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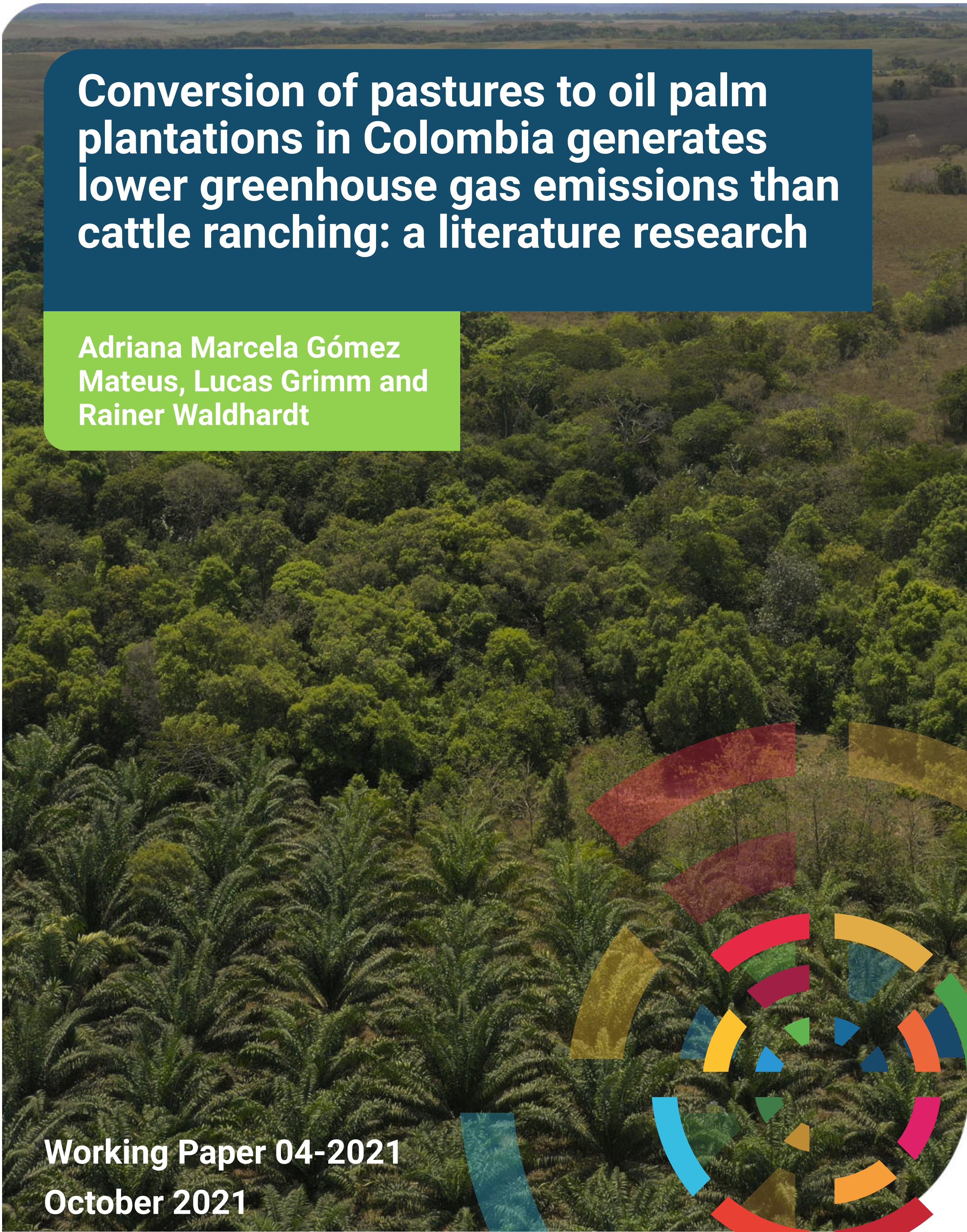

Conversion of pastures to oil palm plantations in Colombia generates lower greenhouse gas emissions than cattle ranching: a literature research

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Working Paper 04-2021
October 2021

DAAD The SDG[nexus] Network is supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ)

