Comparing the Carbon Footprint of Alternative Banana Value-Chain Arrangements

A draft case study using the EX-Ante C-balance Tool (EX-ACT version 4.0)

Draft Version

– Not for citation or circulation –

EASYPol
Resources for policy making

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Related resources

Easypol Key words: Mitigation, Impact appraisal, Climate smart agriculture, Agricultural, Environment and Rural Development Policies

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1. INTRODUCTION

Objectives

The paper at hand measures and compares the carbon footprint of two alternative arrangement of the banana value chain, that differ from each other mainly by an organic and conventional production system and the associated chain wide consequences. Data is based on a secondary source for the case of the conventional production system (Luske, 2011), while the organic cultivation scenario is an assumption based variation of the former.

As such, the paper at hand does not aim to provide a precise estimation of the carbon footprint of the conflicting value chain arrangements. While displaying a realistic approximation, it is instead the objective to show how methodological policy support tools need to be designed in order to provide chain actors with directly adaptable information for increasing the environmental sustainability of currently dominant value chain arrangements.

It is argued that for carbon footprint tools it is firstly essential not to be delimited to purely accounting for the climate impact of actually implemented practices, but to name and quantify instead simultaneously available, alternative practices that are more climate smart. Secondly, it is argued that adapted policy support tools need to link actively to other aspects of sustainability, as e.g. climate change adaptation, water-use efficiency and soil fertility management as well as the economic capacity of such approaches to perform in the market.

While the Ex-ante Carbon Balance Tool (EX-ACT) provides this functionality greatly for the agricultural production sector as only one central value chain segment, neither EX-ACT, nor other established carbon footprint and live cycle methodologies provide this functionality for the other stages of the value chain. This identifies a strong gap of scientific based policy support capacity.

Target audience

This document particularly aims at current or future practitioners who work on the formulation and analysis of value chain interventions and investment projects as well as on agricultural and food policy. At the same time the document wants to be useful for value chain actors, such as farmers association or federations, e.g. involved in bulking, grading and export/ commercialization of agricultural commodities. Further audience are employees of public administrations, in NGO's, professional organizations or consulting firms working on issues of climate change and environmental sustainability. Academics can also find this material useful to support their courses in carbon balance analysis and development economics.

Required background

To fully understand the content of this document the user must be familiar with:
- Concepts of value chain accounting and analysis;
- Concepts of climate change mitigation and adaptation;
- Concepts of land use planning and management.

Readers can follow links included in the text to other EASYPol modules or references[1]. See also the list of EASYPol links included at the end of this module[2].

[1] EASYPol hyperlinks are shown in blue, as follows:
a) training paths are shown in **underlined bold font**
b) other EASYPol modules or complementary EASYPol materials are in ***bold underlined italics***;
c) links to the glossary are in **bold**; and
d) external links are in *italics*.

2. THE EX-ANTE CARBON-BALANCE TOOL (EX-ACT)

EX-ACT is a tool developed by FAO. The tool is aimed at providing ex-ante estimates of the impact of agriculture and forestry development projects/policies/programmes on GHG emissions and carbon sequestration (Bernoux et al., 2010). The C-balance[3] is selected as indicator of the mitigation potential of the project/policy/programme. EX-ACT can be used in the context of ex-ante project formulation and it is capable of covering a range of projects relevant for the land use, land use change and forestry sector. It can compute the C-balance by comparing scenarios: "without project" (i.e. the "Business As Usual" or "Baseline") and "with project". The main output of the tool consists of the C-balance resulting from the difference between the "with project" minus the "without project" scenario.

EX-ACT has been developed mainly using the Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) complemented with other methodologies and review of default coefficients for mitigation options as a base. Most calculations in EX-ACT use a Tier 1 approach[4] (Bernoux et al., 2010). This, as default values are proposed for each of the five pools defined by the Intergovernmental Panel on Climate Change (IPCC) guidelines and the United Nations Framework Convention on Climate Change (UNFCCC): above-ground biomass, below-ground biomass, soil, deadwood and litter. It should be highlighted that EX-ACT also allows users to incorporate specific coefficients (e.g. from project area) in case they are available, therefore working at Tier 2 level too. EX-ACT measures carbon stocks and stock changes per unit of land, as well as Methane (CH_4) and Nitrous Oxide (N_2O) emissions expressing its results in tons of Carbon Dioxide equivalent per hectare ($tCO_2e.ha^{-1}$) and in tons of Carbon Dioxide equivalent per year ($tCO_2e.year^{-1}$).

EX-ACT consists of a set of Microsoft Excel sheets in which project designers insert information on dominant soil types and climatic conditions of project area together with basic data on land use, land use change and land management practices foreseen under projects' activities as compared to a business as usual scenario (Bernoux et al., 2010).

