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EU Biofuel Policies in Practice – A Carbon Map for the Llanos Orientales in Colombia*

Mareike Lange and César Freddy Suarez

Abstract:

It is still difficult for biofuel producers to prove the contribution of their biofuels to reducing carbon emissions because the production of biofuel feedstocks can cause land use change (LUC), which in turn causes carbon emissions. A carbon map can serve as a basis to proof such contribution. We show how to calculate a carbon map according to the sustainability requirements for biofuel production adopted by the European Commission (EU-RED) for the Llanos Orientales in Colombia. Based on the carbon map and the carbon balance of the production process we derive maps showing the possible emission savings that would be generated by biofuels based on palm, soy and sugar cane if an area were to be converted to produce feedstock for these biofuel options. We evaluate these maps according to the criterion contained in the EU-RED of 35% minimum emission savings for each biofuel option compared to its fossil alternative. In addition, to avoid indirect LUC effects of the EU-RED that might offset any contribution of biofuels to reducing carbon emissions, we argue that all agricultural production should be subject to sustainability assessments. In this effort, our carbon map can be the basis for a sustainable land use planning that is binding for all agricultural production in the country.

Keywords: biofuels, carbon emissions, Renewable Energy directive, carbon map, land use change, Colombia

JEL classification: Q42, Q58, Q56, Q16

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1. Introduction

One of the components of the European Commission´s (EC) strategy to replace fossil energy sources by non-fossil renewable sources is to expand the production of biofuels. On the one hand, this promotion of biofuels has been widely criticized. Due to an increase in biomass demand for feedstocks for biofuel production and a continuously high demand for feedstocks in the food and feed sector, the demand for agricultural land is expected to increase globally (Erb et al. 2009, Hertel et al. 2008, Haberl et al. 2011). Meeting this demand causes emissions from LUC that still contribute approximately 9% to global emissions (Global Carbon Project 2011). Thus, it is questionable whether using biofuels can reduce emissions as long as there are any emissions from LUC.

On the other hand, biofuels are considered to be especially important for reducing the dependency of the transport sector on fossil fuel and for decarbonising the fuel it uses. Through its biofuel sustainability regulation (EU-RED), the EC seeks to achieve a minimum target of 10% renewables in the transport sector by 2020 (EU-RED 2009). The EU-RED was supplemented by a regulation stipulating a mandatory reduction of 6% in the emission intensity of fuels used in transport (European Union 2009) to emphasize the aim to reduce greenhouse gas emissions (emissions). According to the national renewable energy action plans biofuels will account for 90% of the mandated target of 10% renewables in the transport sector (EC 2011).

To ensure that biofuels contribute to a reduction in emissions and that biofuels are sustainably produced, the EU-RED contains a sustainability regulation in order to avoid undesirable LUCs caused by expanding biofuel feedstock production. These undesirable LUCs can be divided into direct land use change (DLUC) and indirect land use change (ILUC). DLUC is the conversion of land that has not been cultivated before, into land used to produce a particular biofuel feedstock. ILUC is an external effect of the promotion of biofuels. This effect is caused by changes in prices for agricultural products on the world market, particularly food and feed products in the form of grains and oils. The cropland used to produce food and feed is reduced globally when the cropland is used to produce biofuel feedstock instead. Consequently, the supply of food and feed products on world markets is reduced, which drives up their prices, which in turn creates an incentive to convert new land to produce food and feed.

Regarding DLUC, the EU-RED stipulates that, in order to be counted towards the 10% target imposed on the mineral oil industry, biofuel feedstocks may not be produced on land with high carbon stocks such as continuous forests or peatlands, or on land with high biodiversity.

In addition, in order to assure that biofuels reduce emissions even when they cause emissions from DLUC, the EU-RED stipulates a mandatory minimum emission saving threshold. Accounting for possible emissions from DLUC and emissions from production and transportation till the final use of the biofuel, it has to be proved that each biofuel provides emission savings of at least 35% compared to the fossil fuel alternatives

The EC implemented the EU-RED by adapting 13 certification schemes[1] aimed at verifying compliance with the sustainability criteria set out in the EU-RED, including those regarding DLUC. Within the certification process it is possible to account for possible emissions from DLUC as they can be directly linked to a particular biofuel production, and can thus be allocated to the specific emission balance of the biofuel at hand.

In practice, the main problem for producers to verify compliance with the sustainability criteria is to account for possible emission from DLUC because the land use at the beginning of 2008 must be known. This is because 2008 is the reference year to calculate emissions from DLUC. Thus, for an individual accounting of emissions from DLUC, the producer needs a land cover and carbon map of 2008 of the cultivation area used to produce the feedstock to be potentially certified. A carbon map displays the carbon stocks stored in the biomass and soil of different land covers. Such maps are often not available, particularly in remote areas. This increases the cost of the certification process for the individual producer as the land cover and carbon stock of 2008 would need to be determined in an individual assessment. This can be an exclusionary burden for small producers.

Beyond the direct accounting of possible emissions from DLUC for EU-RED, a carbon map could represent a tool for land use planning which aims at reducing emissions from LUC in general. If LUC is only allowed on areas with low carbon content, emissions from LUC would be reduced compared to a situation where LUC is allowed independent of the carbon stock stored in the expansion area. This is in line with the claim of researchers that LUC emissions cannot be controlled for biofuels alone but need to be controlled for all agricultural production in order to avoid ILUC effects.

Thus, the problem of ILUC regulation is only a problem of an incomplete emission accounting of land use practices when only biofuel production is subject to such accounting, but food, feed and bioenergy production other than biofuel production are not (see also Lange 2011, Lange and Delzeit 2012). A land use planning based on a carbon map for all agricultural production could thus be a tool used for an overall reduction of LUC emissions. Including all agricultural production in such land use planning by defining priority areas for expansion would account at the same time for the need of countries to further develop their agricultural sector and meet increasing global demand for agricultural production.

The use of maps that determine carbon stored in natural vegetation has already become the common tool for countries preparing for the UNFCCC (united Nations Framework Convention on Climate Change) REDD+ (Reduced Emissions from Deforestation and Degradation) mechanism that aims to pay developing countries to halt their deforestation (Gibbs et al. 2007) Such maps could be used to determine a baseline for the payments and to monitor deforestation over time. Two examples of global above ground carbon maps can be found in Saatchi et al. 2011 and Baccini et al. 2012. Due to their different purpose, maps produced for REDD+ cannot be used here as they focus only on determining

[1] ISCC, Bonsucro EU, RTRS EU RED, RSB EU RED, 2BSvs, RBSA, Greenenergy, Ensus, Red Tractor, SQC, Red Cert, NTA 8080, RSPO RED, Biograce GHG calculation tool

carbon in forests. In addition, they aim at determining forest carbon dynamics, do not necessarily start at the baseline year 2008 for biofuels and do not necessarily have a spatial resolution of 30 meters as required by the EC.

In this paper we show how such a carbon map could be derived for the Llanos Orientales in Colombia and discuss which consequences such map brings for a sustainable land use planning in this region. We begin by briefly presenting the method and data requirements to calculate LUC emissions in the EU-RED context which draws on the method in the IPCC 2006. We then introduce the pilot region Llanos Orientales by giving a brief overview over the land use and agricultural sector. Next, we present the database for our calculation of the carbon mapping and then present the results carbon maps. Finally, we apply the carbon mapping to the sustainability requirements of the EU-RED and draw conclusions. A similar analysis for Kalimantan and Sumatra can be found in Lange 2013.

2. EU-RED sustainability requirements and land use change calculation

To first understand which criteria a carbon map for the EU-RED needs to fulfil, in this section we shortly discuss the sustainability requirements of the EU-RED. These sustainability requirements mainly tackle the problem of possible DLUC to produce feedstocks for biofuel production. Under this framework, which is shown systematically in figure 1, biofuels and bioloquids shall not be made from raw material obtained from land with high biodiversity value (primary forest and other wood land; areas designated for nature protection or protection of rare, threatened, endangered ecosystem or species; and highly biodiverse grasslands), lands with high carbon stocks (wetlands, continuously forested areas with a canopy cover higher than 30%[2], and land spanning more than one hectare with trees higher than five meters and canopy cover of between 10% and 30%, unless evidence is provided that the carbon stock before and after conversion apply to saving greenhouse gas emission at least at 35% (EU-RED Art.17(3,4)).

For all other production areas, accounting for possible emissions from DLUC and production and transportation emission, it has to be proved that the resulting biofuel will provide emission savings of at least 35% compared to the fossil fuel alternatives (EU-RED Art 17(2))(third column of Figure 1) This implies that biofuel crops produced on land with high carbon content before the LUC are less likely to achieve this target as well as biofuels with low energy yields per hectare and high process emissions. This minimum emission saving threshold will be increased to 50% in 2017 and 60% in 2018 for new installations for biofuel production (EU-RED 2009).

These sustainability requirements need to be met by both imported bioliquids and bioliquids produced within the European Union in order to count towards the national targets of renewable energy.

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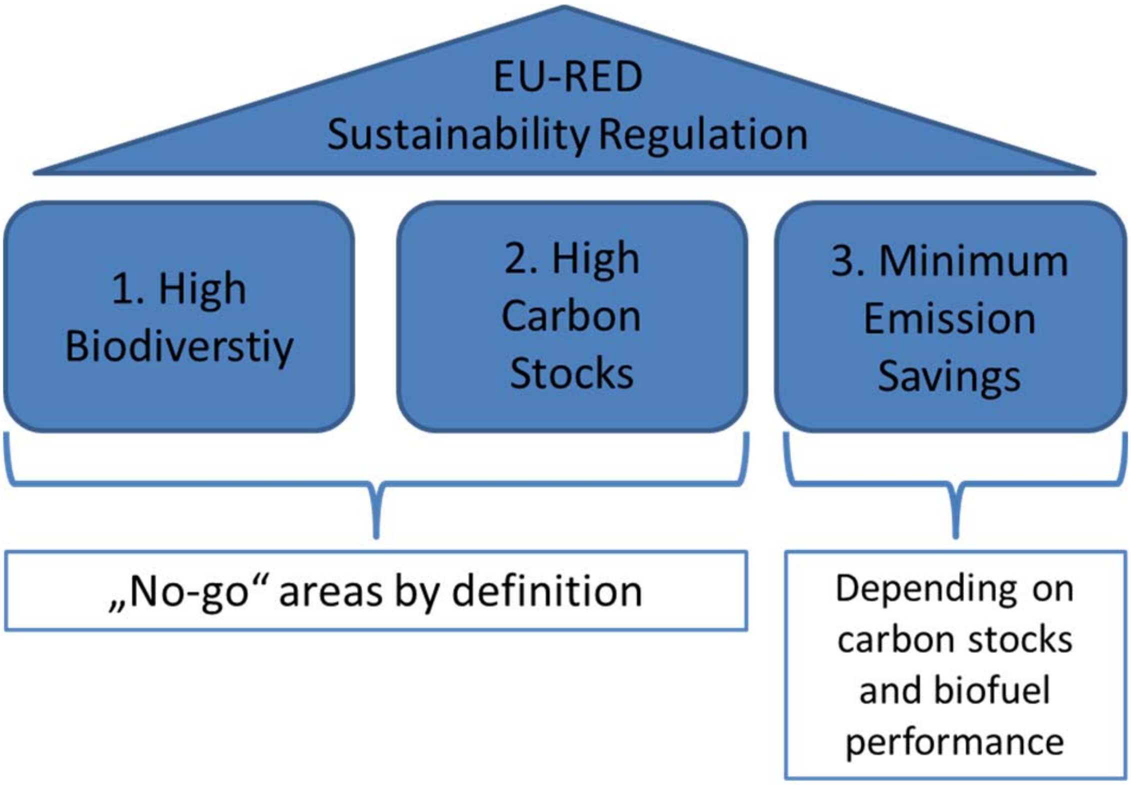
[2] This corresponds to the upper level of canopy cover of the forest definition in UNFCCC (2001)

Figure 1. Framework of the EU-RED sustainability regulation



This paper focuses on the third column of the sustainability criteria, which is all area not already excluded by definition from being suitable for biofuel production. However, as far as possible, column 1 and 2 are included into the final maps in order to get the full picture. Thus, the major challenge of this paper is to provide a good measurement of potential DLUC emissions that would occur if an area where to be converted for biofuel feedstock production. This measurement is based on the carbon map.

According to the EU-RED, the method and data used for the calculation of emissions from DLUC should be based on the IPCC Guidelines for National Greenhouse Gas Inventories – Volume 4 (IPCC 2006) and should be easy to use in practice (EU-RED Annex V C(10)). With the "Background Guide for the Calculation of Land Carbon Stocks in the Biofuels Sustainability Scheme drawing on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories" Carré et al. 2010 published guidelines for the calculation of land carbon stocks for the purpose of Annex V of the EU-RED. We present this method in order to produce the carbon map after introducing the study region Llanos Orientales.

3. The Llanos Orientales

The study area is located within the Orinoco basin which lies between Colombia and Venezuela from the Andes to the Atlantic. The river flows 2140 km from its source in the extreme south of the Guianan massif until it reaches the ocean. Its tributary basins represent one of the most biologically and hydrologically diverse areas of the world. It is considered to be the 3rd most important river system on the planet, particularly due to the volume of water flowing into the Atlantic - an average of 36000 m3 per second.