Conversion of pastures to oil palm plantations in Colombia generates lower greenhouse gas emissions than cattle ranching: a literature research

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Abstract

We conduct a literature research to compare GHG emissions between oil palm plantations and cattle ranching, two of the most common land uses in eastern Colombia. Our results show that conversion of pastures to oil palm plantations or cattle ranching generates greenhouse gas emissions (GHG). Oil palm cultivation generates lower GHG emissions than cattle ranching. Oil palms can stock high amounts of carbon and alternate uses of organic waste (e.g., composting, energy generation) lead to carbon sequestration and even to carbon savings. The establishment of oil palm plantations in eastern Colombia might mitigate the effects of global warming due to the creation of a carbon stock. The availability of pastures in Colombia offers an opportunity to minimize the impacts of future oil palm expansion. However, further studies are needed to understand the GHG emissions, carbon savings, and carbon stock values in the region, from the palm oil plantations and cattle ranching. In addition to its climatic performance, attention should be paid to how the land use change could improve sustainable production, and whether oil palm plantations or cattle ranching, in eastern Colombia, can contribute to both social and environmental factors.

Keywords: greenhouse gas emissions (GHG), oil palm plantations, cattle ranching, land use change

1. Introduction

Palm oil production has grown rapidly since 1970 and will continue to grow (Ritchie & Roser, 2021). The palm oil characteristics of high yields, low production costs, and versatility, as compared to other vegetable oils, make palm oil an indispensable ingredient for many products (Khatun et al., 2017; Qaim et al., 2020). Indonesia and Malaysia are the first and second large producers of palm oil (Ritchie & Roser, 2021). However, the oil palm expansion in south-East Asia has happened on previously forested land, causing deforestation, biodiversity loss, and generating a high amount of GHG emissions (Reijnders & Huijbregts, 2006; Ritchie & Roser, 2021). In Colombia, the fourth largest palm oil producer worldwide (FAO, 2020; Indexmundi, 2020), the oil palm expansion has happened on former pastures or degraded land. Thus, the agricultural expansion results in low levels of deforestation (Furumo & Aide, 2017; Vijay et al., 2016) and GHG emissions (Ramirez-Contreras et al., 2020). The National Association of Oil Palm Growers (Fedepalma) claims that the conversion of pastures into plantations in the eastern zone is a sustainable way of growing oil palm without causing deforestation, distancing their business from environmental problems linked to oil palm in South-East Asia (Michail, 2018).

The eastern zone of Colombia has the largest number of oil palm plantations (41%), compared to the Central Zone (31.4%), Northern Zone (23.19%), and the Southwestern Zone (4%) (Girón-Amaya et al., 2020). The eastern zone in Colombia has been rapidly changing because of intensive grazing, plantations of oil palm, rubber, and timber, and intensive cropping (rice, maize, soybean, sorghum, and sugarcane) (Ramírez-Restrepo et al., 2019). The land use change, palm oil production, and cattle ranching in the eastern zone are causing greenhouse gas emissions (GHG). Methane and nitrous dioxide are GHG with a high global warming potential (GWP) as compared to carbon dioxide (Myhre et al., 2013). The nitrous dioxide is the third biggest contributor to global warming after carbon dioxide and methane (NOAA, 2021) and derives from various sources in both palm oil cultivation and cattle ranching.

The GHG emissions come from different sources in the life cycle of palm oil production and cattle ranching. For instance, land conversion provokes carbon dioxide and methane emissions because of vegetation burning (Bergier et al., 2019; NOAA, 2021), the direct and indirect use of fossil fuels, pesticide use (Klaarenbeeksingel, 2009), and fertilizer application (Henson & Ruiz, 2012) provoke carbon dioxide emissions. On one hand, growing oil palm generates considerable amounts of GHG and changes carbon stocks in vegetation and soil (Wahyono et al., 2020). Cattle ranching, on the other hand, is the major source of methane emissions (Bergier et al., 2019; Chamberlain et al., 2015). Methane stems from the cow's enteric fermentation (Chamberlain et al., 2015). Methane emissions have higher global warming potential as compared to carbon dioxide (Myhre et al., 2013).

