4	3
Calves		17	2	5	4
Bulls		1	0	0	0
Total		64	48	46	42

PASTURE		BL	Y1	Y5	Y10
Area	ha	50	50	50	50
Degradated	%	20	10	0	0
Nominal		80	82	20	0
Improved		0	8	80	100
Animal stocking rate	head /ha	1.28	0.96	0.92	0.84
Use of fossil fuel	liter /ha	0	16	16	16
Silvipastoral trees	tree /ha	0	120	130	144

MILK	BL	Y1	Y5	Y10
L/head/day	7.4	8.6	9.8	9.8
L/ha/year	23**k**	50,5**k**	53,5**k**	49,4**k**

⚠ 115% increase on milk productivity by hectare

MILK

04/40 farms fit this profile (10% of total)

FARM TYPE 5

= 5 animals = 10ha

Average livestock areas of **327 ha**

Average quantity of **95 animals**

LIVESTOCK		BL	Y1	Y5	Y10
Cows - Dry	head	22	17	25	24
Cows - Producing		34	54	50	47
Heifers - 1 year old		23	6	7	7
Heifers - 2 years old		18	21	8	6
Calves		32	7	11	10
Bulls		2	1	1	1
Total		131	106	102	95

PASTURE		BL	Y1	Y5	Y10
Area	ha	327	327	327	327
Degradated	%	20	10	0	0
Nominal		80	89	60	40
Improved		0	1	40	60
Animal stocking rate	head /ha	0.40	0.33	0.31	0.29
Use of fossil fuel	liter /ha	0	16	16	16
Silvipastoral trees	tree /ha	10	120	130	144

MILK	BL	Y1	Y5	Y10
L/head/day	9.1	10.6	12.1	12.1
L/ha/year	74.2**k**	137**k**	146**k**	136**k**

⚠ 83% increase on milk productivity by hectare

MILK

03/40 farms fit this profile (7,5% of total)

One of the first steps of the program was to prepare a technical diagnosis of each farm. This diagnosis evaluated the current production and management status of each farm, identifying priority actions to raise their production levels and structure future activities with the aim of continuously improving them.

Due to the large areas of degraded pastures in the region, the diagnosis of all farms evaluated in this study showed the need for pasture renovation or recovery. However, because this action has a relatively high financial cost, the Chaco Sustentable Project found a solution to initially recover only 4 hectares of the pastures in those farms, ranging from 1 to 17% of their total area.

The recovery of these 4 hectares of pasture consisted of implanting silvopastoral systems with *Prosopis nigra* and *Prosopis alba* trees (Algarrobo) at a density of 30 trees per hectare. In addition, these pasture areas were fenced and divided into plots, and then used for rotational grazing of animals, which were kept in each plot for a period of three to four days.

This management practice was combined with farmer training on hay and silage (*sorghum*) production, to be provided to animals as feed supplement, along with installation of drinking water facilities in the pastures and improvements on herd reproductive and health management practices. The only input used for feed supplement production was diesel in machinery, at a rate of 64 and 72 liter per hectare of, respectively, hay and sorghum (according to Solidaridad one hectare of hay and sillaje was reported to feed 5.8 and 10.4 animals in one year, respectively).

In order to promote a transformational change and increase farm resilience, Solidaridad has also worked on a 10-year production plan for these farms. Since 2017, the Chaco Sustentable Project has assisted more than 48 farmers, covering more than 300 people in the region. These are pilot farms and the project aims at providing technical assistance to 400 dairy producers by the end of year 2020. Milk production has increased 17% and, over the next decade, an extra 15% increase is expected.

GREENHOUSE GAS BALANCE ANALYSES

Five dairy farm types were evaluated in this study. These farms types represent the farm categories covered by the Chaco Sustentable Project (Figure 2). The analytical framework for evaluating the GHG emissions balances of the Chaco Sustentable Project was based on the IPCC guidelines (IPCC, 2006), facilitated by the GHG emission and removal factors of the EX-ACT Tool (EX-ACT/FAO) (Table 1), coupled with dairy farm management factors gathered from Solidaridad records, such as number of animals, areas of degraded and improved pastures and milk production.

The following GHG emission sources and sinks were considered (IPCC, 2006):

- Methane (CH_4) emissions from enteric fermentation.
- CH_4 and nitrous oxide (N_2O) emissions from animal manure management.
- N_2O and carbon dioxide (CO_2) emissions from soil application of synthetic nitrogen (N-urea) fertilizer.

- CO_2 emissions from the application of limestone to soil;
- CO_2 emissions from the burning of fossil fuel (diesel) in machinery for recovering and maintaining pasture and produce feed supplements;
- CO_2 emissions from soil of degraded pasture;
- CO_2 removal from soil C sequestration in improved pasture and silvopastoral areas;
- CO_2 removal from aboveground biomass of trees planted over improved pasture and silvopastoral systems.

Table 1. Greenhouse gas emission factors and removals used for dairy production in the Chaco Region, Paraguay, based on the EX-ACT (EX-ACT/FAO) calculator for a tropical dry climate pasture-based dairy system.