The combination of three different ecosystems (Andes, Guiana and Orinoco Delta) forms an extraordinary aquatic and terrestrial biodiversity within the ecoregion. To date, 17420 species of plants, 1300 species of birds, more than 1000 species of fish, 250 mammals and 119 reptiles have been recorded in the area. The area also has a high ethnic diversity and is home to different indigenous groups.

The Llanos of the Orinoco is an open land, flooded in the rainy season, dried out in the dry season. They are some of the world's richest tropical grasslands, harbouring more than 100 species of mammals and over 700 species of birds.

The study area which we call "the Llanos" throughout the paper has an area of approximately 14,9 million ha. Its limits are the 1500 m of altitude over the Andean Mountain at the west, the international boundaries with Venezuela at the North and East, and the Amazon biome at the South. The extension is along the Vichada, Arauca, Casanare, Boyacá, Cundinamarca and Meta departments.

The study region has been selected based on areas projected for oil palm expansion in the Orinoco basin in the near future which is the main potential biofuel feedstock produced in this region. During the last decade, the area cultivated in oil palms increased 104.621 hectares, from 53.783 in 2000 to 158.404 hectares by 2010 which account for 39.40 % of the total area currently planted in oil palm in Colombia (Palacios Lozano 2011). This growth was mainly in response to governmental incentives in the form of credits , hedge loans, research and technology transfer for increasing palm oil for exports as well as meeting blending targets for biodiesel production (5% in 2008) (Pacheco 2012). Currently Colombia does not export biofuels because it is still lacking behind to cover the local demand. However, the palm oil planted area is increasing and has doubled since 2001. The Colombia Palm Growers Federation (FEDEPALMA) considers that with the current expansion in the area planted, an internal blending capacity of B20 would be possible. It is expected that in the medium term, Colombia may become an exporter of biofuels, particularly biodiesel from palm oil, as expansion of palm oil area continues (Pinzon 2012).

This expected increase in production is further triggered by an expected increasing demand for vegetable oils on the world market for food and bioenergy production. This expected increase should influence the choice of new areas for palm oil plantations today as they are a long term investment for at least 20 years due to the life cycle of an oil palm. In order to maintain all export options to the international markets, the currently implemented sustainability criteria for biofuels in the European Union should be integrated into the spatial planning for new areas for palm oil plantations and other biofuel crops. In this sense, in the next section, we show how a carbon map according to the EU-RED could be developed for the Llanos Orientales in Colombia. Such carbon map is not only useful to prove compliance with the EU-RED sustainability criteria but can be used for a low carbon strategy to develop the agricultural sector in the region.

1. Carbon Mapping according to the EU-RED for the Llanos Orientales in Colombia

In this section we demonstrate the method of the EU-RED for calculating carbon emissions from LUC as presented in Carré et al. 2010. We only go into the details of Carré et al. 2010 where it is relevant for our purpose. After each calculation step we represent the data used for the carbon map of our study region.

For the calculation of a carbon stock (CS_{il}) per unit area *i* associated with a particular land use *l*, the carbon stock stored in the soil $(SOCact_{il})$ and the carbon stock stored in biomass $(Cbio_{il})$ need to be summarized and multiplied with the hectares per unit area (A_i). [3]

$$CS_{il} = (SOCact_{il} + Cbio_{il}) \times A_i \qquad (1)$$

a. Biomass Carbon

I. Method

For the calculation of carbon stock stored in biomass $(Cbio_{il})$ it is assumed that it can be subdivided into carbon stock stored in above ground biomass (C_{AGB}), below ground biomass (C_{BGB}) and dead organic matter (C_{DOM})[4]. The carbon stock stored in below ground biomass is normally calculated by applying a constant ratio factor (R) to the carbon stock stored in above ground biomass.

$$Cbio_{il} = C_{AGB} + C_{BGB} + C_{DOM} \qquad (2)$$

$$C_{BGB} = C_{AGB} \times R \qquad (3)$$

II. Data

Different methods are available for the calculation of the carbon stock stored in biomass. The very basic method for producers is to produce ground based inventory data of the land cover classes present on their land. The carbon values could be determined by field surveys on the diameter at breast height which along with information on tree height can be converted to estimates of forest carbon stocks using allometric relationships (Wertz-Kanounnikoff 2008). Data on the allometric relationship can be based on data from sample sites or forest inventories (Wertz-Kanounnikoff 2008). However, this method seems like a disproportional burden particularly for small producers. In addition, to determine

[3] Normally one uses one hectare as the unit area. However, it could be every other area like the area of a pixel if the analysis is made on the basis of a raster data set.
[4] In line with the EU-Red we use a value of 0 for C_DOM, except in the case of forest land – excluding forest plantations – having more than 30% canopy cover.

LUC emissions, not the present but the land cover present in 2008 is the reference land cover. If there have been changes in between, it might be difficult to retrace the land cover in 2008.

The most commonly used method is to use land cover maps based on satellite images and to combine them with carbon values that represent the biome-average carbon value. This method corresponds with the Tier 1 method of the IPCC. The EC adopts this method presenting carbon values for the purpose of calculating emissions from LUC in Carré *et al.* 2010. Other data sources are the scientific literature on carbon values generated on sample sites. A major drawback of this method is that the biome average analyzed in the scientific literature does not necessarily adequately represent biomes or regions or overestimate the carbon stored in premature stands (Gibbs et al. 2007, Wertz-Kanounnikoff 2008, Goetz et al. 2009)

There has been a fast development of techniques to determine above ground biomass carbon in particular for tropical forests via remote sensing techniques based on active signals such as Synthetic Aperture Radar technologies (SAR) and or Light Detection and Ranging (LIDAR) (Engelhart et al. 2011). The signal of SAR penetrates through clouds and returns the ground terrain as well as the level of the top of the canopy cover which in turn gives the basis for deriving the height of the biomass cover. Thus, SAR provides a 2 dimensional image of the ground. If slightly different angles are used, this 2D image can be converted into a 3D image. The knowledge about typical biomass heights of different land covers can then be used to derive a land cover map (Mette et al 2003, Kellndorfer et al, 2004, Shimada et al 2005). Recent applications to tropical forest can be found e.g. in Gama et al. 2010, Engelhart et al. 2011, Kuplich et al. 2005, Michard et al. 2009, Pandey et al. 2010 or Santos et al. 2006)

Instead of using radar signals, the Light Detection and Ranging (LIDAR) method uses pulses of laser light and analyses the signal return time (Engelhart et al. 2011). This method cannot penetrate through clouds but allows estimating the height and density of the biomass cover resulting in a detailed 3D image (Patenaude et al 2004). The biomass density and height is linked to biomasses and thus the 3D image can be converted into above ground carbon estimates applying allometric height–carbon relationships (Hese et al 2005). Recent application for tropical forest can be found e.g. in Saatchi et al 2011, Duncanson et al. 2010 or Zao et al. 2009.

The purpose of this paper is not to evaluate the different methods but to demonstrate the use of the available data and maps for the sustainability regulation of the EU-RED[5] in the Llanos. We therefore use the carbon average method together with a satellite based land cover map based on the following arguments:

- The resolution of the map must be 30 meters according to EU-RED: The resolution of global remote sensing data from Radar or Lidar technology such as Saatchi et al 2011 that also covers the Llanos Orientales have much lower resolutions.

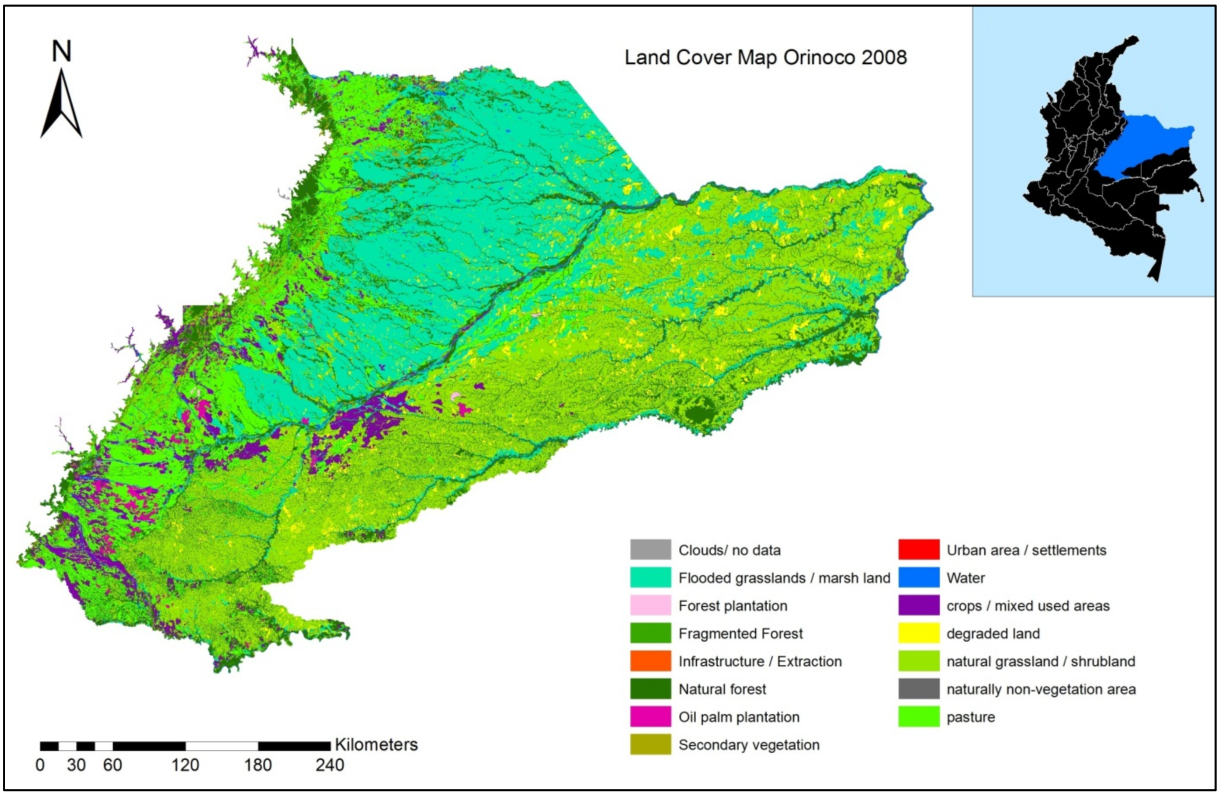
[5] A comparison of different methods can be found in Goetz et al. 2009 or Wertz-Kanounnikoff 2008.

- The motivation behind Lidar and Radar applications is mostly because REDD+ projects require an explicit determination of the carbon stored in the biomass of forest to determine a baseline for the payments for ecosystem service mechanism. For the EU-RED the land cover change/land use change emissions are the important figure to determine. However, this is less relevant for forest as forests and wetlands are generally excluded from being suitable areas for feedstocks to produce biofuels.
- Most of the area in the Llanos Orientales is covered by different savannah types and not by forest. Thus, it is difficult to differentiate between different biomass types. For example it might be difficult to differentiate between natural grassland and pasture because their above ground biomass density and height is similar. However, their below ground carbon might differ substantially. Thus, Lidar and Radar technology might not differentiate enough between different land cover types. In addition it is crucial to know the land cover and land use to determine the soil carbon.
- Part of the area is covered with water for several month of the year. In most of the areas varies the water content throughout the year substantially. Some projects using active data show that they have difficulties with high water content in the soil (e.g. OIR 2013. Thompson and Maune 2013).
- Cost – benefits: Landsat and others optical sensors are cheaper than LIDAR or SAR technology.
- Last but not least, the impact of a derived carbon map strongly depends on acceptance of policy makers and producers in the country. The land cover map used in this paper is officially recognized by the ministry of Environment in Colombia.

The carbon values that we use for the land cover classes where derived by studies in local assessments in the Llanos Orientales and/or the rest of Colombia. Thus, these values where particularly determined for the region that the map covers and therefore can be considered representative for the different land cover classes.

To map the carbon stock stored in above ground biomass in the Llanos Orientales, we use the land cover map made by IDEAM et al. (2012) based on the CORINE (Coordination of Information on the environmental) classification system which was adapted to Colombia (IDEAM, 2010). The land cover map was updated from the land cover map for the period (2000-2002) through Landsat images at scale of 1:100 000 and a spatial resolution of 30 meters (IDEAM *et al.* 2010). To update the map at January 2008 according with EU-RED (2009), we use Landsat images from December 2007 up to February 2008, interpreting them with onscreen digitization into vector format, updating the extension and areas of each polygon land cover class according with the Landsat image changes. Figure 2 shows the resulting land cover map for 2008.

Figure 2.