The present paper aims to evaluate the GHG emissions from oil palm plantations and cattle ranching, the most common land use in eastern Colombia. We conducted literature research to compare GHG emissions between oil palm plantations and cattle ranching in the eastern zone of Colombia. This paper is the first approximation to compare GHG emissions, reductions, and carbon saving from oil palm and cattle ranching. This information helps us to understand the GHG emissions sources and in the future to conduct field experiments and propose feasible solutions for the productive sector in Colombia. Our research questions are: first, which type of GHG emissions are generated by the oil palm plantations and cattle ranching in Colombia?, and second, which volume of GHG do these two activities emit? The two land use types are compared considering emissions of the three most significant GHG, carbon dioxide (including carbon stock changes), methane, and nitrous oxide.

2. Methods

This paper is carrying out a literature research to collect quantitative information about GHG emissions from oil palm cultivation and cattle ranching in Colombia. First, we selected studies related to GHG emissions in oil palm plantations and cattle ranching, primarily but not exclusively on the east of Colombia. Second, we selected the GHG emissions values (carbon dioxide, nitrous dioxide, and methane) from the selected studies. Third, we elaborated a quantitative comparison of the successional land uses and their carbon budget. We describe and compare the GHG emission for oil palm plantations and cattle ranching. The findings of the literature research are presented in Tables 1 and 2.

We present values in ton CO_2, or ton/CO_2-equivalent per hectare and year (CO_2-eq/ha/year), for comparison. Values found as ton/C (carbon stocks) were converted into CO_2-eq. by multiplying with the fraction 44:12 to account for the molecular mass of CO_2 (Penman et al., 2003). Those found as ton/CH_4 or N_2O were converted considering their global warming potential relative to CO_2. The functional unit is one hectare, for which an oil palm yield of 20 tons of fresh fruit bunch (FFB) per year was considered.

3. Results

3.1. Carbon dioxide emissions and carbon sequestration

Most of the carbon dioxide emissions are from pasture burning and direct fossil fuel use (DFF) and indirect fossil fuel use (IFF). Even when the highest possible emissions from DFF and IFF are combined with the lowest savings from land use change the conversion of pasture to oil palm would save 2.148 t CO_2-eq/ha/year, and up to 9.043 CO_2-eq/ha/year considering the lowest OP emissions and the highest land use change savings (*Table 1*, *Table 2*).

3.1.1. Land conversion

In Colombia, between 1990 and 2009, oil palm expansion occurred on shrubland (51%), savanna (42%), arable land (7%), and less than 1% from the forest (Castanheira et al., 2014). Castiblanco et al. (2013) reported, between 2002 and 2008, that 68.8% of new oil palm land happened on savannas in the eastern zone of Colombia. Oil palm expansion of savannas increases biomass and soil carbon, and thus, a carbon sink, as found out by Germer & Sauerborn (2008). The carbon sequestration is higher when oil palm plantations occur under savanna vegetation (Henson & Ruiz, 2012) (*Table 1*).

Cattle ranchers induce fire to eliminate inedible grass material for cattle and to stimulate vegetation regrowth during the dry season (Etter et al., 2011; López-Hernández et al., 2011). The quantification of emissions caused by these anthropogenic fires is rather complex because the values differ depending on the frequency of fires, the density of cows foraging on the savanna, and whether the fires are during the dry or rainy season (*Table 2*).

3.1.2. Emissions from the direct use of fossil fuels

The carbon dioxide comes from the use of fossil fuels for running combustion motors (e.g., agriculture machinery and vehicles). As for cattle ranching, no data on the direct use of fossil fuels were found (Hoogesteijn & Hoogesteijn, 2010) (*Table 1*, *Table 2*).

3.1.3. Emissions from Indirect use of Fossil Fuels

The production and transportation of plantation inputs, such as fertilizers, crop protection chemicals, machinery, are sources of indirect fossil fuel emissions. Assuming that cattle ranching in the eastern takes place on unimproved pastures (Etter et al., 2008), no emissions for input production and transport were considered (*Table 1*, *Table 2*).