GHG SOURCE / SINK

= Sink / Emission = Source / Sequestration / Removal

	EMISSION FACTOR
Beef Cattle (Enteric Fermentation + Manure Management) t CO_2e head^{-1} y^{-1}	1.59
Dairy Cattle (Enteric Fermentation + Manure Management) t CO_2e head-1 y^{-1}	2.00
Input t CO_2e head-1 y^{-1}	
Fossil Fuel (Diesel)	0.0027
Soil Carbon Stock Variation tCO_2e ha^{-1} y^{-1} *	
Moderately degraded / Severely degraded	1.67
Moderately degraded / No degraded (nominal)	- 0.26
Moderately degraded / Improved without inputs	- 1.28
Aboveground Carbon Sequestration in *P. nigra trees* tCO_2e tree^{-1} y^{-1} **	0.0031
Production of Feed Supplements ***	
Hay tCO_2e head^{-1}y^{-1}	0.0296
Sorghum silage tCO_2e head^{-1}y^{-1}	0.0187

Notes: * Tropical dry climate. Management and emission factors are accounted for up to 20 year (IPCC, 2006 – EX-ACT/FAO tool). Negative and positive values represent soil carbon sequestration and emission, respectively. **Annual value derived from Lima et al. (1996) for aboveground carbon biomass in stem for a single tree of *P. nigra* aging 106 months (~9 years). ***Farm types 1 and 4 uses only hay; and Farm types 2, 3 and 5 use both hay and sorghum silage.

Three assumptions were applied to the framework described above. The first refers to the soil carbon emission and removal calculations: for this study, it was considered that 100% of the pasture areas at the beginning of the project were moderately degraded, non-recovered/renovated areas that would continue to degrade, meaning that their status would shift from moderately to severely degraded and recovered/renovated shifted from the status of moderately degraded to non-degraded areas (nominally) or improved level by applying no inputs (EX-ACT-FAO; IPCC, 2006) (Table 1).

The second assumption is related to the aboveground carbon of *P. nigra* trees planted in the pasture areas. We used values found by Lima et al. (1996) of 15.24 kg abo-veground carbon biomass (in stem) for a single tree of *P. nigra* aging 106 months (~9year old) - or an annual carbon accumulation of 0.85 kg, assuming 50% carbon in biomass (0.0031 tCO_2e $tree^{-1}$ $year^{-1}$).

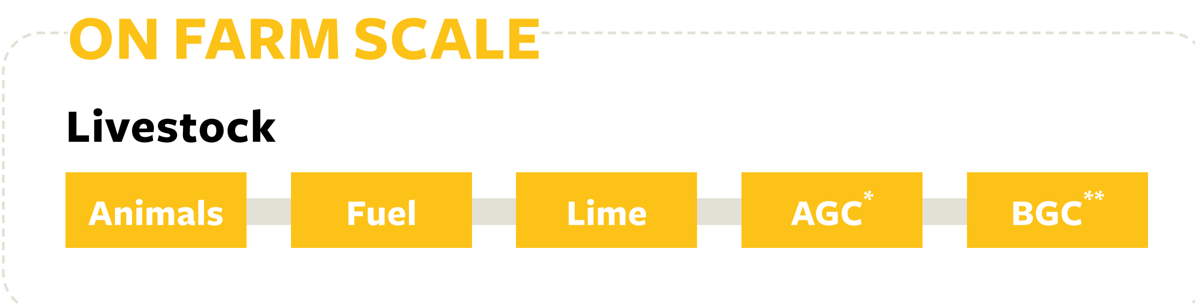
Lastly, the effect of fodder from *P. nigra* was not reflected in the animals' enteric fermentation and manure emissions within the silvopastoral system (Table 1), mainly due to lack of data. Despite their influence on the reported variables, developing emissions factors for these conditions requires field data on factors such as dry matter consumption and levels of crude protein in fodder (IPCC, 2006).

All sources and removals of GHG listed above for each dairy system are converted into CO_2 equivalents (CO_2e) using Global Warming Potential (GWP) factors provided by the IPCC 5^{th} Assessment Report (CO_2 = 1, CH_4 = 28 and N_2O = 265) (IPCC, 2014) and, finally, summed up as follows:

GHG EMISSION = GHG enteric fermentation
+ GHG manure management
+ GHG soil inputs
+ GHG soil carbon stock
+ GHG trees aboveground biomass

The results were further correlated with the production variables described in Table 1 (e.g. pasture area required for production and milk), resulting in GHG emission intensity metrics for the systems studied.

Figure 3. Scope of the greenhouse gas emissions assessment of the five dairy farms types involved in the Chaco Sustentable Project, Paraguay.



Notes: * Above-ground carbon (AGC) Soil carbon stock silvopastoral. ** Below-ground carbon (BGC) soil carbon stock.