3. BACKGROUND

Bananas are the world's most exported fresh fruit in terms of volume and value and contribute significantly to the income of agricultural workers as well as resource poor farmers in various low income countries, such as Ecuador, Honduras, Guatemala, Cameroon, Côte d'Ivoire and The Philippines (FAO, 2003).

After coffee, cocoa and cotton, bananas receive an increasing attention for their social and environmental impact in producing communities as well along the entire value-chain. Some evidence for this situation is the growing quantity of bananas commercialized under certification such as organic or fair trade: Thus the annual quantity of exported fair trade bananas grew by 46% in 2005 and again by 50% in 2006 respectively, although still only accounting for 1.7 percent of global banana exports (FAO, 2008).

Existing corporate (Luske, 2010; Craig, 2012) as well as scientific studies also evaluate the carbon footprint of the transnational crop along longer segments of the value chain and come usually to a result that per ton of exported banana roughly one ton of greenhouse gases in CO_2-e are emitted[5]. Besides academic institutions also international production and sourcing companies as Dole and Chiquita as well as retailers like Tesco have been initiators of carbon

[2] This module is part of the EASYPol Resource Package: Macroeconomic, agricultural, trade and development policy, module1: macroeconomics and instrument of protection.

[3] C-balance = GHG emissions -carbon sequestered above and below ground.

[4] IPCC Guidelines provide three methodological tiers varying in complexity and uncertainty level: Tier1, simple first order approach which uses data from global datasets, simplified assumptions, IPCC default parameters (large uncertainty); Tier 2, a more accurate approach, using more disaggregated activity data, country specific parameter values (smaller uncertainty); Tier 3, which makes reference to higher order methods, detailed modeling and/or inventory measurement systems driven by data at higher resolution and direct measurements (much lower uncertainty).

5 Luske (2010) estimates the emissions for one ton of banana produced in Costa Rica by Dole Food Company, Inc., and consumed in Germany to be 1124 kg CO2-e while Craig et al. (2012) estimates the value to be 937kg CO2-e for produce sourced in different Central American countries by Chiquita Brands L.L.C. and commercialized in the Eastern States of the USA.

footprint studies for banana. Research interests are thereby the need for information provision as part of corporate social responsibility strategies, the use of carbon labelling for product differentiation as well as, more generally speaking, the identification of synergies between increased commercial competitiveness and climate friendliness.

The disadvantage of existing carbon footprint studies is their design as pure accounting frameworks of the existing value chain arrangement, that omit to identify which alternative, enhanced value chain arrangements do exist as well as how such innovations could be quantify in terms of reductions in GHG emissions.
The second major shortcoming of accounting frameworks is that they shed little light on which relations there are between objectives of GHG emission reductions as well as other elements of environmental sustainability and economic outcomes for different chain actors.

The paper at hand discusses which different tools would be needed in order to provide directly adapted information to chain actors about alternative value chain arrangements. For this purpose an organic and a conventional production system of banana is compared along the value chain. The study is thereby a first appraisal that is intended to discuss issues of study design and has not the purpose of representing the banana value chain in details in an adequate way. Data are mainly taken from the study of Luske (2010), focussing on banana produced in Costa Rica and exported to Germany.

4. COMPARING THE CARBON FOOTPRINT OF ALTERNATIVE BANANA VALUE-CHAIN ARRANGEMENTS

Fresh fruit value chains are composed of comparably few steps between production and retail. The banana value chain thereby experiences at the same time high market concentration in certain market segments (horizontal aspect) and in some commercialization channels as well a low number of actors along the complete value chain (vertical aspect), for which *Chiquita fruit bars* can be an example with which Chiquita covers all aspects from production up to retail to end-consumers.

Some studies thereby sub-differentiate the value chain along functional aspects as *production – packaging – transport*, while accumulating e.g. under the transport segment all aspects of the respective resource use without differentiating where they occurred along the value chain (e.g. for transportation to national ports or retail transportation in consuming countries). Other study designs are structured by chain actors instead or mix the two approaches.

EX-ACT differentiates firstly between various elements of agricultural production. Those relevant in our case are namely: land use change, crop residual use, use of agro-chemicals as well as energy & fossil fuel consumption for production. While entering the data in EX-ACT it is possible to identify which of the entered activities especially contribute to GHG emissions as well as which alternative management practices exist to further minimize GHG emissions.