3.2. Methane emissions

In oil palm cultivation, methane comes from wastewater management, palm oil mill effluent (POME). POME is usually discharged into open ponds (Rupani et al., 2010). The anaerobic conditions cause the generation of biogas, comprising methane and carbon dioxide (Rupani et al., 2010). It is possible to cover ponds or digester tanks to capture the biogas emitted by POME (Rupani et al., 2010). The methane can then be flared and turned into carbon dioxide or used to generate electricity, thus reducing the environmental impact of POME significantly (Wu et al., 2009). Another source of methane is the decomposition of empty fruit bunches (EFB) in dumping sites or buried (Baharuddin et al., 2009). Co-Composting POME and EFB is an alternative for waste management (Krishnan et al., 2016). The compost can be applied on the plantation and reduce the demand for mineral fertilizer (*Table 1*).

In cattle ranching, the source of methane comes from the cow's enteric fermentation (Chamberlain et al., 2015). A smaller amount of methane is also emitted when savanna pastures are burned (Bergier et al., 2019) (*Table 2*).

3.3. Nitrous oxide emissions

In palm oil cultivation, nitrous oxide emissions mainly stem from the application of mineral N fertilizer (Qaim et al., 2020; Ramirez-Contreras et al., 2020). In cattle ranching, nitrous oxide emissions come from urine and dung into the ground (Hoogesteijn & Hoogesteijn, 2010).

3.4. Overall GHG emissions from oil palm plantations and cattle ranching

The methane emissions are higher in oil palm plantations compared to cattle ranching only if EFB are dumped and POME is treated in ponds or digester tanks. However, when methane, from POME ponds, is captured for biomethane, GHG emissions are lower for oil palm plantations compared to cattle ranching. The emission difference is found to be 24.6179 t CO_2-eq. /ha/year in favor of palm oil cultivation. The average emissions for cattle ranching are 7.389 t CO_2-eq. /ha/year. The average emissions for palm oil plantations are 0.53 t CO_2-eq. /ha/year (*Table 3*).

Overall, cattle ranching contributed more to GHG emissions than oil palm cultivation considering the number of methane emissions and land cover change. The highest emission difference between oil palm plantation and cattle ranching is 39.0909 t CO_2-eq. /ha/year (*Table 3*).

Table 1 Types of GHG emissions (carbon dioxide, nitrous dioxide, methane) and carbon sequestration from oil palm cultivation processes. The process comprises land conversion, use of fossil fuels, fertilizer application, and treatment of sub-products (POME, EFB)

Item	Description	Emissions	Source
Carbon sequestration			
Land conversion	Pastures and savannas are turned into oil palm plantations	• The stock of soil organic carbon (SOC) stocks down to 50 cm constantly decreased until the beginning of the second oil palm planting cycle (breakpoint, 36.1 ± 9.0 years) at a rate of 1.26 ± 0.26 Mg C/ha/year. • The pasture-derived SOC stocks (102.8 ± 8.3 Mg C/ha) almost halved until the oil palms reached their time-averaged stocks equilibrium (62.61 ± 2.73 Mg C/ha). • Oil palm biomass carbon stocks: 49.5 ± 1.5 Mg C/ha. • Conversion of pastures to oil palm plantations is close to carbon neutrality (−0.5 ± 8.8 Mg C/ha). • Total ecosystem carbon in pastures at 112.8 ± 8.3 Mg C/ha total ecosystem carbon in oil palm plantations reaching 112.3 ± 3.2 Mg C/ha. • The emissions are neutral from land conversion and lead to a net sequestration of 135 Mg CO2-eq. / ha. • The aboveground biomass in oil palm plantations can fix about 129 ± 40 Mg ha CO2-eq. • Carbon accumulation: 3.3 ± 0.1 ton C/ha/year. • Yearly net sequestration: 2.04 ton C/ha or 7.48 t CO_2-eq./ha/year	(Quezada et al., 2019)
		• Carbon sequestration (1959–2009) in eastern Colombia: 5.445 ton CO_2-eq. per hectare and year.	(Henson & Ruiz, 2012)
		• Carbon sequestration: 24 or 54 ton C/ha or 4.4 or 9.9 t CO_2-eq./ha/year.	(Castanheira et al., 2014)
		• Increase of soil matter: net fixation of 13.2 ± 6.6 Mg C/ha after 25 years of economic life span through the augmentation of soil carbon.	(Germer & Sauerborn, 2008)
		• 25-year rotation (of oil palm) and 95% confidence interval to be 42.07 (42.04 - 42.10) Mg C/ha.	(Khasanah et al., 2015)
		• Aboveground biomass in unfertilized Llanos pastures at a maximum of around 3-4 Mg/ha.	(Anaya et al., 2009)
Carbon oxide emissions			