The scope of this work concentrates on on-farm emissions and removals. Therefore, no emissions from transport of manufacturing of soil inputs from outside the farm area have been considered. In addition, we assumed no restrictions regarding time-dependence of soil and tree carbon sequestration (Henry et al., 2009) (Figure 3).

Although, as mentioned above, this study represents the starting point of a longer monitoring programme to be implemented by Solidaridad and, therefore, these results are expected to be improved over time. Use of local field measurements of the variables analyzed in this study is recommended to obtain a better picture of the systems being analyzed (IPCC, 2006).

All data required for calculating GHG emissions balances from each of the five farm types evaluated in this work (Figure 2) were carried out by field visits and interviews with Solidaridad representatives as well as via literature review.

RESULTS

Multiple ways to reduce environmental impacts, supporting far better decisions.

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GHG EMISSION SOURCES AND SINKS

At the beginning of the project the estimate GHG emissions of the five types of dairy farms evaluated in this work ranged from 0.8 (Farm Type 5) to 2.6 (Farm Type 1) $tCO_2e\ ha^{-1}\ y^{-1}$. These emissions were mainly driven by the livestock heard size followed by soil degradation.

Figure 4. Greenhouse gas emissions (GHG) per hectare of five dairy farm types involved in the Chaco Sustentable Project, Paraguay.

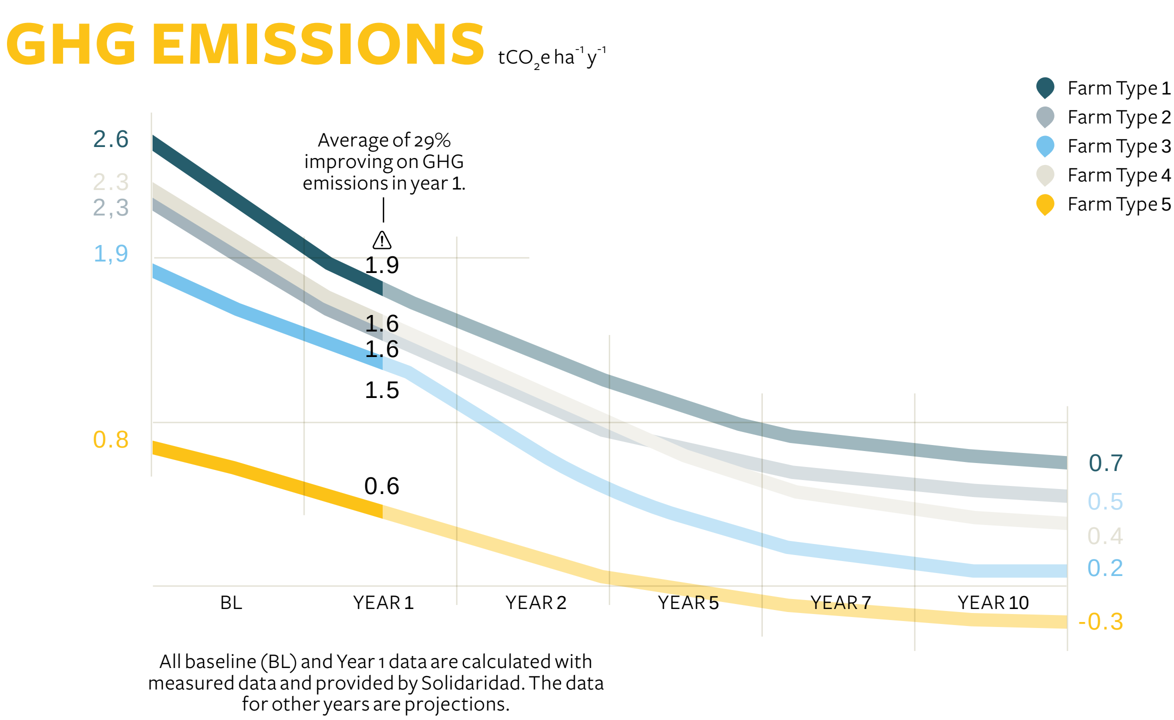
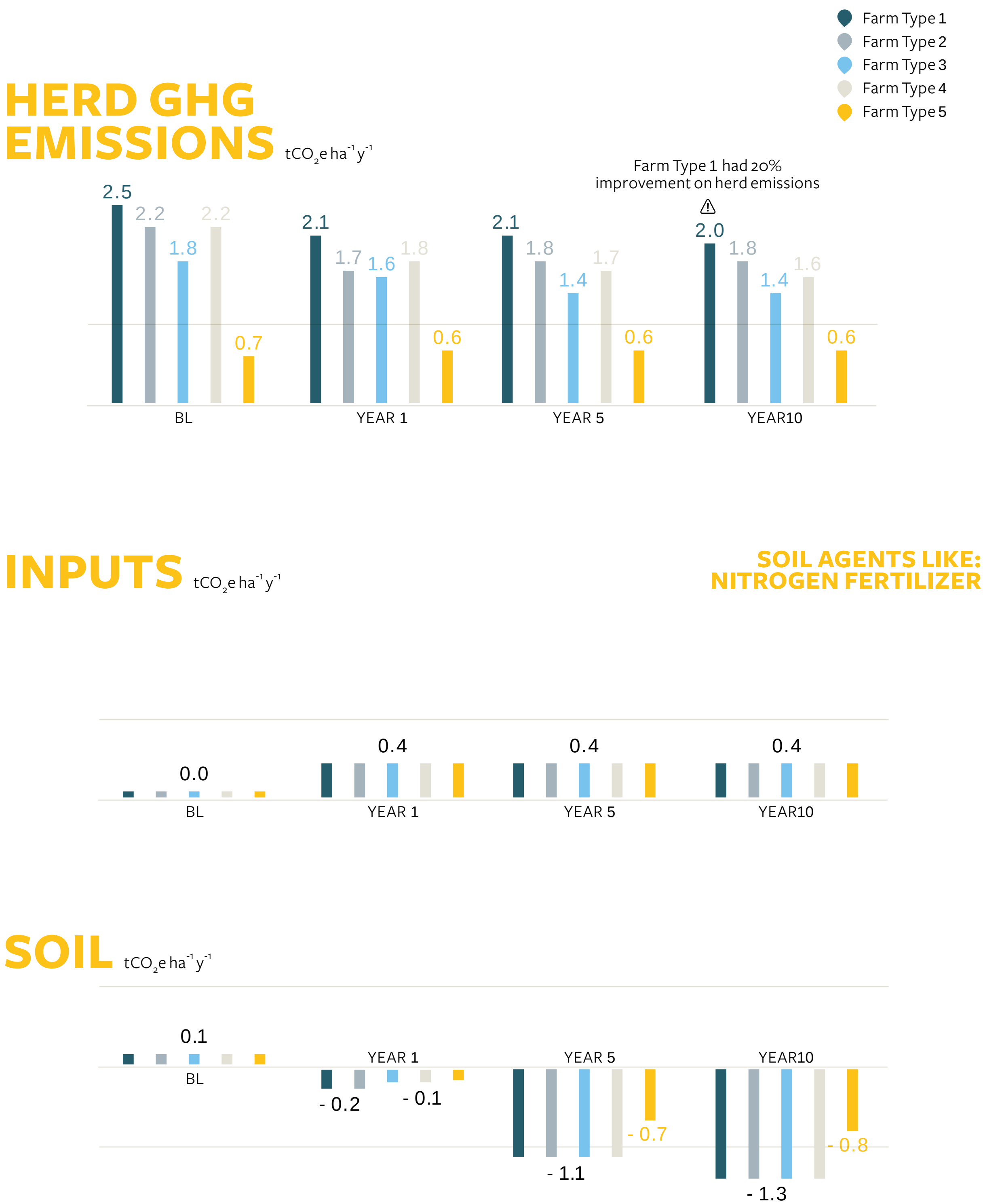