In the following the different modules of EX-ACT are presented that account for GHG emissions from the relative activity in question. Thereby two scenarios are differentiated: One value chain arrangement characterized by conventional production of banana, identifiable by comparatively high yields (45.78 t/ha, Luske, 2010), the use of synthetic fertilizer & pesticides. Throughout the paper the conventional value chain is called the *without project* scenario. The organic production system is instead characterized by comparatively lower yields[6], use of organic fertilizer (manure), while not relying on aircraft application of pesticides or any in-organic fertilizer. The organic scenario we will refer to as the *with project* projection. We analyse the banana production originating from 13,500 hectare of banana production in Costa

[6] Assumption of 35 t/ha which is an optimistic estimation at the upper spectrum of organic production systems and above non-improved traditional production systems, as referenced in FAO (2003).

Rica and assume for simplicity a uniform context of high activity clay soils in a tropical wet climate.

Soil carbon changes and residual burning

Table 1: GHG emissions from banana cultivation under different management practices

B	C Your description	D	E Name	F Rate in tC/ha/yr	G -nomic practice	H management	I management	J management	K application	L Burning	M t dm/ha	N t/ha/yr
Reserved system A1	from Deforestation	NO			?	?	?	?	?	NO	10	10
Reserved system A2	Converted to A/R	NO			?	?	?	?	?	NO	10	10
Reserved system A3	Annual From OLUC	NO			?	?	?	?	?	NO	10	10
Reserved system A4	Converted to OLUC	NO			?	?	?	?	?	NO	10	1
Annual System1	Current system *	YES	Equilibrium	0	* A conservative approach is to consider this system at equilibrium or decreasin					NO	10	10
Annual System2	Conventional banan	NO			?	?	?	?	?	NO	9,2	45,78
Annual System3	Organic banana	NO			Yes	?	?	?	Yes	NO	9,2	35
Annual System4		NO			?	?	?	?	?	NO	10	0
Annual System5		NO			?	?	?	?	?	NO	10	0
Annual System6		NO			?	?	?	?	?	NO	10	0
Annual System7		NO			?	?	?	?	?	NO	10	0
Annual System8		NO			?	?	?	?	?	NO	10	0
Annual System9		NO			?	?	?	?	?	NO	10	0
Annual System10		NO			?	?	?	?	?	NO	10	0

B	P t CO2 /ha/yr	Q	R	S	T	U Users	V	W kg	X kg	Y t
Reserved system A1	0	0	0	0	0	0,00	0	0	0	0,00
Reserved system A2	0	0	0	0	0	0,00	0	0	0	0,00
Reserved system A3	0	0	0	0	0	0,00	0	0	0	0,00
Reserved system A4	0	0	0	0	0	0,00	0	0	0	0,00
Annual System1						0,00	0	0	0	0,00
Annual System2	0	0	0	0	0	0,00	0	0	0	0,00
Annual System3	0,88	0	0	0	2,79	0,00	2,79	0	0	0,00
Annual System4	0	0	0	0	0	0,00	0	0	0	0,00
Annual System5	0	0	0	0	0	0,00	0	0	0	0,00
Annual System6	0	0	0	0	0	0,00	0	0	0	0,00
Annual System7	0	0	0	0	0	0,00	0	0	0	0,00
Annual System8	0	0	0	0	0	0,00	0	0	0	0,00
Annual System9	0	0	0	0	0	0,00	0	0	0	0,00
Annual System10	0	0	0	0	0	0,00	0	0	0	0,00

Positive value= gain for soil

Description/example of the different options
Improved agronomic practices: using improved varieties, extending crop rotation...
Nutrient management: precision farming, improve N use effciency
Tillage / residues Management: Adoption of reduced,minimum or zero tillage, with or without mulching, including Conservation Agriculture
Water management: Effective irrigation measure
Manure application: Manure or Biosolids application to the field as input