Direct use of fossil fuels	Direct use of fossil fuels for running combustion motors, for instance, in plantation machinery or transport vehicles	• 180 to 404 kg CO_2-eq. per hectare and year.	(Klaarenbeeksingel, 2009)
		• Diesel consumption in an oil palm plantation of 113 liters per hectare and year, and at 266 liters for its out-growers.	(Chase & Henson, 2010)
		• Combustion of one liter of Diesel leads to an emission of 2.65 kg of CO_2: emission of 299.45 kg CO_2- eq/ha/year and 704.9 kg CO_2- eq/ha/year.	(August, 2020)
		• Total emission from diesel consumption: 731.27 kg CO_2-eq/ha/year.	(Rivera-Méndez et al., 2017)
		• Diesel consumption at 114.7 kg CO_2-eq/ton/ CPO. • With an assumed input of 4,683 kg FFB for 1 ton of CPO and an average yield of 19.3 ton FFB/ ha/ year, direct fossil fuel emissions in this study reached 472.72 kg CO_2-eq/ha/year.	(Ramirez-Contreras et al., 2020)
		• Direct fossil fuel emissions in eastern Colombia to be 0.363 ton C-eq/ha/year, equals 1,332.21 kg CO_2-eq. Median value being at 666.075 kg CO_2-eq.	(Henson & Ruiz, 2012)
Indirect use of fossil fuels	Transportation of inputs e.g., fertilizers	• 0.251 ton C eq/ ha/year equals the emission of 0.92 ton CO_2-eq/ha/year.	(Henson & Ruiz, 2012)
		• The fertilizer and pesticide use oscillated between 470 and 884 kg CO_2-eq/ha/year. The mean value would then be 677 kg CO_2-eq/ha/year.	(Klaarenbeeksingel, 2009)
Nitrous Oxide Emissions			
Fertilizer	Application of N fertilizer	• 0.155 ton CO_2-eq. per hectare and year for eastern Colombia.	(Henson & Ruiz, 2012)
		• Production and application of ammonium sulfate and urea fertilizer: 0.119 and 0.134 ton CO_2-eq/ha/year.	(Wicke et al., 2008)
		• Emissions of 1.052-1.21 ton CO_2-eq/ha fin Malaysia, with a median value of 1.131 ton CO_2 ha/year.	(Kusin et al., 2017)
		• Emissions of 2.926 ton CO_2-eq. per hectare and year of urea and ammonium nitrate being used as average national fertilizers in Colombia.	(Ramirez-Contreras et al., 2020)
		• Minimal and maximal N_2O from poultry manure: 0.797 and 7.001 ton CO_2-eq ha/year. • Minimal and maximal N_2O for the four inorganic fertilizers: from 1.635 up to 7.672 ton CO_2-eq ha/year.	(Castanheira et al., 2014)