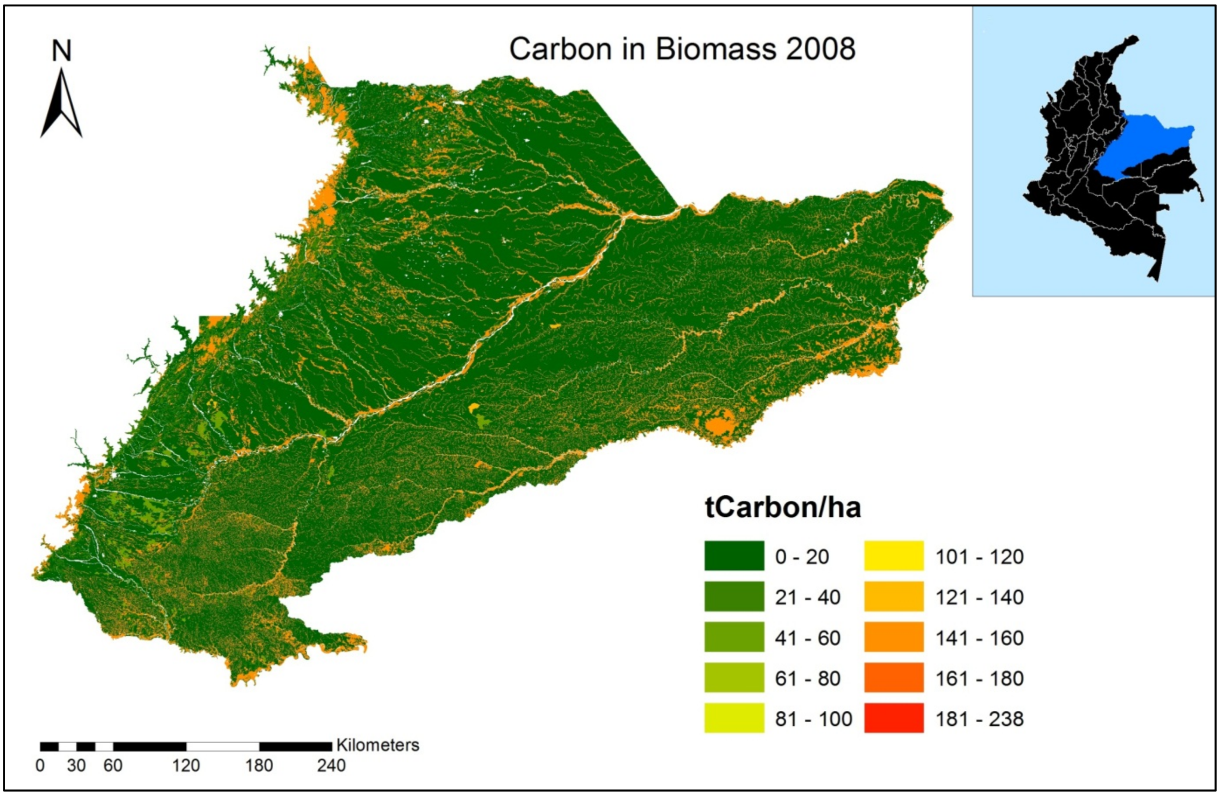


To convert the land cover map into a map that displays the carbon stock stored in above ground biomass, the values for carbon stock stored in above ground biomass associated with different land cover classes were taken from several sources. All values could have been taken from the Carré *et al.* 2010 or the IPCC 2006, however, these carbon values do not always correspond one to one to the land cover classes in the map. Furthermore, Carré *et al.* 2010 or the IPCC (2006) values are, if at all, only specified for South America in general and not specific for Colombia or the Llanos Orientales. For the forest land cover classes we mainly use data from the Institute for Hydrology, Meteorology and Environmental Studies (IDEAM) from the Colombian Ministry of Environment and Sustainable Development (Phillips et al. IDEAM (2011)). Carbon values to other land cover classes were taken from Yepes *et al.* IDEAM (2011), who compiled and summarized the biomass and carbon stored on various land cover types to Colombia. However, these two sources do not cover the natural grassland areas in the Llanos Orientales. Values about carbon in different savannah types where calculated by Etter et al. 2010 in local assessment in the Llanos Orientales and thus have a high specificity[6]. Missing values and values for perennial crops were taken from Carré *et al.* 2010. All carbon values used in our calculation can be found in Appendix 1 of this paper. For some of the carbon values taken from the Carré *et al.* 2010 or the IPCC 2006 the climate zone of the area must be known. For this purpose, we used the climate zone map provided by the Joint Research Center (EC-JRC 2010).

6 San José et al (2008) calculate carbon values for the same ecosystems in Venezuela but get slightly lower values than those used in our calculation.

Figure 3 shows the resulting map of carbon stocks stored in total biomass. One can clearly determine the difference in carbon content between forest areas at the foothill of the Andes or riparian forest and the grassland and savannah areas.

Figure 3.



b. Soil Carbon

I. Method

For the calculation of the carbon stock stored in the soil, information of the land cover map needs to be combined with a soil map. This is because the carbon stock stored in the soil under natural vegetation is changed once the land is used for agricultural production. Soil maps are commonly provided by national institutions as they cannot be derived directly from remote sensing methods. Here, WEonly consider the Tier 1 approach of the IPCC 2006 which models soil carbon stocks influenced by climate, soil type, land use, management practices and inputs. The method is based on the assumption that the actual carbon stock stored in the soil $(SOCact_{il})$ is the product of the carbon stock under natural land cover $(SOCref_i)$ and the influence of land use (Flu_l), management (Fmg_l) and input factors $(Fi_{\ l})$, which can increase or decrease the carbon content under natural land cover.[7] Thus, the working steps to be done for the calculation of a soil carbon map is to first choose a suitable soil map, second, allocate the carbon values for soil under natural land cover to the soil categories in the map and, third, define and allocate the influence factors from the IPCC 2006 based on the land cover map (see

[7] The EU Background Guide gives more details and data about land cover classes not explicitly covered by the IPCC 2006 e.g. savannahs and degraded land.

equation 4).

$$SOCact_{il}\left(\frac{tC}{ha}\right) = SOCref_i\left(\frac{tC}{ha}\right) \times Flu_l \times Fmg_l \times Fi_l \qquad (4)$$

The reasons why we generally exclude peatland areas from this mapping exercise are the following. The carbon content is to be calculated for the first 30 centimeters according to EU-RED as this is the layer where most of the carbon is stored in mineral soils. This does not apply for peatswamp areas which can have a thickness of several meters. In addition, the EU-RED method based on the IPCC 2006 assumes that the carbon content of a soil after a LUC stabilizes again after 20 years of agricultural production (excluding emissions from tillage and inputs). This is an arbitrary assumption for calculation purposes but not totally unrealistic for mineral soils. However, peatland soils converted to agriculture can keep on causing emissions for hundreds of years and for sure do not stabilize after 20 years. For a discussion of annual emission factors for different land uses in Southeast Asian peatlands see e.g. Hergoulc'h and Verchot (2013).

II. Data

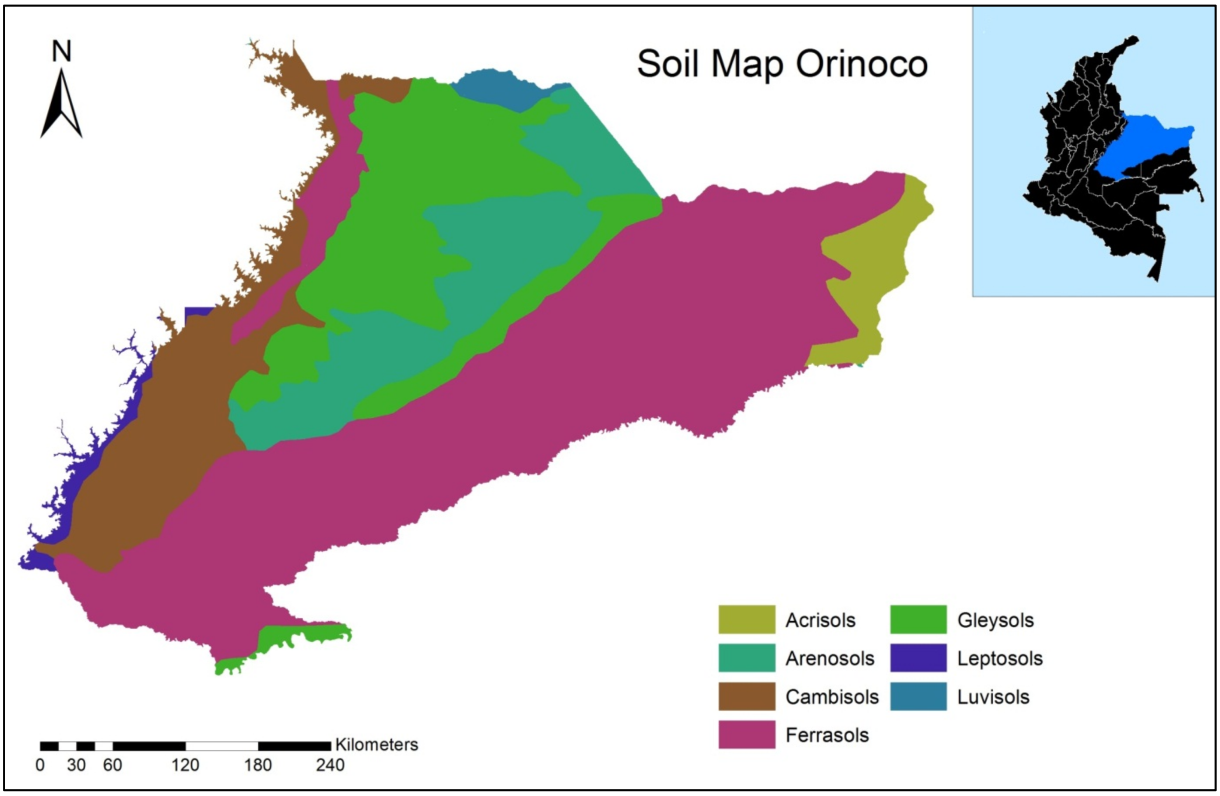
The EC provides a soil map based on the FAO harmonized world soil database (HWSD) generated by IIASA (FAO/IIASA/ISRIC/ISSCAS/JRC, (2012).[8] The categories used in this map correspond to the categories of the SOCref values in the IPCC 2006. The HWSD is shown in Figure 4.

These values are climate region specific. To determine the climate zone of a certain area we use the climate map provided by the EC. As a first step we then get a map of soil carbon as if the whole area where under natural land cover. The SOCref carbon values corresponding to the soil map categories are taken from the EU Guidelines which corresponds to the data in IPCC 2006.

As a second step, to determine the actual carbon stock stored in the soil, the carbon stock under natural land cover must be adjusted with the soil use factors that correspond to the current (2008) land use. For natural land cover these factors are 1. Thus, the soil carbon under natural vegetation remains the same after this calculation step.

[8] We know of a soil map that the National Geographic Institute of Colombia produced for the Llanos. However, we did not have access to this map. Once this map is available for the public we will be able to further regionalize the data source for the soil. Nevertheless, we did robustness checks for our analysis with higher natural carbon stocks in the soil. This did not substantially change the final results as it is mainly the relative changes in carbon stocks that drive the results and not so much the natural level of carbon stocks.

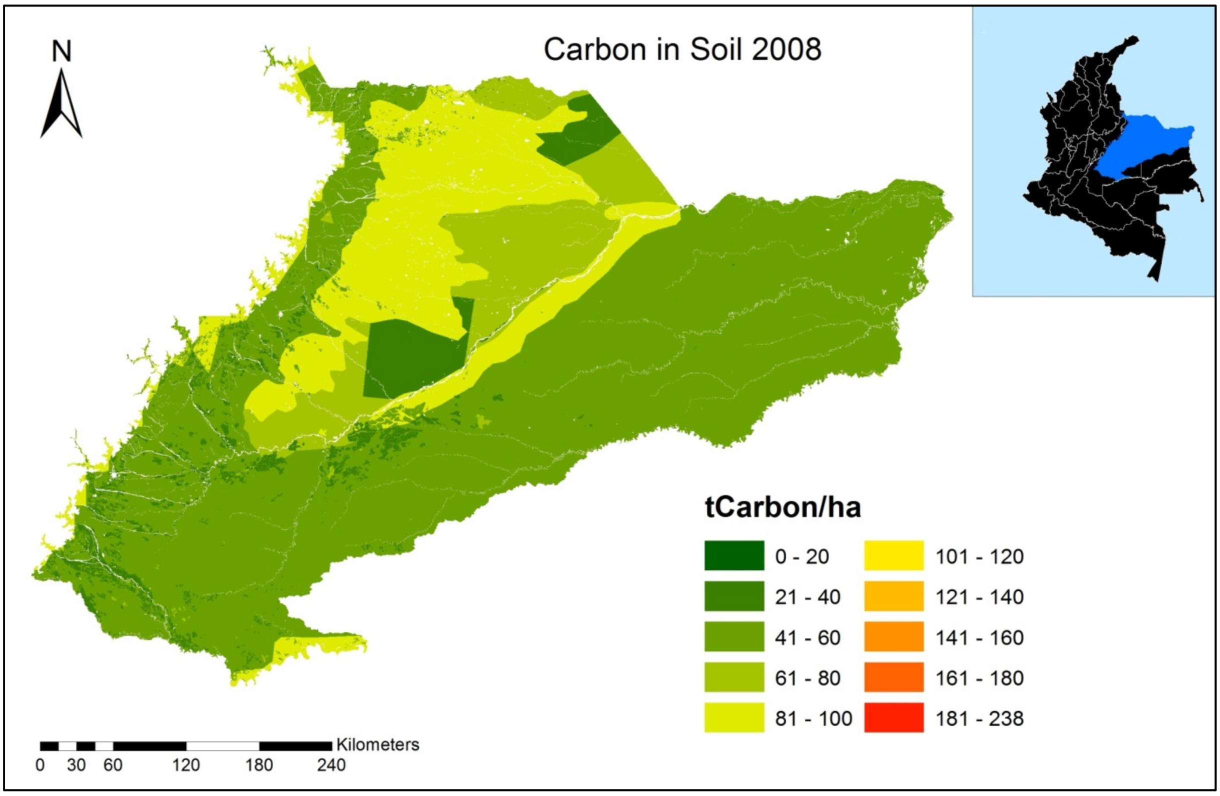
Figure 4.