Figure 5. Greenhouse gas emissions by source of five dairy farm types involved in the Chaco Sustentable Project, Paraguay.



Generally, the higher the animal stocking rate the higher the GHG emissions per hectare of these farms – which is a characteristic of larger dairy farmers in the Chaco Region covered by the Chaco Sustentable Project (Table 1; Figures 2, 4 and 5).

Livestock is a significant GHG emitter, with two main associated sources: enteric fermentation and manure management. Enteric fermentation emits CH_4 as a consequence of anaerobic digestion of the animal feed in the rumen, whereas manure emits N_2O and CH_4 through microbial processes during the degradation of this material when in contact with soil in pasturelands. In general, the better the quality of the animal feed the lower the emissions from these sources (IPCC, 2006).

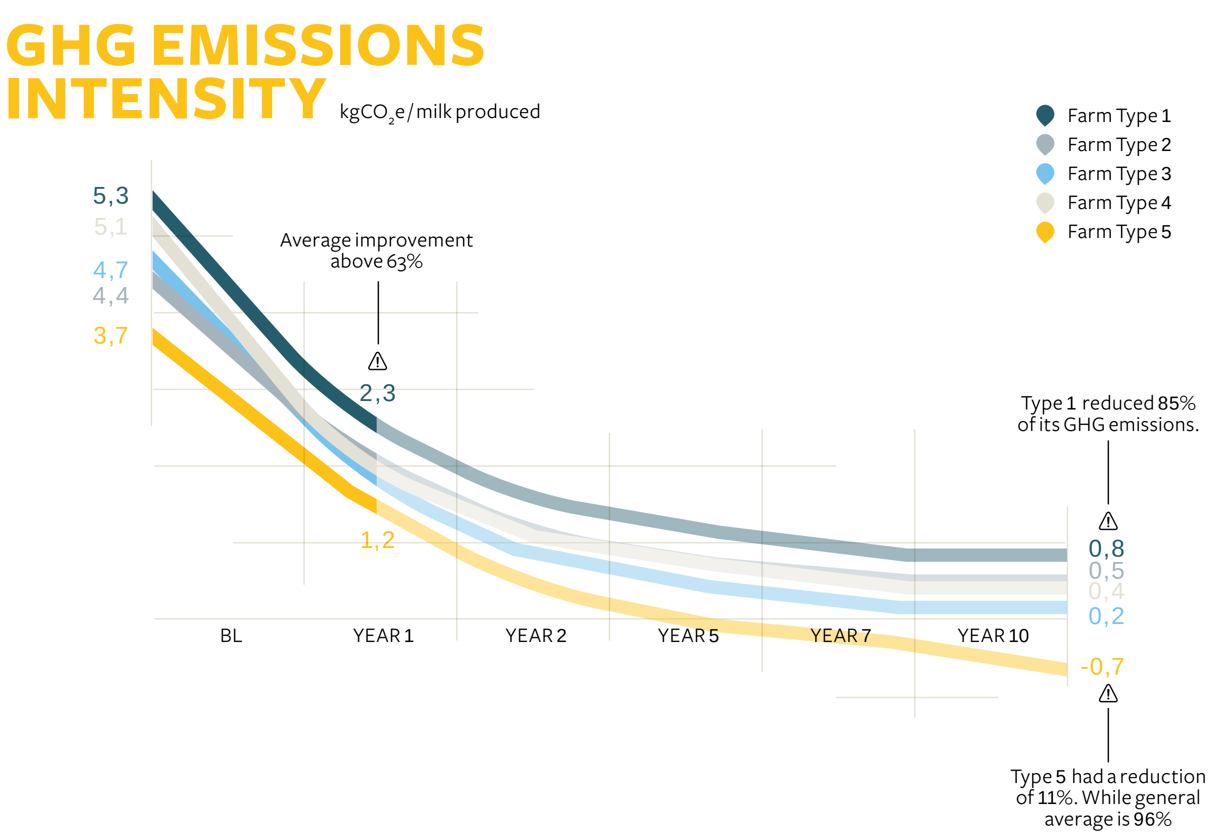
The use of soil inputs, especially nitrogen fertilizer can also be a significant source of GHG emissions (IPCC, 2006; Davidson, 2009). However, as stated by the Chaco Sustentable Project, there is no need for addition of soil inputs to achieve moderate production intensification.

After joining the Chaco Sustentable Project, the farms reduced soil degradation through recovery of part of their pasture area (4 ha), which was found to remove 1.7 t $CO_2e\ ha^{-1}\ y^{-1}$ through soil carbon sequestration (EX-ACT/FAO). In addition, the implementation of silvopastoral systems with *P. nigra* trees promoted extra aboveground carbon sequestration of 0.37 $tCO_2e\ ha^{-1}\ y^{-1}$. These values are consistent with the scientific literature, which show that estimated aboveground carbon sequestration in silvopastoral systems range from 0.55 to 8.4 $tCO_2e\ ha^{-1}\ y^{-1}$ and from 0.22 to 24.0 $tCO_2e\ ha^{-1}\ y^{-1}$ for soil carbon sequestration (Feliciano *et al.*, 2018).

Thus, during the first year of the Chaco Sustentable Project, the implementation of soil recovery and silvopastoral areas (4 ha) led to offsets between 9-14% of the total GHG emissions. Furthermore, the combined effects of the farmers' capacity building for better farm management were reflected in the milk production of the dairy farms. After one year of the project, milk production had increased by 17%. The major influence was related to the herd adjustment implemented by the project.

All farm types increased their herds of productive cows and reduced other categories (Figure 2) as a strategy to use farm resources more efficiently, concentrating efforts on the dairy cow population by providing the animals with higher quality and quantity of feed (pasture and forage). As a result, GHG emissions per hectare and milk produced were reduced by 29 and 63% compared to the figures at Year 1, respectively (Figure 6; Table 2).

Figure 6. Greenhouse gas emissions per liter of milk produced on the five dairy farm types involved in the Chaco Sustentable Project, Paraguay.



POTENTIAL OF THE CHACO SUSTENTABLE PROJECT

The next steps of the Chaco Sustentable Project target a substantial improvement in the milk production and environmental variables related to greenhouse gas emissions of the farms taking part in the project. This plan focuses on stimulating fur-ther pasture recovery and adoption of silvopastoral areas, along with appropriate increase in herd size and management.

In the next 6 years of the project it is estimated that GHG emissions from those farms will be reduced to the range of -0.1 to 0.8 tCO_2e ha^{-1} $year^{-1}$ and by -0.3 to 0.8 tCO_2e per liter of milk produced. This means that the Chaco Sustentable Project is likely to achieve a 33% increase in milk production for all farm types, which will reduce GHG emissions by 69-117% per hectare and by 84-109% per liter of milk produced as com-pared with levels at the beginning of the program in 2017 (Table 3; Figures 3; 5).

Table 2. Greenhouse gas emissions per hectare and per liter of milk produced on five dairy farm types involved in the Chaco Sustentable Project, Paraguay.