		• 48.7% of 119 kg CO_2-eq. emitted during the production of 1 t FFB was related to N fertilizer, leading to 1.159 ton CO_2-eq/ha/year.	(Choo et al., 2011)
		• Emissions from manure fertilizer and resulting N_2O of 1.14 and 1.01 ton CO_2-eq/ha/year.	(Chase & Henson, 2010)
		• In Indonesia, the N fertilizer emissions range between 0.183 and 0.46 ton CO_2-eq/ha/year, with a median of 0.3215 ton CO_2-eq/ha/year.	(Harsono et al., 2011)
		Methane emissions	
Treatment of sub-products from the milling process	Methane emissions from the residual products of the milling process, the palm oil mill effluent (POME)	• Average methane composition of 54.4% for anaerobic ponds, ranging from 35.0% up to 70.0. • Methane emissions: 3.617 ton CO_2-eq.	(Yacob et al., 2006)
		• 40% CH_4, also in anaerobic ponds.	(Wicke et al., 2008)
		• POME ponds emitted 125 kg CO_2-eq. worth of methane per t FFB, equaling 2.5 ton CO_2-eq/ha/year.	(Schuchardt et al., 2011)
		• Methane emissions from POME of 2.72 and 2.44 ton CO_2-eq.	(Chase & Henson, 2010)
		• Methane emissions: 2.8 ton CO_2-eq.	(Krishnan et al., 2016)
		• Methane emissions: 4.011 ton CO_2-eq.	(Choo et al., 2011)
		• The mean emission value of these findings is 3.051 ton CO_2-eq/ha/year.	Own calculations
	Treatment of POME in digester tanks	• 4.1 kg methane per t FFB or 2.3 ton CO_2-eq/ha/year.	(Stichnothe & Schuchardt, 2011)
		• 5.67 m^3/ ton FFB, equaling 2.286 ton CO_2.	(Stichnothe & Schuchardt, 2010)
		• 1.63 ton CO_2-eq. from an open digester tank at a CH_4-content between 13.5% and 49.0%, the other part being carbon dioxide emissions of about 0.32 ton per hectare and year, leading to 1.95 ton CO_2-equivalent.	(Yacob et al., 2006)
	Biogas capture from POME digester tanks or ponds	• Methane-derived emissions for an oil palm estate and its out-growers at 0.51 ton CO_2-eq. and 0.46 ton CO_2-eq.	(Chase & Henson, 2010)
		• Biogas capture and its use as energy with emission savings of 0.0023 ton CO_2-eq.	(Schuchardt et al., 2011)
EFB as mulch or in		• Emissions of 245 kg CO2-eq/ton FFB for the dumping sites, leading to 4.9 ton CO2-eq/ha/year.	(Stichnothe & Schuchardt, 2011)

dumping sites		• Emissions of 230 kg CO2-eq/ton FFB for dumping EFB, leading to emissions of 4.6 ton CO2 ha/year.	(Krishnan et al., 2016)
EFB as fuel and fiber		• Emission savings of 1.12 ton CO_2-eq for the use as biofuel in a combined heat and power plant, and 0.793 ton CO_2-eq for the biogas capture.	(Chiew & Shimada, 2013)
Co-compostin g POME and EFB	The compost can be applied on the plantation and reduce the demand for mineral fertilizer.	• Emissions of 7.4 up to 68.8 kg CO2-eq/ ton FFB, leading to 0.148 ton up to 1.376 ton, or 0.762 ton CO2-eq/ha/year as the median value.	(Stichnothe & Schuchardt, 2011)
		• Emissions of 0.11 ton CO2-eq/ha/year to co-composting.	
		• Composting emitted 0.0222 ton CO2-eq. per ton EFB, and at the same time saved 0.177 tons of avoided fertilizer use. • With a FFB/EFB ratio of 3.9, their findings lead to net savings of 0.787 t CO2-eq/ha/year.	(Chiew & Shimada, 2013)
		• Co-composting emitted 2.2 ton CO2-eq/ha/ year, considering 0.23 ton EFB / FFB, save 1.178 ton CO2-eq/ha/year worth of fertilizer, leading to net emissions of 1.022 ton CO2-eq. / ha / year. • The average emission of co-composting is 0.277 ton CO_2-eq/ha/year.	(Krishnan et al., 2016)

Table 2 Types of GHG emissions (carbon dioxide, nitrous dioxide, methane) from cattle ranching.