For all other land use with non-natural land cover, these factors indicate how much the land use type (Flu_l) the management practice (Fmg_l) and the inputs (Fi_l) change the carbon stock stored in the soil compared to a natural land cover. The categories for the land use type factor are annual cropland, perennial cropland, pasture or forest plantations. The categories for management factor mainly account for the tillage regime and the input factor account for the amount of fertilizer/manure applied to the production. In order to determine which of these factors apply, we use the land cover map. We do this by defining for each land cover category the land use factor, the typical management regime applied for a particular land use in the Llanos and the corresponding typical input. These typical management and input regimes where discussed with stakeholders in the region. The corresponding values for the factors are exclusively taken from the EU/RED and the IPCC. Thus, to determine the actual carbon stock stored in the soil ($SOCact_{il}$) we multiply the SOCref calculated in the first step with these soil factors.

The result of that calculation is shown in figure 5. One can clearly identify the marsh land in the north-west of the Orinoco region which are very rich in carbon.

Figure 5.

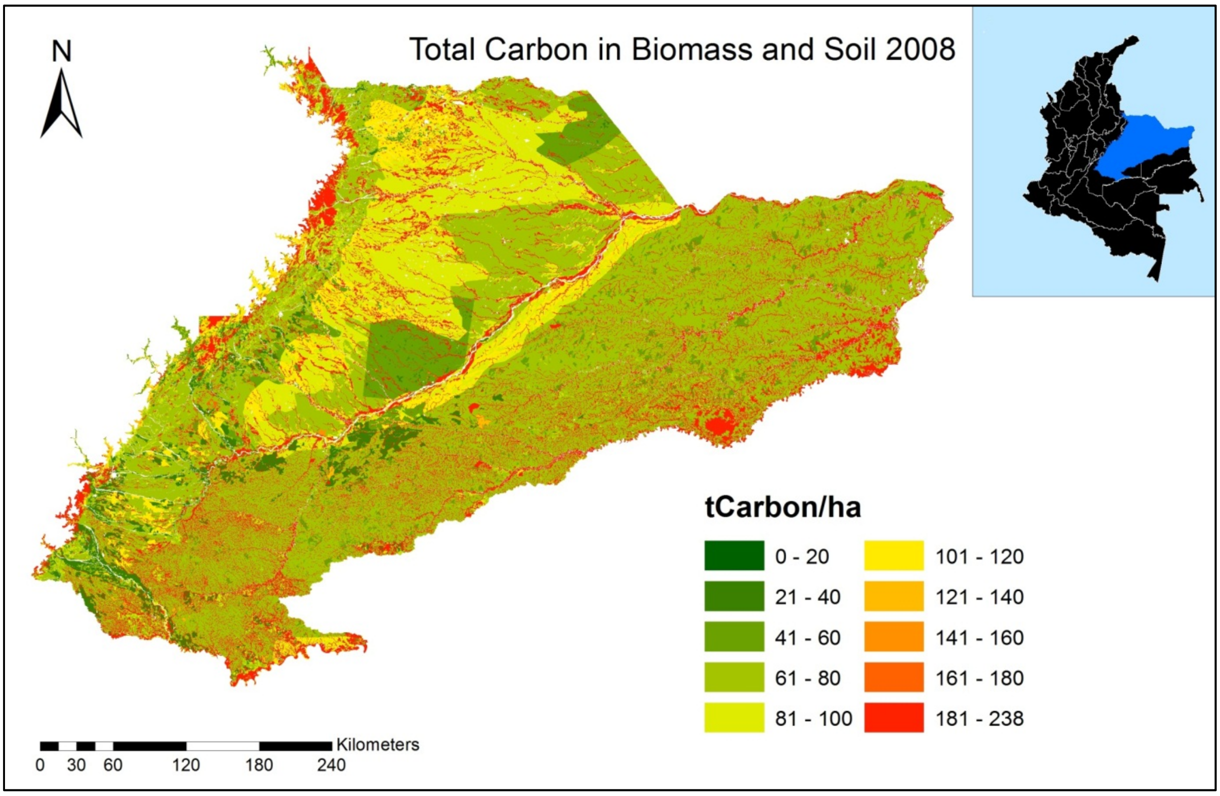


c. Result Colombia

We calculate the final carbon map by overlaying the map about carbon stocks stored in total biomass and the map about actual carbon stocks stored in the soil. The result in figure 6 is a carbon map which indicates the high and low carbon stock areas in 2008. Areas with high carbon stocks are mainly those with shrub or wooden vegetation e.g. at the foothill of the Andes or in riparian areas. Particularly north the Orinoco River, where totally flooded or partially flooded areas are dominant, one can identify higher carbon areas due to higher soil carbon.

Our resulting carbon map can serve as a basis for a low carbon spatial planning for a sustainably expanding agricultural sector. Low carbon stock areas could be priority areas for agricultural expansion whereas high carbon stock areas should remain untouched for a climate friendly expansion policy.

Figure 6:



In terms of the practical implementation of the sustainability regulation of the EU-RED, a further step of calculation is necessary. To prove the compliance with 35% emission saving threshold, we need to calculate the emission savings for each spatial unit that would occur if this spatial unit were to be converted into cropland to produced biofuel feedstock. Thus, we calculate the emission savings of each spatial unit if this unit were converted into a cultivation area to produce feedstock for biofuel production. Emission savings represent average annual savings for a production period of 20 years.

For the calculation, first, the emissions caused by the land use change (LUC_i) needs to be calculated by taking the difference between the carbon stocks stored in the land use at t0 ($CS_{i_{before}}$) (which is 2008 for the current regulation) and the carbon stocks stored in the land use at t1. For our purpose, t1 represents the carbon stock stored in the feedstock for biofuel production($CS_{i\_biofuel\_feedstock}$).

$$LUC_i = CS_{i_{before}} - CS_{i_{biofuel_{feedstock}}} \qquad (5)$$

We derive $CS_{i\_biofuel\_feedstock}$ for each crop by repeating all calculations steps again under the assumption that all areas are under palm plantations, sugar cane or soy respectfully.

Second, we convert the total emissions caused by the land use change (LUC_i) into emissions per year on the basis of a 20 year period and convert carbon stocks into carbon dioxide stocks by multiplying the former by the factor 3.664. Third, we convert the LUC emissions per hectare into LUC emissions of the final biofuel unit (LUC_{mj_i}). Thus, we divide the LUC emissions per hectare with the energy yield per hectare of the biofuel feedstock (P_i). Consequently, the resulting LUC emissions per MJ biofuel (LUC_{mj_i}) are specific for each biofuel due to the specific energy yield per hectare. Higher energy yields result in fewer emissions per MJ biofuel.[9]

$$LUC_{mj_i}\frac{CO_2}{MJ} = LUC_i\frac{C}{ha} * 3.664 * \frac{1}{20} * \frac{1000000}{P_i\frac{MJ}{ha}} * AL_i \qquad (6)$$

To complete the calculation of the LUC emissions, the EC allows for an allocation of the resulting LUC emission to each biofuel or its intermediate products and possible by-products. The allocation factor (AL) should be calculated on the basis of the energy content, that is, the lower heating value. This means that for example from the soy bean, only the oil is used for biodiesel production. The remaining soy cake is mainly used as animal feed. Consequently both the soy cake and the soy oil are evaluated with their lower heating values. Then, land use and production pathway emissions are allocated to the emissions caused by the soy biodiesel in the same proportion as the proportion of the soy oil on the total lower heating value of the harvested soy bean.

Table 1. Feedstock and biofuel specific values

	$P_i\frac{MJ}{ha}$	Source	AL_i	Source	WTW_i	Source
Palm biodiesel with methane capture in the production process	140758	Pancheco (2012) and FNR (2012)	0.91	IES 2008	37	EU-RED
Palm biodiesel without methane capture in the production process	140758	Pancheco (2012) and FNR (2012)	0.91	IES 2008	68	EU-RED
Soy biodiesel	19719	FNR (2012)	0.32	IES 2008	58	EU-RED
Sugar-Cane ethanol	134573	FNR (2012)	1	IES 2008	24	EU-RED

As a last step, We calculate emission savings (ES_i). Emission savings mean savings generated due to the use of biofuel feedstock compared to the alternative use of fossil fuels. The term "emission savings" used by the EU-RED is slightly misleading as it does not indicate that every biofuel saves emissions. It could be also negative if the production and use of the biofuel causes higher emissions than the fossil fuel alternative. With respect to LUC emissions, one can generally say that **high LUC emissions due to high carbon stocks before the LUC result in low or negative emission savings.**

As the three factors, the energy yield per hectare ($P_i\frac{MJ}{ha}$), the emission caused in the production process (WTW_i) and the fraction of the biomass that is allocated to the biofuel production (AL_i), are specific for each biofuel option, also the resulting emissions savings are specific for each biofuel option(see

[9] We assume no production on degraded land and thus ignore a possible emission bonus granted by the EU-RED for emission savings.

Table1 for the values used for equation 6 and 7 in the carbon maps). We use the default values for production emission (WTW_i) from the EU-RED for different biofuel production pathways and take average values for energy yields from FNR (2012). We consider an allocation factor (AL_i) for the main co-products according to their heating value[10] based on EU-JRC Data (IES 2008). The total resulting emissions are then compared to 83.8gCO2/MJ emissions of the fossil fuel alternative. Emission savings are derived in % according to equation 7.

$$ES_i\% = \frac{100}{83.8} * \left[83.8 - \left(LUC_{mj_i} + WTW_i\right)\right] \qquad (7)$$

We calculate the emission savings of four biofuel options which are shown in the maps below: biodiesel based on palm with and without methane capture[11] in the production process, biodiesel based on soy and bioethanol based on sugar-cane. In terms of the minimum emission saving threshold, it is allowed to convert land when the final biofuel option does not cause less than 35% emission savings. Thus, according to the EU-RED, all areas that result in 35% or more emission savings would be potentially eligible for certification with respect to carbon emissions when converted for biofuel production. However, we do not consider biodiversity or other sustainability criteria here and consequently do not call these areas “go-areas”. As the minimum emission savings threshold is about to rise to 50% for new installations from 2017[12] on, and to 60% in 2018 for installations built after 2017. We also indicate these thresholds in the maps.

Based on the total carbon map derived above, it is only logical that areas with high carbon stocks are less likely to achieve the 35% minimum emission saving threshold than areas with low carbon stocks.

[10] The lower heating value is used as an indicator for the heating energy contained in a fossil fuel or organic material. The EC decided to use this value as a unit to base on the allocation of emission on different co-products.

[11] Methane capture means the capture of methane gas from the anaerobic digestion of palm oil mill effluent in open ponds.

[12] The threshold might be increased already in 2014.

Figure 7[13]