GHG emissions **per hectare** tCO_2e

Farm type	tCO_2e BL	tCO_2e YEAR 1	tCO_2e YEAR 10	BL/YEAR 1	YEAR 1/10
1	2.6	1.9	0.7	-29%	-72.4%
2	2.3	1.6	0.5	-30.7%	-75.5%
3	1.9	1.5	0.2	-24.3%	-92.1%
4	2.3	1.7	0.4	-28.6%	-84.8%
5	0.8	0.6	-0.3	-32%	-133%
AVERAGE	2.0	1.4	0.3	-28.9%	-91.8%

GHG emissions **per liter of milk produced** tCO_2e

Farm type	tCO_2e BL	tCO_2e YEAR 1	tCO_2e YEAR 10	BL/YEAR 1	YEAR 1/10
1	5.3	2.3	0.8	-57.1%	-84.9%
2	4.4	1.8	0.5	-59.2%	-88.8%
3	4.7	1.6	0.2	-65.3%	-96.6%
4	5.1	1.7	0.4	-67.4%	-92.9%
5	3.7	1.3	-0.7	-63.4%	-118%
AVERAGE	4.6	1.7	0.2	-62.5%	-96.3%

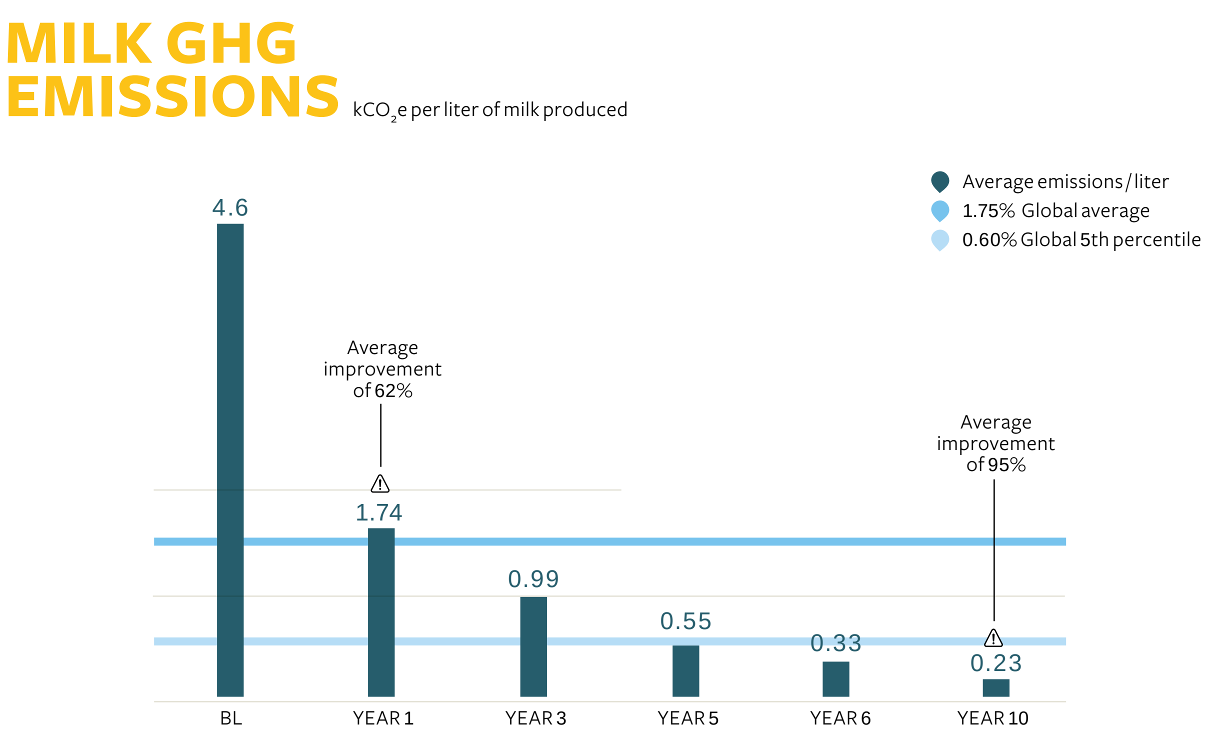
According to this scenario, the farms are projected to have no degraded pastures and will implement 5 to 50% more trees, able to support a stocking rate 30-43% higher than the average capacity in 2017 (Figure 2; Table 2). Above and belowground carbon sequestration will support GHG emissions offsetting from these farms – crucial for maintaining a low GHG emissions impact of milk production in the Chaco region (Figure 5). This plan is designed so that Solidaridad assists farmers in consolidating practices in the region.

DISCUSSION

Given the current, real threats of global warming and the mitigation potential of the land use sector (Griscom *et al.*, 2017), meeting future demand for agricultural products while lowering GHG emissions impacts would appear to be the future of sustainable food production.

Reducing GHG emissions from agricultural production can also be translated into improvements in production efficiency. According to our results, the average emissions of the five farm types at the beginning of the project were 4.6 kg CO_2e to pro-duce 1 liter of milk, which is 3.0 times higher than the global average (Poore *et al.*, 2018). After one year of implementing best management practices, farms fell close to the 10th percentile of global averages, and are projected to reach the 5th percen-tile by the 5th year of the project (Figure 7).