Item	Description	Emissions	Source
Carbon oxide, methane, and nitrous dioxide emissions			
Burning of savannas	To stimulate vegetation regrowth during the dry season	• Biomass loss during a fire: 2920 kg per hectare.	(Hernandez-Valencia & López-Hernández, 2002)
		• Dioxide emissions from vegetation burning: 4.98 ton/ha/year.	(Andreae, 2019)
		• The savanna burning accounts for 0.135 t CO_2-eq/ha/year nitrous oxide emissions, assuming an above-ground dry biomass of 3 tons and a N_2O emission factor of 0.17 g per kg burned dry matter.	(Andreae, 2019)

Cow densities	Methane emissions/ cow	• The estimated cattle densities in 2012 for the department in the eastern zone in Colombia are: Arauca (0.53 cow/ha), Casanare (0.51 cow/ha), Meta (0.24 cow/ha) and Vichada (0.03 cow/ha) (OIE Animal Health Information System, 2020). • The methane emissions for the eastern departments: Arauca (850.01 kg/year), Casanare (862.13 kg/year), Meta (876.75 kg/year,) and Vichada (892.37 kg/year). The median is 870.315 kg.	(FAOSTAT, 2020; IDEAM et al., 2015)
		• Manure: 1 kg per head and year.	(Cederberg et al., 2009)
Nitrous Exide Emissions			
Cow excretions	From the urine and dung into the ground	• Nitrous dioxide emission for 2012 in Arauca (0.484 ton CO_2-eq), Casanare (0.537 ton CO_2-eq), Meta (0.524 ton CO_2-eq) and Vichada (0.511 ton CO_2-eq).	(FAOSTAT, 2020; IDEAM et al., 2015)
		• The total nitrous oxide emissions from cattle ranching are 0.238 ton CO_2-eq/ha/year for low, 0.443 ton CO_2-eq/ha/year for middle, and 0.649 ton CO_2-eq/ha/ year for high animal densities.	(Andreae, 2019)

Table 3 Overall GHG emissions from oil palm plantations and cattle ranching. Own calculations based on the literature research

Item	Oil palm plantation	Cattle ranching
Land use change	Carbon sequestration: Average carbon sequestration of 4.4 or 9.9 ton CO_2-eq./ ha/ year.	The savanna burning accounts for 0.135 t CO_2-eq/ha/year nitrous oxide emissions, assuming above-ground dry biomass of 3 tons and a N_2O emission factor of 0.17 g per kg burned dry matter (Andreae, 2019). A standard value of 870 kg methane emissions from bovine enteric fermentation. We calculate the methane emissions from cattle for low (0.2 cow/ha), middle (0.6 cow/ha) and high (1 cow/ha) densities. The emissions per head and year: 174, 522, and 870 kg per hectare for the low, middle, and high cattle density.
Fossil fuel use	We calculated the direct fossil fuel emissions of 472.72 kg CO_2-eq./ha/year. We assume an input of 4,683 kg FFB for 1 ton CPO, an average yield of 19.3 t FFB/ ha/year.	No information on direct or indirect fossil fuel use.

Fertilizer application	Emissions from N application 2.926 ton CO_2-eq./ha/year.	No information on fertilizer application.
Organic waste management	Waste management would lead to methane emissions of 7.801 t CO_2-eq. /ha/year when POME treated in ponds, and EFB dumped. Savings of 0.0179 t CO_2-eq. /ha /year when POME biogas is captured and used for electricity generation, EFB is used as mulch. Average emissions from POME tanks would be 2.179 t CO_2-equivalent per hectare and year.	Cow excretions: The total nitrous oxide emissions from cattle ranching are 0.238 ton CO_2-eq/ha/year for low, 0.443 ton CO_2-eq/ha/year for middle, and 0.649 ton CO_2-eq/ha/ year for high animal densities (Andreae, 2019).

4. Discussion

Overall, oil palm plantations in the eastern zone of Colombia have a positive GHG balance as compared to cattle ranching. Quezada et al. (2019) found that pasture conversion to oil palm plantations causes almost neutral carbon emissions after 56 years. Castanheira et al. (2014) and Henson et al. (2012) also found a positive outcome for oil palm plantations. The oil palm plantations can reduce the GHG by capturing biogas from POME or co-composting. Using POME-derived biogas for electricity generation resulted in emission savings, as the energy can be used in the mill or induced into the national grid. However, Krishnan et al. (2016) pointed out that financial constraints exist to install biogas capture. Other waste management practices could also improve the GHG emissions of oil palm plantations at a lower cost. Lin Chiew & Shimada (2013) found that co-composting has the lowest energy demand of all waste management methods. Krishnan et al. (2016) argued that co-composting is an emission-saving method, thanks to avoiding emissions from chemical fertilizer and additional carbon sequestration through the use of compost for land and crops.