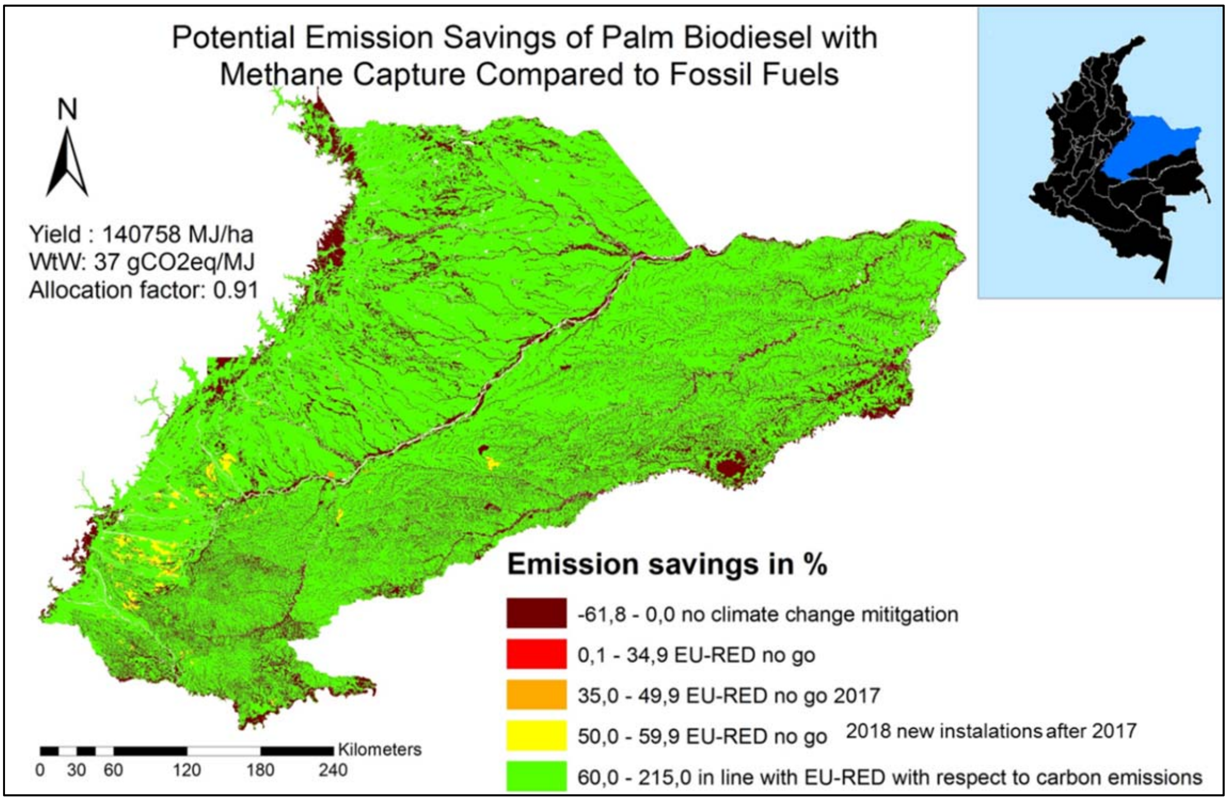
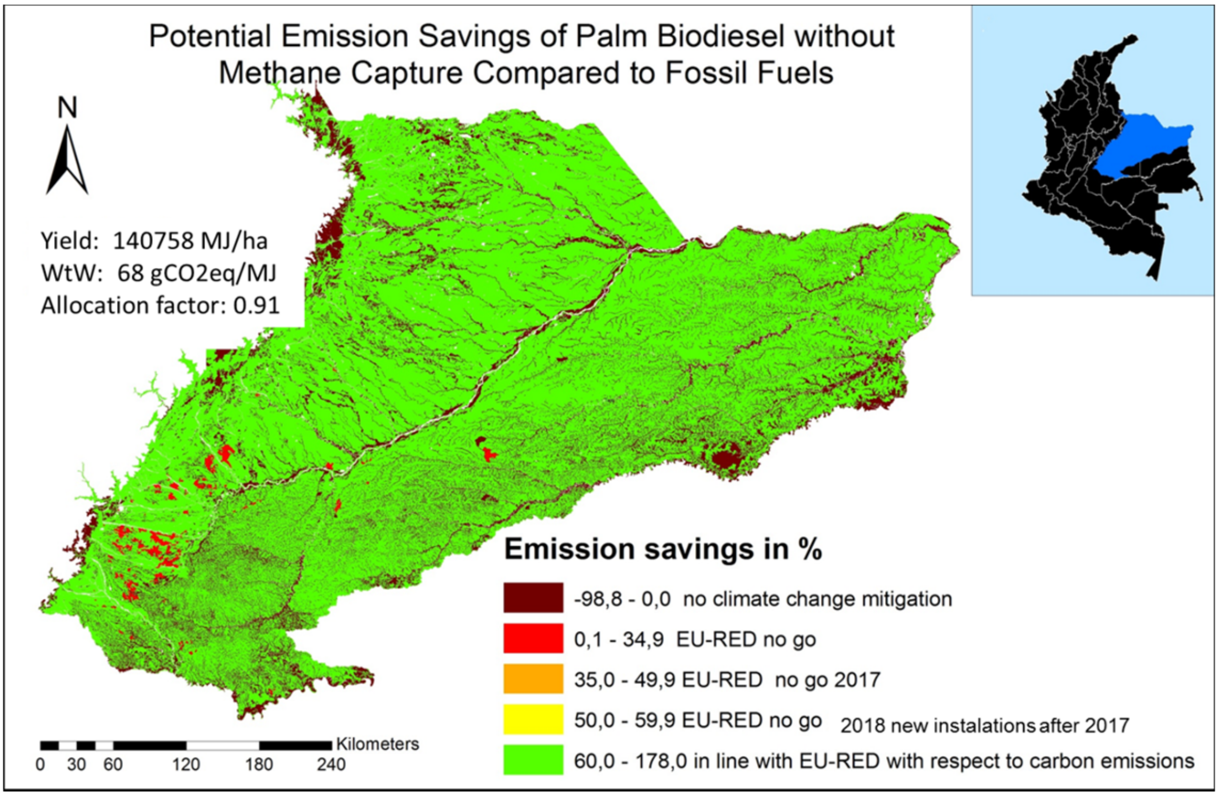


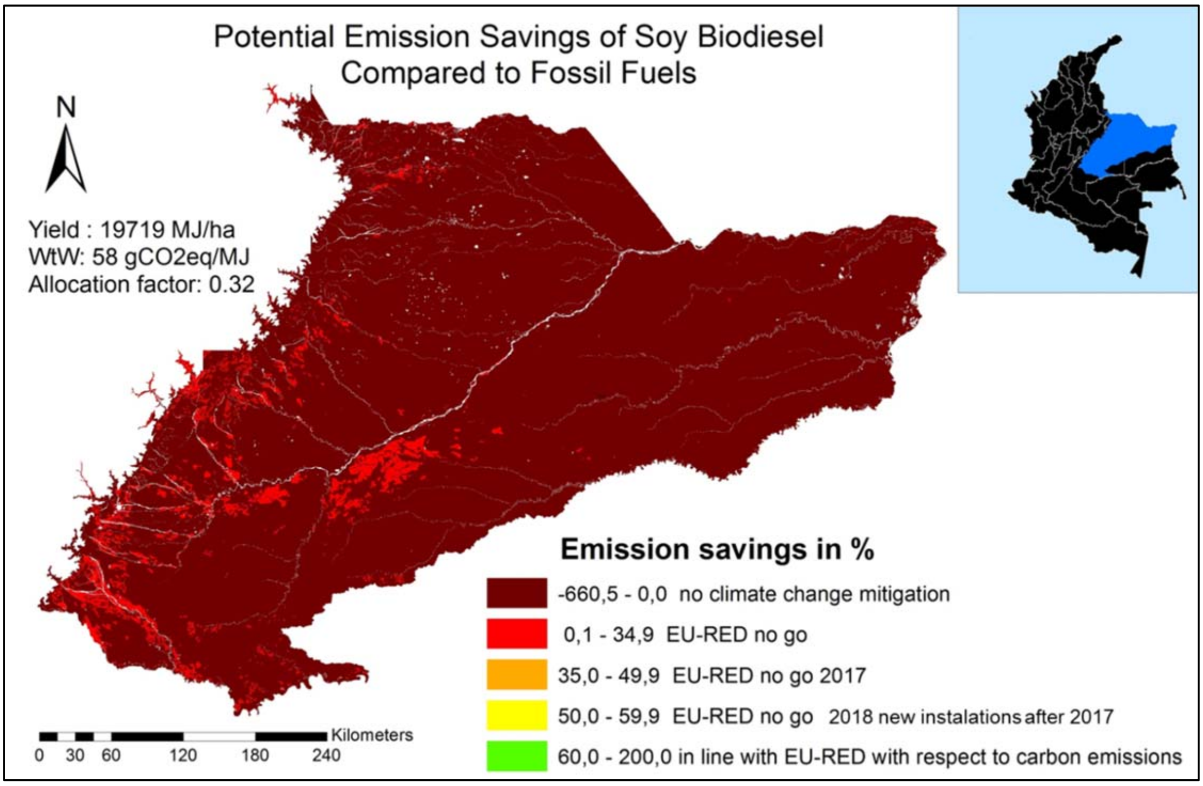
Figure 8.



[13] Palm oil area remaining palm oil area and maintaining the same land management system of course have LUC emissions of zero. Results are then purely driven by the process emissions WtW. Thus, the qualification into "no-go" area in Figure 8 is purely driven by the high process emissions of 68 gCO2/MJ.

Due to the high energy yield per hectare and the low emissions caused in the production process because of methane capture, biodiesel production based on palm oil can be an option under the EU-RED sustainability requirements (see figure 7 and 8). Even the conversion of pastures and non-wooded grasslands might be possible. This seems to be the case even when methane is not captured in the production process (figure8). This is mainly due to the EU-RED assumption that palm plantations contain 60 tC/ha in biomass carbon which is more than most of the grassland vegetation cover. In addition, due to the perennial plantation structure of palm oil production it is assumed that carbon accumulates in the soil. Not possible, independent on the production process, is the conversion of areas with high biomass density such as forested zones in riparian areas or wooded scrublands. The changes in thresholds do not change these results.

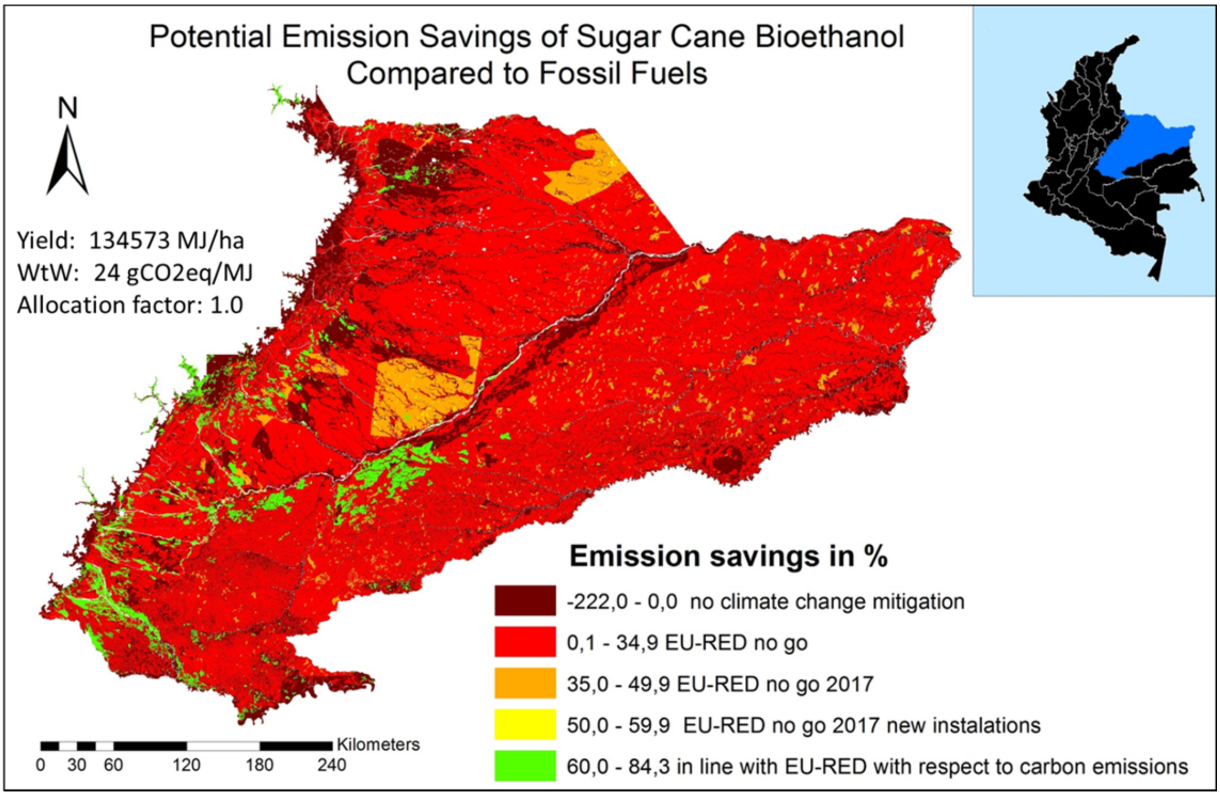
Figure 9.



The results in figure 9 for biodiesel produced from soy are the total opposite to biodiesel produced from palm. Due to the low energy yield per hectare and high emissions in the production process, it is not possible to produce biodiesel based on soy in the Llanos Orientales and be countable for the EU-RED biofuel mandate. In most of the cases this production pathway produces even more emissions than the fossil fuel alternative. However, this might change in the future in case energy yield per hectare increase or production emissions decrease.

Due to higher energy yields per hectare and a small amount of carbon accumulation in biomass due to the perennial nature of sugar-cane production, results for ethanol based on sugar-cane in figure 10 lie between the results of palm biodiesel and soy biodiesel. However, the expansion areas for sugar-cane which would be in line with the EU-RED are mainly located on areas already used for agricultural production or on degraded areas. In addition, degraded areas might have very low productivity values. Thus, also for sugar- cane expansion, there are limited areas available which are in line with the EU-RED sustainability requirements. However, even though the 35% emission saving threshold is not met in most of the areas, emission savings are positive apart from the forested areas. This means that by increasing yields or decreasing production emissions it might well be possible that the emission saving threshold is met in practise.

Figure 10.



2. Conclusion

We show how to calculate a carbon map according to the sustainability requirements of the EU-RED for biofuel production with the example of the Llanos Orientales in Colombia. Based on the carbon map we derive maps showing the emission savings for biodiesel based on palm and soy and bioethanol based on sugar-cane. It was important to fill this gab as the region of the Llanos Orientales is considered one of the main areas for agricultural development in the future. Our maps can be used for a low carbon development policy of the agricultural sector in the region.

Our maps can further serve as a basis for investors which want to produce biofuels for the European market. We show that if there are ambitions to produce biofuels for the European market, they should concentrate on biofuels based on palm with methane capture as this production generates the highest emission savings. A sustainable expansion of palm plantations in order to produce feedstock for biodiesel is possible with respect to carbon emissions, according to the EU-RED, on grassland with low biomass cover. The expansion of production areas for soy biodiesel and sugar-cane ethanol on former natural areas is not possible according to the EU-RED emission saving requirements. However, as results for sugar-cane are not too far away from the 35% emission saving threshold, higher energy yields or lower production emissions might change our results in practise.