Figure 7. Greenhouse gas emissions per liter of milk produced on five dairy farm types involved in the Chaco Sustentable Project (Paraguay) compared to global benchmarks.

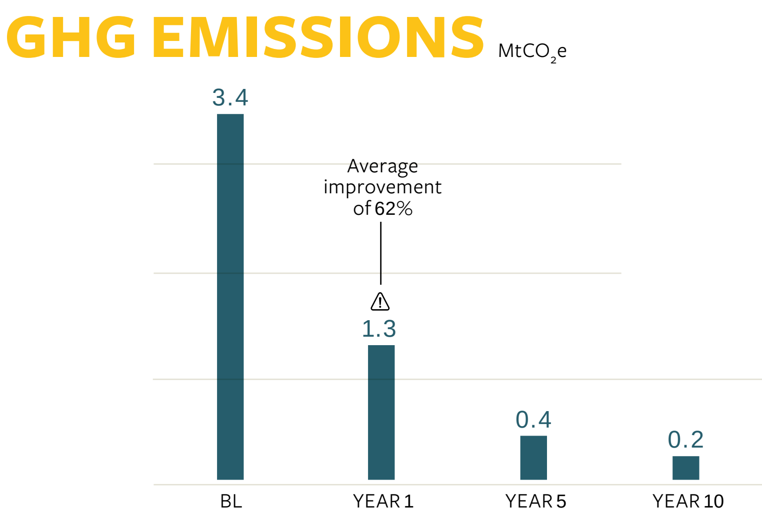


Paraguayan milk production is supposed to increase by 40% (from 533 to 737 Mton) from 2015-17 to 2027 (OECD-FAO, 2018). In order to gain a sense of the GHG emissions impacts of large-scale implementation of Chaco Sustentable practices, by scaling up its practices to meet milk production targets the GHG emissions of 3.0 $MtCO_2e$ could be avoided in 2027. This volume of emissions represents about 2% of the total GHG emissions from Paraguay's agricultural sector in 2014 (WRI-CAIT), or 4% of the GHG emissions reductions of the total Paraguayan pledge to the Paris Agreement (UNFCCC, 2015a, b).

These values corroborate assertions from Bartl *et al.* (2011) and Cederberg *et al.* (2009) regarding the possibility of GHG reductions through increments in production, through both pasture management improvement and productive herd indicators. This is especially applicable to silvopastoral systems.

It is important to point out the effects of silvopastoral schemes on other emissions sources, such as animal enteric fermentation, on which literature data is rare. For example, Pineiro-Vazquez *et al.* (2018) reported that the inclusion of *L. leucocephala* in the diet of heifers fed low-quality tropical forages has the capacity to reduce enteric methane emissions by up to 61.3%. On the other hand, Mauricio *et al.* (2014) showed that including *T. diversifolia* in sowings with *Brachiaria brizantha cv.* Marandu may not have positive effects on animal performance, and limited possibilities that grazing animals would emit less methane. Therefore, it is worth noting that the Chaco Sustentable Project keep gathering data, as used in this study, in order to better understand and monitor the GHG emissions balance of its silvopastoral production systems.

Figure 8. Greenhouse gas emissions averages (5 farm types) in milk production to meet Paraguayan milk production targets in 2027 within the Chaco Sustentable Project, Paraguay.



Above all, the results of this study suggest that the implementation of best management practices in the Chaco region, independent of farm size, promote appropriate conditions to deliver attractive productivity levels compared to Paraguayan averages, as well as lower GHG emissions impacts.

Therefore, the implementation of best management practices presents themselves as critically important potential means to mitigate the environmental impacts of dairy production, and food production more broadly, in the Paraguayan Chaco. Reducing impacts means focusing on different areas for different producers and, by implication, adopting good agricultural practices. Providing producers with options – multiple ways to reduce their environmental impacts, supporting far better decisions and helping to prevent unintended consequences, avoiding "production" proxies and helping producers to navigate trade-offs and make choices that align with local and global priorities (Poore & Nemecek, 2018).

CONCLUSION

The implementation of the Chaco Sustentable Project on dairy farms in the Paraguayan Chaco region has shown that:

1. By 2027, the Project has the potential to increase average milk productivity by 33% and to reduce average GHG emissions by 92% per hectare of productive area and 97% per liter of milk produced.
2. One year after progressively adopting good agricultural practices (recovery of degraded pastures, animal supplementation, improvements in the health and reproductive management of the herd and in farm management), milk productivity on participating farms increased by an average of 17%, while GHG emissions declined by 29% per hectare – resulting in 63% less intensive GHG emissions per liter of milk produced.
3. If there is an upscale in the Chaco Sustentable Project could avoid almost 3 MtCO_2e while meeting Paraguayan milk demands by 2027. This GHG volume can contribute to almost 4% of the total GHG emissions reductions pledged by Paraguay in its NDC to the Paris Agreement.
4. The transition of farms to more efficient production systems in degraded ecosystems is likely to be a viable means to meet an increasing demand for agricultural/livestock products while contributing to mitigating global climate change.