While oil palm-related deforestation appears to be low in eastern Colombia (Castanheira et al., 2014; Henson & Ruiz, 2012), we can only speculate so far on the effect that oil palm expansion into the Llanos might have on the quality of local aquatic ecosystems and aquatic life, as no publications seem to exist. It will most likely depend on the type and amount of fertilizer that is applied, and on how future palm oil plantations deal with POME. According to Rodríguez & Van Hoof (2003), 98% of palm oil mills in Colombia had water treatment systems in 2003, removing 95% of the organic load from POME, more than half of the mills disposed of their wastewater by leading it into water bodies afterward, thus contributing to eutrophication and losing aquatic life.

Pardo Vargas et al. (2015) argued that the availability of pastures in Colombia offered an opportunity to minimize the effects of future oil palm expansion. However, further evidence is needed on the potential adverse and positive impacts of biodiversity in oil palm plantations.

The literature research is a great source of information to know the GHG causes and the state of the art in GHG research in Colombia and the oil palm sector. However, the data has been calculated in different years, and comparisons among years and GHG types are complex. In this study, we provide some indications on carbon sequestration and GHG emission of oil palm plantations and cattle ranching processes. The results show that oil palm has a higher chance of carbon sequestration over the productive time in comparison to cattle. Thus, the amount and type of emission depend on the agricultural management practices. Sustainable management practices in both oil palm cultivation and cattle ranching could reduce GHG emissions and enhance agriculture practices and carbon sequestration (Johnson et al., 2007). More information on these management practices, GHG sources, and GHG emissions monitoring are needed. Therefore, field experiments are necessary to have recent GHG data on possible GHG emissions reductions and carbon sequestration in oil palm cultivation and cattle ranching in eastern Colombia.

5. Conclusions

According to the results, converting cattle pastures into oil palm plantations has a generally positive effect on GHG emissions in eastern Colombia. Ranching has lower emissions than oil palm only when the highest possible emissions from palm oil cultivation are compared to cattle ranching in its lowest density. Nonetheless, some factors remain subject to uncertainties. The results show that cattle ranching contributes more to GHG emissions than oil palm cultivation.

Methane emissions from EFB were found to be higher if dumped compared to alternative uses, while no data on emissions for using EFB as mulch were found, thus assumed to be zero. The emissions from co-composting POME and EFB are found to be relatively low.

Agriculture and livestock have the potential to reduce GHG emissions by incorporating better management practices that increase carbon stock, reductions, and savings. For instance, consider conservation areas for biodiversity, agroforestry, polyculture, or even mixing livestock and crops. Clear management practices for each production sector are needed to achieve sustainability of crop and livestock production regarding the local situation (e.g., type of soil, climate, water availability). Researchers and policymakers must work together to generate land use sustainable strategies, mitigate climate change, reduce GHG emissions and assure food consumption and food security.

Acknowledgments

This investigation is based on a literature research for a BSc thesis of the second author. We are grateful to Martin Petrick for comments on a draft version of the manuscript.

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Authors: Adriana Marcela Gómez Mateus, Lucas Grimm and Rainer Waldhardt

Recommended citation: Gómez, A. M. M.; Grimm, L.; Waldhardt, R. (2021). Conversion of pastures to oil palm plantations in Colombia generates lower greenhouse gas emissions than cattle ranching: a literature research, SDGnexus Network Working Paper 04-2021. Center for international Development and Environmental Research (ZEU), Justus Liebig University Giessen. DOI: http://dx.doi.org/10.22029/jlupub-249

Front cover photo: Adriana Marcela Gómez Mateus

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German Academic Exchange Service (DAAD) grant number 57526248,
programme "exceed - Hochschulexzellenz in der Entwicklungszusammenarbeit".