However, two main aspects need to be considered when using our maps. First, we do not consider any biodiversity aspects in the maps. The EU-RED prohibits converting high biodiversity grassland to produce feedstocks for biofuels and the natural grasslands in the Llanos Orientales can be very rich in biodiversity. As long as there is no concrete definition and global mapping of high biodiversity grassland from the EC, an individual biodiversity assessment is still necessary in order to be countable for the EC biofuel mandate with biofuels produced in the Llanos Orientales.[14]

Second, at the moment, most of the agricultural production in the Llanos Orientales region is for internal use as transportation cost through the Andes for export are still very high. As long as there are no sustainability requirements for the agricultural production other than for exporting to the European biofuel market, there will be external effects of the biofuel production in the Llanos. Feedstocks for the European biofuel market will be produced on land already used as cropland close to the international market as this "minimizes" the emission balance. Other feedstocks might be replaced and might move into new, virgin areas in the Llanos without any restrictions (Lange and Delzeit 2012). This minimizes DLUC for the cost of ILUC.

The only way to overcome this problem is by requiring that all agricultural production be subject to sustainability assessments. The problem of ILUC regulation is only a problem of an incomplete emission accounting of land use practices when only biofuel production is subject to such accounting, but food, feed and bioenergy production other than biofuel production are not. To avoid indirect effects, our carbon map can be the basis for a sustainable land use planning that is binding for all agricultural production in the Llanos and in the whole country.

[14] The WWF Colombia is currently producing a biodiversity mapping in for the Llanos under the Global Land Use Change project. Results will soon be available under www.globallandusechange.org.

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APPENDIX I																										TC
Land Cover	Climate	Soil	SOCref	ABC		R		BGC		TBC		DOM		Fi	Fmg	Flu	TF		Palm TBC	TBC Sugar Cane	TBC Soy	Palm TF	Sugar cane TF	Soy TF	SOCact	Total Carbon
								ABC*R		ABC+BGC+DOM		ABG*0.1 (Forest)					Fi*Fmg*Flu								SOCref*TF	SOCact*TBC
				tC/ha	S	Ratio	S	tC/ha	S	tC/ha	S	tC/ha	S					S	tC/ha	tC/ha	tC/ha				tC/ha	tC/ha
crops / mixed used areas	Tropical Moist	HAC	65	5.8	2					0.0		0.0	6	1	1.15	0.48	0.552	6,8	60	5	0	1.15	0.586	0.48	35.9	35.9
crops / mixed used areas	Tropical Moist	Sandy	39	5.8	2					0.0		0.0	6	1	1.15	0.48	0.552	6,8	60	5	0	1.15	0.586	0.48	21.5	21.5
crops / mixed used areas	Tropical Moist	wetland	86	5.8	2					0.0		0.0	6	1	1.15	0.48	0.552	6,8	60	5	0	1.15	0.586	0.48	47.5	47.5
crops / mixed used areas	Tropical Montane	HAC	88	5.8	2					0.0		0.0	6	1	1.15	0.48	0.552	6,8	60	5	0	1.15	0.586	0.48	48.6	48.6
crops / mixed used areas	Tropical Wet	HAC	44	5.8	2					0.0		0.0	6	1	1.15	0.48	0.552	6,8	60	5	0	1.15	0.586	0.48	24.3	24.3
crops / mixed used areas	Tropical Wet	LAC	60	5.8	2					0.0		0.0	6	1	1.15	0.48	0.552	6,8	60	5	0	1.15	0.586	0.48	33.1	33.1
crops / mixed used areas	Tropical Wet	Sandy	66	5.8	2					0.0		0.0	6	1	1.15	0.48	0.552	6,8	60	5	0	1.15	0.586	0.48	36.4	36.4
crops / mixed used areas	Tropical Wet	wetland	86	5.8	2					0.0		0.0	6	1	1.15	0.48	0.552	6,8	60	5	0	1.15	0.586	0.48	47.5	47.5
crops / mixed used areas	Warm Temperate Dry	HAC	38	5.8	2					0.0		0.0	6	1	1.15	0.48	0.552	6,8	60	5	0	1.15	0.586	0.48	21.0	21.0
crops / mixed used areas	Warm Temperate Moist	HAC	88	5.8	2					0.0		0.0	6	1	1.15	0.48	0.552	6,8	60	5	0	1.15	0.586	0.48	48.6	48.6
crops / mixed used areas	Warm Temperate Moist	Sandy	34	5.8	2					0.0		0.0	6	1	1.15	0.48	0.552	6,8	60	5	0	1.15	0.586	0.48	18.8	18.8
degraded land	Tropical Moist	Sandy	39							0.0		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	39.0	39.0
degraded land	Tropical Moist	wetland	86							0.0		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	86.0
degraded land	Tropical Montane	HAC	88							0.0		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	88.0
degraded land	Tropical Wet	HAC	44							0.0		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	44.0	44.0
degraded land	Tropical Wet	LAC	60							0.0		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	60.0	60.0
degraded land	Tropical Wet	Sandy	66							0.0		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	66.0	66.0
degraded land	Tropical Wet	wetland	86							0.0		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	86.0
degraded land	Warm Temperate Moist	HAC	88							0.0		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	88.0
Flooded grasslands / marsh land	Tropical Moist	HAC	65	3.2	1	1.6	6	5.1		8.3		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	65.0	73.3
Flooded grasslands / marsh land	Tropical Moist	Sandy	39	3.2	1	1.6	6	5.1		8.3		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	39.0	47.3
Flooded grasslands / marsh land	Tropical Moist	wetland	86	3.2	1	1.6	6	5.1		8.3		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	94.3
Flooded grasslands / marsh land	Tropical Wet	HAC	44	3.2	1	1.6	6	5.1		8.3		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	44.0	52.3
Flooded grasslands / marsh land	Tropical Wet	LAC	60	3.2	1	1.6	6	5.1		8.3		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	60.0	68.3
Flooded grasslands / marsh land	Tropical Wet	Sandy	66	3.2	1	1.6	6	5.1		8.3		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	66.0	74.3
Flooded grasslands / marsh land	Tropical Wet	wetland	86	3.2	1	1.6	6	5.1		8.3		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	94.3
Forest plantation	Tropical Moist	Sandy	39	89.8	2	0.24	6	21.6		120.3		9.0	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	39.0	159.3
Forest plantation	Tropical Wet	HAC	44	89.8	2	0.24	6	21.6		120.3		9.0	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	44.0	164.3
Forest plantation	Tropical Wet	LAC	60	89.8	2	0.24	6	21.6		120.3		9.0	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	60.0	180.3

																										TC
Land Cover	**Climate**	**Soil**	**SOCref**	**ABC**		**R**		**BGC**		**TBC**		**DOM**		**Fi**	**Fmg**	**Flu**	**TF**		**Palm TBC**	**TBC Sugar Cane**	**TBC Soy**	**Palm TF**	**Sugar cane TF**	**Soy TF**	**SOCact**	**Total Carbon**
								ABC*R		**ABC+BGC+ DOM**		**ABG*0.1 (Forest)**					**Fi*Fmg*Flu**								**SOCref* TF**	**SOCact*TBC**
				tC/ ha	**S**	**Ratio**	**S**	**tC/ha**	**S**	**tC/ha**	**S**	**tC/ha**	**S**					**S**	**tC/ha**	**tC/ha**	**tC/ha**				**tC/ha**	**tC/ha**
Forest plantation	Tropical Wet	Sandy	66	89.8	2	0.24	6	21.6		120.3		9.0	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	66.0	186.3
Forest plantation	Tropical Wet	wetland	86	89.8	2	0.24	6	21.6		120.3		9.0	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	206.3
Fragmented Forest	Tropical Moist	HAC	65	22.3	3			12.2	3	36.7		2.2	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	65.0	101.7
Fragmented Forest	Tropical Moist	Sandy	39	22.3	3			12.2	3	36.7		2.2	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	39.0	75.7
Fragmented Forest	Tropical Moist	wetland	86	22.3	3			12.2	3	36.7		2.2	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	122.7
Fragmented Forest	Tropical Montane	HAC	88	22.3	3			12.2	3	36.7		2.2	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	124.7
Fragmented Forest	Tropical Montane	LAC	63	22.3	3			12.2	3	36.7		2.2	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	63.0	99.7
Fragmented Forest	Tropical Wet	HAC	44	22.3	3			12.2	3	36.7		2.2	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	44.0	80.7
Fragmented Forest	Tropical Wet	LAC	60	22.3	3			12.2	3	36.7		2.2	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	60.0	96.7
Fragmented Forest	Tropical Wet	Sandy	66	22.3	3			12.2	3	36.7		2.2	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	66.0	102.7
Fragmented Forest	Tropical Wet	wetland	86	22.3	3			12.2	3	36.7		2.2	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	122.7
Fragmented Forest	Warm Temperate Moist	HAC	88	22.3	3			12.2	3	36.7		2.2	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	124.7
Natural forest	Tropical Moist	HAC	65	101.4	4	0.37	6	37.5		149.1		10.1	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	65.0	214.1
Natural forest	Tropical Moist	Sandy	39	101.4	4	0.37	6	37.5		149.1		10.1	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	39.0	188.1
Natural forest	Tropical Moist	wetland	86	101.4	4	0.37	6	37.5		149.1		10.1	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	235.1
Natural forest	Tropical Montane	HAC	88	101.4	4	0.37	6	37.5		149.1		10.1	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	237.1
Natural forest	Tropical Montane	LAC	63	101.4	4	0.37	6	37.5		149.1		10.1	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	63.0	212.1
Natural forest	Tropical Wet	HAC	44	101.4	4	0.37	6	37.5		149.1		10.1	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	44.0	193.1
Natural forest	Tropical Wet	LAC	60	101.4	4	0.37	6	37.5		149.1		10.1	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	60.0	209.1
Natural forest	Tropical Wet	Sandy	66	101.4	4	0.37	6	37.5		149.1		10.1	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	66.0	215.1
Natural forest	Tropical Wet	wetland	86	101.4	4	0.37	6	37.5		149.1		10.1	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	235.1
Natural forest	Warm Temperate Moist	HAC	88	101.4	4	0.37	6	37.5		149.1		10.1	7	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	237.1
natural grassland / shrubland	Tropical Moist	HAC	65	4.5	5	2.8	6	12.7		17.2		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	65.0	82.2
natural grassland / shrubland	Tropical Moist	Sandy	39	4.5	5	2.8	6	12.7		17.2		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	39.0	56.2
natural grassland / shrubland	Tropical Moist	wetland	86	4.5	5	2.8	6	12.7		17.2		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	103.2
natural grassland / shrubland	Tropical Montane	HAC	88	4.5	5	2.8	6	12.7		17.2		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	105.2
natural grassland / shrubland	Tropical Montane	LAC	63	4.5	5	2.8	6	12.7		17.2		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	63.0	80.2

																										TC
Land Cover	**Climate**	**Soil**	**SOCref**	**ABC**		**R**		**BGC**		**TBC**		**DOM**		**Fi**	**Fmg**	**Flu**	**TF**		**Palm TBC**	**TBC Sugar Cane**	**TBC Soy**	**Palm TF**	**Sugar cane TF**	**Soy TF**	**SOCact**	**Total Carbon**
								ABC*R		**ABC+BGC+ DOM**		**ABG*0.1 (Forest)**					**Fi*Fmg*Flu**								**SOCref* TF**	**SOCact*TBC**
				tC/ ha	**S**	**Ratio**	**S**	**tC/ha**	**S**	**tC/ha**	**S**	**tC/ha**	**S**					**S**	**tC/ha**	**tC/ha**	**tC/ha**				**tC/ha**	**tC/ha**
natural grassland / shrubland	Tropical Wet	HAC	44	4.5	5	2.8	6	12.7		17.2		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	44.0	61.2
natural grassland / shrubland	Tropical Wet	LAC	60	4.5	5	2.8	6	12.7		17.2		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	60.0	77.2
natural grassland / shrubland	Tropical Wet	Sandy	66	4.5	5	2.8	6	12.7		17.2		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	66.0	83.2
natural grassland / shrubland	Tropical Wet	wetland	86	4.5	5	2.8	6	12.7		17.2		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	103.2
natural grassland / shrubland	Warm Temperate Moist	HAC	88	4.5	5	2.8	6	12.7		17.2		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	105.2
Oil palm plantation	Tropical Wet	HAC	44							60.0	8	0.0	6	1	1.15	1	1.15	6,8	60	5	0	1.15	0.586	0.48	53.7	113.7
Oil palm plantation	Tropical Wet	LAC	60							60.0	8	0.0	6	1	1.15	1	1.15	6,8	60	5	0	1.15	0.586	0.48	73.2	133.2
Oil palm plantation	Tropical Wet	Sandy	66							60.0	8	0.0	6	1	1.15	1	1.15	6,8	60	5	0	1.15	0.586	0.48	80.5	140.5
Oil palm plantation	Tropical Wet	wetland	86							60.0	8	0.0	6	1	1.15	1	1.15	6,8	60	5	0	1.15	0.586	0.48	104.9	164.9
pasture	Tropical Moist	HAC	65	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	65.0	81.6
pasture	Tropical Moist	Sandy	39	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	39.0	55.6
pasture	Tropical Moist	wetland	86	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	102.6
pasture	Tropical Montane	HAC	88	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	104.6
pasture	Tropical Montane	LAC	63	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	63.0	79.6
pasture	Tropical Wet	HAC	44	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	44.0	60.6
pasture	Tropical Wet	LAC	60	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	60.0	76.6
pasture	Tropical Wet	Sandy	66	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	66.0	82.6
pasture	Tropical Wet	wetland	86	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	102.6
pasture	Warm Temperate Dry	HAC	38	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	38.0	54.6
pasture	Warm Temperate Moist	HAC	88	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	104.6
pasture	Warm Temperate Moist	Sandy	34	6.4	2	1.6	6	10.2		16.6		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	34.0	50.6
Secondary vegetation	Tropical Moist	HAC	65	19.6	2	0.37	6	7.3		26.9		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	65.0	91.9
Secondary vegetation	Tropical Moist	Sandy	39	19.6	2	0.37	6	7.3		26.9		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	39.0	65.9
Secondary vegetation	Tropical Moist	wetland	86	19.6	2	0.37	6	7.3		26.9		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	112.9
Secondary vegetation	Tropical Montane	HAC	88	19.6	2	0.37	6	7.3		26.9		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	114.9
Secondary vegetation	Tropical Montane	LAC	63	19.6	2	0.37	6	7.3		26.9		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	63.0	89.9
Secondary vegetation	Tropical Wet	HAC	44	19.6	2	0.37	6	7.3		26.9		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	44.0	70.9
Secondary vegetation	Tropical Wet	LAC	60	19.6	2	0.37	6	7.3		26.9		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	60.0	86.9
Secondary vegetation	Tropical Wet	Sandy	66	19.6	2	0.37	6	7.3		26.9		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	66.0	92.9
Secondary vegetation	Tropical Wet	wetland	86	19.6	2	0.37	6	7.3		26.9		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	86.0	112.9
Secondary vegetation	Warm Temperate Moist	HAC	88	19.6	2	0.37	6	7.3		26.9		0.0	6	1	1	1	1	6,8	60	5	0	1.15	0.586	0.48	88.0	114.9