REFERENCES

BARTL, K., GOMEZ, C. A., & NEMECEK, T. (2011). LIFE CYCLE ASSESSMENT OF MILK PRODUCED IN TWO SMALLHOLDER DAIRY SYSTEMS IN THE HIGHLANDS AND THE COAST OF PERU. J. OF CLEANER PRODUCTION, 19, 1494-1505.

BUOL, S. W. (2007). SOILS. IN T. T. VEBLEN, K. R. YOUNG, & A. R. ORME (EDS.), THE PHYSICAL GEOGRAPHY OF SOUTH AMERICA (PP. 101–111). OXFORD: OXFORD UNIVERSITY PRESS.

DAVIDSON, E.A. (2009) THE CONTRIBUTION OF MANURE AND FERTILIZER NITROGEN TO ATMOSPHERIC NITROUS OXIDE SINCE 1860. NATURE GEOSCIENCE, 2, 659-662.

EX-ACT/FAO. EX-ANTE CARBON-BALANCE TOOL. AVAILABLE AT: HTTP://WWW.FAO.ORG/TC/EXACT/EX-ACT-HOME/EN/

HENRY, M. *ET AL*. 2009. BIODIVERSITY, CARBON STOCKS AND SEQUESTRATION POTENTIAL IN ABOVEGROUND BIOMASS IN SMALLHOLDER FARMING SYSTEMS OF WESTERN KENYA. AGRICULTURE, ECOSYSTEMS & ENVIRONMENT, 129, 238-252.

FAO, 2019. FAOSTAT. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, ROME, ITALY. WEB. AVAILABLE AT: HTTP://WWW.FAO.ORG/FAOSTAT/EN/#DATA.

FELICIANO, D., *ET AL*. 2018. WHICH AGROFORESTRY OPTIONS GIVE THE GREATEST SOIL AND ABOVE GROUND CARBON BENEFITS IN DIFFERENT WORLD REGIONS? AGRICULTURE, ECOSYSTEMS AND ENVIRONMENT 254 (2018) 117–129.

IPCC, 2006. INTERGOVERNAMENTAL PANEL ON CLIMATE CHANGE. IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES. AVAILABLE AT: HTTPS://WWW.IPCC-NGGIP.IGES.OR.JP/PUBLIC/2006GL/INDEX.HTML.

IPCC, 2014. CLIMATE CHANGE 2014: SYNTHESIS REPORT. CONTRIBUTION OF WORKING GROUPS I, II AND III TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [CORE WRITING TEAM, R.K. PACHAURI AND L.A. MEYER (EDS.)]. IPCC, GENEVA, SWITZERLAND, 151 PP.

LIMA *ET AL*, 1996. EQUAÇÕES PARA ESTIMATIVA DE BIOMASSA DE ESPÉCIES DE PROSOPIS NO SEMI-ÁRIDO BRASILEIRO. PARTE DO BOLETIM DE PESQUISA FLORESTAL, COLOMBO, 32/33, 67-79.

MAURICIO, ROGÉRIO M. ET AL, 2014. TITHONIA DIVERSIFOLIA FOR RUMINANT NUTRITION. TROPICAL GRASSLANDS-FORRAJES TROPICALES, V. 2, N. 1, P. 82-84.

OECD-FAO, 2018. AGRICULTURAL OUTLOOK 2018-2027. DAIRY AND DAIRY PRODUCTS. AVAILABLE AT: HTTP://WWW.AGRI-OUTLOOK.ORG/COMMODITIES/AGRICULTURAL-OUTLOOK-2018-DAIRY.PDF

PINEIRO-VAZQUEZ, AT AL., *ET AL*, 2018. EFFECT OF CONDENSED TANNINS FROM LEUCAENA LEUCOCEPHALA ON RUMEN FERMENTATION, METHANE PRODUCTION AND POPULATION OF RUMEN PROTOZOA IN HEIFERS FED LOW-QUALITY FORAGE. ASIAN-AUSTRALAS J ANIM SCI., 11, 1738-1746.

POORE, J, NEMECEK, T., 2018. REDUCING FOOD'S ENVIRONMENTAL IMPACTS THROUGH PRODUCERS AND CONSUMERS. SCIENCE, 360, 987–992.

UNFCCC. ADOPTION OF THE PARIS AGREEMENT, 2015A. AVAILABLE AT: HTTPS://UNFCCC.INT/PROCESS-AND-MEETINGS/THE-PARIS-AGREEMENT/D2HHDC1PCY

UNFCCC. NDC REGISTRY, 2015B. AVAILABLE AT: HTTPS://WWW4.UNFCCC.INT/SITES/NDCSTAGING/PUBLISHEDDOCUMENTS/PARAGUAY%20FIRST/DOCUMENTO%20INDC%20PARAGUAY%2001-10-15.PDF

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