S=Source

1 Etter et al. (2010)	3 Sierra et al (2007) Secondary Forest	5 Average of Yepes et al. (IDEAM) 2011 data and Etter et al 2010	7 Delaney et al. (1998) 10% of ABC
2 Yepes et al. (IDEAM) 2011	4 Phillips et al. (IDEAM) 2010	6 IPCC	8 EU-RED

			Ypalm	Apalm	WtWpalm 1	WtWpalm 2	Dpalm1		Dpalm2		Ysugar	Ysoy	Asoy	Asugar	WTWsoy	WtWsugar	Dsugar		Dsoy	
Land Cover	Climate	Soil	Yield Palm	Allocation Factor Palm	WtW Palm methane capture	WtW Palm no methane capture	Debt Palm methane capture	Emission Savings Palm methane capture	Debt Palm no methane capture	Emission Savings Palm no methane capture	Yield Sugar Cane	Yield Soy	Alloca-tion Factor Soy	Alloca-tion Factor Sugar Cane	WtW Soy	WtW Sugar Cane	Debt Sugar	Emission Savings Sugar	Debt Soy	Emission Savings Soy
			13	own calculation	EU-RED	EU-RED	9	100-(100/83.8*Dpalm1)	10	100-(100/83.8*Dpalm2)					EU-RED	EU-RED	11	100-(100/83.8*Dsugar)	12	100-(100/83.8*Dsoy)
			MJ/ha		gCO2eq/MJ	gCO2eq/MJ	gCO2eq/MJ	%	gCO2eq/MJ	%	MJ/ha	MJ/ha			gCO2eq/MJ	gCO2eq/MJ	gCO2eq/MJ	%	gCO2eq/MJ	%
crops / mixed used areas	Tropical Moist	HAC	140757.8	0.91	37	68	-85.5	202.0	-54.5	165.0	134573.3	19719.4	0.32	1	58	24	14.2	83.0	71.9	14.2
crops / mixed used areas	Tropical Moist	Sandy	140757.8	0.91	37	68	-64.9	177.5	-33.9	140.5	134573.3	19719.4	0.32	1	58	24	15.4	81.6	66.3	20.8
crops / mixed used areas	Tropical Moist	wetland	140757.8	0.91	37	68	-102.1	221.8	-71.1	184.8	134573.3	19719.4	0.32	1	58	24	13.3	84.2	76.4	8.8
crops / mixed used areas	Tropical Montane	HAC	140757.8	0.91	37	68	-103.7	223.7	-72.7	186.7	134573.3	19719.4	0.32	1	58	24	13.2	84.3	76.8	8.3
crops / mixed used areas	Tropical Wet	HAC	140757.8	0.91	37	68	-68.9	182.2	-37.9	145.2	134573.3	19719.4	0.32	1	58	24	15.2	81.9	67.4	19.5
crops / mixed used areas	Tropical Wet	LAC	140757.8	0.91	37	68	-81.5	197.3	-50.5	160.3	134573.3	19719.4	0.32	1	58	24	14.4	82.8	70.8	15.5
crops / mixed used areas	Tropical Wet	Sandy	140757.8	0.91	37	68	-86.3	203.0	-55.3	166.0	134573.3	19719.4	0.32	1	58	24	14.2	83.1	72.1	13.9
crops / mixed used areas	Tropical Wet	wetland	140757.8	0.91	37	68	-102.1	221.8	-71.1	184.8	134573.3	19719.4	0.32	1	58	24	13.3	84.2	76.4	8.8
crops / mixed used areas	Warm Temperate Dry	HAC	140757.8	0.91	37	68	-64.1	176.5	-33.1	139.5	134573.3	19719.4	0.32	1	58	24	15.5	81.6	66.1	21.1
crops / mixed used areas	Warm Temperate Moist	HAC	140757.8	0.91	37	68	-103.7	223.7	-72.7	186.7	134573.3	19719.4	0.32	1	58	24	13.2	84.3	76.8	8.3
crops / mixed used areas	Warm Temperate Moist	Sandy	140757.8	0.91	37	68	-61.0	172.7	-30.0	135.8	134573.3	19719.4	0.32	1	58	24	15.6	81.3	65.3	22.1
degraded land	Tropical Moist	Sandy	140757.8	0.91	37	68	-44.2	152.8	-13.2	115.8	134573.3	19719.4	0.32	1	58	24	39.2	53.2	118.3	-41.2
degraded land	Tropical Moist	wetland	140757.8	0.91	37	68	-56.5	167.4	-25.5	130.4	134573.3	19719.4	0.32	1	58	24	65.7	21.6	190.9	-127.9
degraded land	Tropical Montane	HAC	140757.8	0.91	37	68	-57.0	168.0	-26.0	131.0	134573.3	19719.4	0.32	1	58	24	66.8	20.2	194.0	-131.6
degraded land	Tropical Wet	HAC	140757.8	0.91	37	68	-45.5	154.3	-14.5	117.3	134573.3	19719.4	0.32	1	58	24	42.0	49.9	126.0	-50.4
degraded land	Tropical Wet	LAC	140757.8	0.91	37	68	-49.7	159.3	-18.7	122.3	134573.3	19719.4	0.32	1	58	24	51.0	39.1	150.8	-79.9
degraded land	Tropical Wet	Sandy	140757.8	0.91	37	68	-51.3	161.2	-20.3	124.2	134573.3	19719.4	0.32	1	58	24	54.4	35.1	160.0	-91.0
degraded land	Tropical Wet	wetland	140757.8	0.91	37	68	-56.5	167.4	-25.5	130.4	134573.3	19719.4	0.32	1	58	24	65.7	21.6	190.9	-127.9
degraded land	Warm Temperate Moist	HAC	140757.8	0.91	37	68	-57.0	168.0	-26.0	131.0	134573.3	19719.4	0.32	1	58	24	66.8	20.2	194.0	-131.6
			Ypalm	Apalm	WtWpalm	WtWpalm	Dpalm1		Dpalm2		Ysugar	Ysoy	Asoy	Asugar	WTWso	WtWsu	Dsugar		Dsoy	

					1	2									y	gar				
Land Cover	Climate	Soil	Yield Palm	Allocation Factor Palm	WtW Palm methane capture	WtW Palm no methane capture	Debt Palm methane capture	Emission Savings Palm methane capture	Debt Palm no methane capture	Emission Savings Palm no methane capture	Yield Sugar Cane	Yield Soy	Allocation Factor Soy	Allocation Factor Sugar Cane	WtW Soy	WtW Sugar Cane	Debt Sugar	Emission Savings Sugar	Debt Soy	Emission Savings Soy
			13	own calculation	EU-RED	EU-RED	9	100-(100/83.8*Dpalm1)	10	100-(100/83.8*Dpalm2)					EU-RED	EU-RED	11	100-(100/83.8*Dsugar)	12	100-(100/83.8*Dsoy)
			MJ/ha		gCO2eq/MJ	gCO2eq/MJ	gCO2eq/MJ	%	gCO2eq/MJ	%	MJ/ha	MJ/ha			gCO2eq/MJ	gCO2eq/MJ	gCO2eq/MJ	%	gCO2eq/MJ	%
Flooded grasslands / marsh land	Tropical Moist	HAC	140757.8	0.91	37	68	-41.2	149.2	-10.2	112.2	134573.3	19719.4	0.32	1	58	24	65.1	22.3	183.1	-118.5
Flooded grasslands / marsh land	Tropical Moist	Sandy	140757.8	0.91	37	68	-34.4	141.1	-3.4	104.1	134573.3	19719.4	0.32	1	58	24	50.5	39.8	142.9	-70.5
Flooded grasslands / marsh land	Tropical Moist	wetland	140757.8	0.91	37	68	-46.7	155.7	-15.7	118.7	134573.3	19719.4	0.32	1	58	24	77.0	8.1	215.6	-157.2
Flooded grasslands / marsh land	Tropical Wet	HAC	140757.8	0.91	37	68	-35.7	142.6	-4.7	105.6	134573.3	19719.4	0.32	1	58	24	53.3	36.4	150.6	-79.8
Flooded grasslands / marsh land	Tropical Wet	LAC	140757.8	0.91	37	68	-39.9	147.6	-8.9	110.6	134573.3	19719.4	0.32	1	58	24	62.3	25.6	175.4	-109.3
Flooded grasslands / marsh land	Tropical Wet	Sandy	140757.8	0.91	37	68	-41.5	149.5	-10.5	112.5	134573.3	19719.4	0.32	1	58	24	65.7	21.6	184.6	-120.3
Flooded grasslands / marsh land	Tropical Wet	wetland	140757.8	0.91	37	68	-46.7	155.7	-15.7	118.7	134573.3	19719.4	0.32	1	58	24	77.0	8.1	215.6	-157.2
Forest plantation	Tropical Moist	Sandy	140757.8	0.91	37	68	98.3	-17.3	129.3	-54.3	134573.3	19719.4	0.32	1	58	24	203.0	-142.3	476.0	-468.1
Forest plantation	Tropical Wet	HAC	140757.8	0.91	37	68	97.0	-15.7	128.0	-52.7	134573.3	19719.4	0.32	1	58	24	205.8	-145.6	483.8	-477.3
Forest plantation	Tropical Wet	LAC	140757.8	0.91	37	68	92.8	-10.8	123.8	-47.8	134573.3	19719.4	0.32	1	58	24	214.9	-156.4	508.5	-506.8
Forest plantation	Tropical Wet	Sandy	140757.8	0.91	37	68	91.3	-8.9	122.3	-45.9	134573.3	19719.4	0.32	1	58	24	218.2	-160.4	517.8	-517.9
Forest plantation	Tropical Wet	wetland	140757.8	0.91	37	68	86.0	-2.7	117.0	-39.7	134573.3	19719.4	0.32	1	58	24	229.5	-173.9	548.7	-554.8
Fragmented Forest	Tropical Moist	HAC	140757.8	0.91	37	68	-7.5	108.9	23.5	71.9	134573.3	19719.4	0.32	1	58	24	103.9	-24.0	267.7	-219.5
Fragmented Forest	Tropical Moist	Sandy	140757.8	0.91	37	68	-0.7	100.8	30.3	63.9	134573.3	19719.4	0.32	1	58	24	89.2	-6.5	227.5	-171.5
Fragmented Forest	Tropical Moist	wetland	140757.8	0.91	37	68	-13.0	115.5	18.0	78.5	134573.3	19719.4	0.32	1	58	24	115.7	-38.1	300.2	-258.2
Fragmented Forest	Tropical Montane	HAC	140757.8	0.91	37	68	-13.5	116.1	17.5	79.1	134573.3	19719.4	0.32	1	58	24	116.9	-39.4	303.3	-261.9
Fragmented Forest	Tropical Montane	LAC	140757.8	0.91	37	68	-7.0	108.3	24.0	71.3	134573.3	19719.4	0.32	1	58	24	102.7	-22.6	264.6	-215.8
Fragmented Forest	Tropical Wet	HAC	140757.8	0.91	37	68	-2.0	102.4	29.0	65.4	134573.3	19719.4	0.32	1	58	24	92.0	-9.8	235.2	-180.7
Fragmented Forest	Tropical Wet	LAC	140757.8	0.91	37	68	-6.2	107.4	24.8	70.4	134573.3	19719.4	0.32	1	58	24	101.1	-20.6	260.0	-210.2
Fragmented Forest	Tropical Wet	Sandy	140757.8	0.91	37	68	-7.7	109.2	23.3	72.3	134573.3	19719.4	0.32	1	58	24	104.4	-24.6	269.3	-221.3

			Ypalm	Apalm	WtWpalm 1	WtWpalm 2	Dpalm1		Dpalm2		Ysugar	Ysoy	Asoy	Asugar	WTWsoy	WtWsugar	Dsugar		Dsoy	
Land Cover	**Climate**	**Soil**	**Yield Palm**	**Allocation Factor Palm**	**WtW Palm methane capture**	**WtW Palm no methane capture**	**Debt Palm methane capture**	**Emission Savings Palm methane capture**	**Debt Palm no methane capture**	**Emission Savings Palm no methane capture**	**Yield Sugar Cane**	**Yield Soy**	**Allocation Factor Soy**	**Allocation Factor Sugar Cane**	**WtW Soy**	**WtW Sugar Cane**	**Debt Sugar**	**Emission Savings Sugar**	**Debt Soy**	**Emission Savings Soy**
			13	own calculation	EU-RED	EU-RED	9	100-(100/83.8*Dpalm1)	10	100-(100/83.8*Dpalm2)					EU-RED	EU-RED	11	100-(100/83.8*Dsugar)	12	100-(100/83.8*Dsoy)
			MJ/ha		gCO2eq/MJ	gCO2eq/MJ	gCO2eq/MJ	%	gCO2eq/MJ	%	MJ/ha	MJ/ha			gCO2eq/MJ	gCO2eq/MJ	gCO2eq/MJ	%	gCO2eq/MJ	%
Fragmented Forest	Tropical Wet	wetland	140757.8	0.91	37	68	-13.0	115.5	18.0	78.5	134573.3	19719.4	0.32	1	58	24	115.7	-38.1	300.2	-258.2
Fragmented Forest	Warm Temperate Moist	HAC	140757.8	0.91	37	68	-13.5	116.1	17.5	79.1	134573.3	19719.4	0.32	1	58	24	116.9	-39.4	303.3	-261.9
Natural forest	Tropical Moist	HAC	140757.8	0.91	37	68	125.6	-49.9	156.6	-86.8	134573.3	19719.4	0.32	1	58	24	256.8	-206.5	601.7	-618.0
Natural forest	Tropical Moist	Sandy	140757.8	0.91	37	68	132.4	-57.9	163.4	-94.9	134573.3	19719.4	0.32	1	58	24	242.2	-189.0	561.5	-570.1
Natural forest	Tropical Moist	wetland	140757.8	0.91	37	68	120.1	-43.3	151.1	-80.3	134573.3	19719.4	0.32	1	58	24	268.7	-220.6	634.2	-656.8
Natural forest	Tropical Montane	HAC	140757.8	0.91	37	68	119.6	-42.7	150.6	-79.7	134573.3	19719.4	0.32	1	58	24	269.8	-222.0	637.3	-660.5
Natural forest	Tropical Montane	LAC	140757.8	0.91	37	68	126.1	-50.5	157.1	-87.5	134573.3	19719.4	0.32	1	58	24	255.7	-205.1	598.6	-614.3
Natural forest	Tropical Wet	HAC	140757.8	0.91	37	68	131.0	-56.4	162.0	-93.4	134573.3	19719.4	0.32	1	58	24	245.0	-192.3	569.2	-579.3
Natural forest	Tropical Wet	LAC	140757.8	0.91	37	68	126.9	-51.4	157.9	-88.4	134573.3	19719.4	0.32	1	58	24	254.0	-203.1	594.0	-608.8
Natural forest	Tropical Wet	Sandy	140757.8	0.91	37	68	125.3	-49.5	156.3	-86.5	134573.3	19719.4	0.32	1	58	24	257.4	-207.1	603.3	-619.9
Natural forest	Tropical Wet	wetland	140757.8	0.91	37	68	120.1	-43.3	151.1	-80.3	134573.3	19719.4	0.32	1	58	24	268.7	-220.6	634.2	-656.8
Natural forest	Warm Temperate Moist	HAC	140757.8	0.91	37	68	119.6	-42.7	150.6	-79.7	134573.3	19719.4	0.32	1	58	24	269.8	-222.0	637.3	-660.5
natural grassland / shrubland	Tropical Moist	HAC	140757.8	0.91	37	68	-30.6	136.6	0.4	99.6	134573.3	19719.4	0.32	1	58	24	77.3	7.8	209.6	-150.1
natural grassland / shrubland	Tropical Moist	Sandy	140757.8	0.91	37	68	-23.9	128.5	7.1	91.5	134573.3	19719.4	0.32	1	58	24	62.6	25.3	169.4	-102.2
natural grassland / shrubland	Tropical Moist	wetland	140757.8	0.91	37	68	-36.1	143.1	-5.1	106.1	134573.3	19719.4	0.32	1	58	24	89.1	-6.3	242.1	-188.9
natural grassland / shrubland	Tropical Montane	HAC	140757.8	0.91	37	68	-36.6	143.7	-5.6	106.7	134573.3	19719.4	0.32	1	58	24	90.2	-7.7	245.2	-192.6
natural grassland / shrubland	Tropical Montane	LAC	140757.8	0.91	37	68	-30.1	135.9	0.9	98.9	134573.3	19719.4	0.32	1	58	24	76.1	9.1	206.5	-146.4
natural grassland / shrubland	Tropical Wet	HAC	140757.8	0.91	37	68	-25.2	130.0	5.8	93.0	134573.3	19719.4	0.32	1	58	24	65.4	21.9	177.1	-111.4
natural grassland / shrubland	Tropical Wet	LAC	140757.8	0.91	37	68	-29.3	135.0	1.7	98.0	134573.3	19719.4	0.32	1	58	24	74.5	11.2	201.9	-140.9
natural grassland / shrubland	Tropical Wet	Sandy	140757.8	0.91	37	68	-30.9	136.9	0.1	99.9	134573.3	19719.4	0.32	1	58	24	77.8	7.1	211.2	-152.0
natural grassland / shrubland	Tropical Wet	wetland	140757.8	0.91	37	68	-36.1	143.1	-5.1	106.1	134573.3	19719.4	0.32	1	58	24	89.1	-6.3	242.1	-188.9
natural grassland / shrubland	Warm Temperate Moist	HAC	140757.8	0.91	37	68	-36.6	143.7	-5.6	106.7	134573.3	19719.4	0.32	1	58	24	90.2	-7.7	245.2	-192.6
Oil palm plantation	Tropical Wet	HAC	140757.8	0.91	37	68	37.0	55.8	68.0	18.9	134573.3	19719.4	0.32	1	58	24	136.9	-63.3	333.2	-297.6
Oil palm plantation	Tropical Wet	LAC	140757.8	0.91	37	68	37.0	55.8	68.0	18.9	134573.3	19719.4	0.32	1	58	24	150.7	-79.8	368.4	-339.6

			Ypalm	Apalm	WtWpalm 1	WtWpalm 2	Dpalm1		Dpalm2		Ysugar	Ysoy	Asoy	Asugar	WTWsoy	WtWsugar	Dsugar		Dsoy	
Land Cover	**Climate**	**Soil**	**Yield Palm**	**Allocation Factor Palm**	**WtW Palm methane capture**	**WtW Palm no methane capture**	**Debt Palm methane capture**	**Emission Savings Palm methane capture**	**Debt Palm no methane capture**	**Emission Savings Palm no methane capture**	**Yield Sugar Cane**	**Yield Soy**	**Allocation Factor Soy**	**Allocation Factor Sugar Cane**	**WtW Soy**	**WtW Sugar Cane**	**Debt Sugar**	**Emission Savings Sugar**	**Debt Soy**	**Emission Savings Soy**
			13	own calculation	EU-RED	EU-RED	9	100-(100/83.8*Dpalm1)	10	100-(100/83.8*Dpalm2)					EU-RED	EU-RED	11	100-(100/83.8*Dsugar)	12	100-(100/83.8*Dsoy)
			MJ/ha		gCO2eq/MJ	gCO2eq/MJ	gCO2eq/MJ	%	gCO2eq/MJ	%	MJ/ha	MJ/ha			gCO2eq/MJ	gCO2eq/MJ	gCO2eq/MJ	%	gCO2eq/MJ	%
Oil palm plantation	Tropical Wet	Sandy	140757.8	0.91	37	68	37.0	55.8	68.0	18.9	134573.3	19719.4	0.32	1	58	24	155.9	-86.0	381.6	-355.3
Oil palm plantation	Tropical Wet	wetland	140757.8	0.91	37	68	37.0	55.8	68.0	18.9	134573.3	19719.4	0.32	1	58	24	173.1	-106.6	425.6	-407.8
pasture	Tropical Moist	HAC	140757.8	0.91	37	68	-31.3	137.3	-0.3	100.3	134573.3	19719.4	0.32	1	58	24	76.5	8.7	208.0	-148.2
pasture	Tropical Moist	Sandy	140757.8	0.91	37	68	-24.5	129.3	6.5	92.3	134573.3	19719.4	0.32	1	58	24	61.8	26.2	167.8	-100.2
pasture	Tropical Moist	wetland	140757.8	0.91	37	68	-36.8	143.9	-5.8	106.9	134573.3	19719.4	0.32	1	58	24	88.4	-5.4	240.4	-186.9
pasture	Tropical Montane	HAC	140757.8	0.91	37	68	-37.3	144.5	-6.3	107.5	134573.3	19719.4	0.32	1	58	24	89.5	-6.8	243.5	-190.6
pasture	Tropical Montane	LAC	140757.8	0.91	37	68	-30.8	136.7	0.2	99.7	134573.3	19719.4	0.32	1	58	24	75.4	10.0	204.9	-144.5
pasture	Tropical Wet	HAC	140757.8	0.91	37	68	25.8	130.8	5.2	93.8	134573.3	19719.4	0.32	1	58	24	64.7	22.8	175.5	-109.4
pasture	Tropical Wet	LAC	140757.8	0.91	37	68	-30.0	135.8	1.0	98.8	134573.3	19719.4	0.32	1	58	24	73.7	12.1	200.2	-138.9
pasture	Tropical Wet	Sandy	140757.8	0.91	37	68	-31.6	137.7	-0.6	100.7	134573.3	19719.4	0.32	1	58	24	77.1	8.0	209.5	-150.0
pasture	Tropical Wet	wetland	140757.8	0.91	37	68	-36.8	143.9	-5.8	106.9	134573.3	19719.4	0.32	1	58	24	88.4	-5.4	240.4	-186.9
pasture	Warm Temperate Dry	HAC	140757.8	0.91	37	68	-24.3	128.9	6.7	92.0	134573.3	19719.4	0.32	1	58	24	61.3	26.9	166.2	-98.3
pasture	Warm Temperate Moist	HAC	140757.8	0.91	37	68	-37.3	144.5	-6.3	107.5	134573.3	19719.4	0.32	1	58	24	89.5	-6.8	243.5	-190.6
pasture	Warm Temperate Moist	Sandy	140757.8	0.91	37	68	-23.2	127.7	7.8	90.7	134573.3	19719.4	0.32	1	58	24	59.0	29.6	160.0	-91.0
Secondary vegetation	Tropical Moist	HAC	140757.8	0.91	37	68	-19.2	122.9	11.8	85.9	134573.3	19719.4	0.32	1	58	24	90.4	-7.9	238.3	-184.4
Secondary vegetation	Tropical Moist	Sandy	140757.8	0.91	37	68	-12.4	114.8	18.6	77.8	134573.3	19719.4	0.32	1	58	24	75.7	9.6	198.1	-136.4
Secondary vegetation	Tropical Moist	wetland	140757.8	0.91	37	68	-24.7	129.4	6.3	92.4	134573.3	19719.4	0.32	1	58	24	102.3	-22.0	270.8	-223.1
Secondary vegetation	Tropical Montane	HAC	140757.8	0.91	37	68	-25.2	130.1	5.8	93.1	134573.3	19719.4	0.32	1	58	24	103.4	-23.4	273.9	-226.8
Secondary vegetation	Tropical Montane	LAC	140757.8	0.91	37	68	-18.7	122.3	12.3	85.3	134573.3	19719.4	0.32	1	58	24	89.3	-6.5	235.2	-180.7
Secondary vegetation	Tropical Wet	HAC	140757.8	0.91	37	68	-13.7	116.4	17.3	79.4	134573.3	19719.4	0.32	1	58	24	78.6	6.2	205.8	-145.6
Secondary vegetation	Tropical Wet	LAC	140757.8	0.91	37	68	-17.9	121.4	13.1	84.4	134573.3	19719.4	0.32	1	58	24	87.6	-4.5	230.6	-175.2
Secondary vegetation	Tropical Wet	Sandy	140757.8	0.91	37	68	-19.5	123.2	11.5	86.2	134573.3	19719.4	0.32	1	58	24	91.0	-8.6	239.9	-186.2
Secondary vegetation	Tropical Wet	wetland	140757.8	0.91	37	68	-24.7	129.4	6.3	92.4	134573.3	19719.4	0.32	1	58	24	102.3	-22.0	270.8	-223.1
Secondary vegetation	Warm Temperate Moist	HAC	140757.8	0.91	37	68	-25.2	130.1	5.8	93.1	134573.3	19719.4	0.32	1	58	24	103.4	-23.4	273.9	-226.8

9	(TC-(PalmTBC*SOCref* PamTF)*3.664/20*1000000/Ypalm*Apalm+WtWpalm1	11	(TC-(SugarTBC*SOCref* SugarTF)*3.664/20*1000000/Ysugar*Asugar+WtWsugar		
10	(TC-(PalmTBC*SOCref* PamTF)*3.664/20*1000000/Ypalm*Apalm+WtWpalm2	12	(TC-(SoyTBC*SOCref* SoyTF)*3.664/20*1000000/YSoy*ASoy+WtWSoy	13	Pancheco 2012/FNR 2012