See FAOSTAT
or Click here

Soil mitigation effect limited to 20 years
Positive value= gain for soil

Mitigation potential

Vegetation Type	Areas Start t0	Without project End	Without project Rate	With Project End	With Project Rate	Soil CO2 Change Without tCO2	Soil CO2 Change With tCO2	CO2eq emitted from Burnin Without tCO2	CO2eq emitted from Burnin With tCO2	Total Balance Without tCO2	Total Balance With tCO2	Difference tCO2
System A1	0	0	Linear	0	Linear	0	0	0	0	0	0	0
System A2	0	0	Linear	0	Linear	0	0	0	0	0	0	0
System A3	0	0	Linear	0	Linear	0	0	0	0	0	0	0
System A4	0	0	Linear	0	Linear	0	0	0	0	0	0	0
Annual System1	0	0	*Linear*	0	*Linear*	0	0	0	0	0	0	0
Annual System2	13500	13500	*Immediate*	0	*Immediate*	0	0	0	0	0	0	0
Annual System3	0	0	*Immediate*	13500	*Immediate*	0	-37665	0	0	0	-37665	-37665
Annual System4	0	0	*Linear*	0	*Linear*	0	0	0	0	0	0	0
Annual System5	0	0	*Linear*	0	*Linear*	0	0	0	0	0	0	0
Annual System6	0	0	*Linear*	0	*Linear*	0	0	0	0	0	0	0
Annual System7	0	0	*Linear*	0	*Linear*	0	0	0	0	0	0	0
Annual System8	0	0	*Linear*	0	*Linear*	0	0	0	0	0	0	0
Annual System9	0	0	*Linear*	0	*Linear*	0	0	0	0	0	0	0
Annual System10	0	0	*Linear*	0	*Linear*	0	0	0	0	0	0	0
Total Syst 1-10	13500	13500		13500								
Agric. Annual Total										**0**	**-37665**	**-37665**

Total yield (in t)

Vegetation Type	Without project	With project	Difference
System A1	0,0	0,0	0,0
System A2	0,0	0,0	0,0
System A3	0,0	0,0	0,0
System A4	0,0	0,0	0,0
Annual System1	0,0	0,0	0,0
Annual System2	618030,0	0,0	-618030,0
Annual System3	0,0	472500,0	472500,0
Annual System4	0,0	0,0	0,0
Annual System5	0,0	0,0	0,0
Annual System6	0,0	0,0	0,0
Annual System7	0,0	0,0	0,0
Annual System8	0,0	0,0	0,0
Annual System9	0,0	0,0	0,0
Annual System10	0,0	0,0	0,0
Total	**618030**	**472500**	**-145530**

Table 1 displays the GHG emissions from banana cultivation under different management practices. While conventional as organic producers do not practice any residual burning[7], but fell and partially incorporate banana stems during/after harvest, only organic producers apply in addition manure, engage in shorter crop rotation cycles (e.g. changing annually with chilli pepper or pineapple), or in few cases of commercial oriented production even in intercropping.

Both practices of shorter rotations as well as intercropping are thereby also strongly needed in organic systems as an element of integrated pest management for the reduction of root insects and nematodes (Ternisien & Ganry, 1990). EX-ACT considers that manure management and the extended crop rotation under the organic management scenario are responsible for soil uptake of roughly 2,79t of CO_2 per hectare p.a.
In addition Blanchart et al. (2005) provide experimental evidence from Martinique for the important co-benefit that rotations – in their case with sugarcane or pineapple – reduce soil C losses (from erosion, leaching and C stock changes) as compared to repetitious banana cultivation.

The conventional cropping system is by contrast further characterized by an area that was before and will also after our year of reference be cultivated with banana (e.g. as part of a cropping cycle alternating a 7-10 year cultivation period with 1 year of fallow). This gives us the usual picture that we have no direct emissions from soil CO_2 change or burning in the case of the until now mentioned conventional crop management activities.

Comparing the two cropping systems the organic agricultural management practices incorporate 37,665 tCO_2 more than compared to the carbon neutral conventional agricultural management practices.

Beyond the actual analysed options EX-ACT highlights other practices of relevance for changes in CO_2 stored in soil, which are a) improved N use efficiency, e.g. from targeted incorporation of banana stems into the soil after harvest[8], b) no tillage & methods of conservation agriculture and c) improved water management. Through these options users are getting information

[7] In any other case we would have to account for emissions from burning of roughly 9.2 tDM/ha of above ground biomass at the end of the cropping cycle (Yamaguchi & Araki, 2004).

[8] For the effects of stem corporation into the soil on N fluxes and uptake of the daughter plants please see Raphael et al. (2012).

about which other activities of crop management are important for GHG emissions, even when they did not yet apply or consider them for their own production system. This is an important aspect to familiarize practitioners with further options of climate smart agriculture and could be further enhanced as part of the software.

Input use and GHG emissions

The next central element of the production system for GHG emissions is the use of artificial inputs. Under the conventional management scenario we follow the data collected by Luske (2010), indicating that per hectare 376.96 kg of N, 155.59 kg Calcium Carbonate and 73 l of fungicides are used. For the organic cultivation practices we assume instead that none of these inputs are applied, but instead only ¼ t of manure per ha.

Table 2: GHG emissions from input use in banana production systems

Others GHG Emissions (not related to change in carbon pools) — Back to Description

Carbon dioxide emissions from Lime application

Type of lime	IPCC factor	Specific factor	Default Factor	Amount of Lime in tonnes per year: Start t0	Without Project: End	Without Project: Rate	With Project: End	With Project: Rate	Emission (t CO2eq) per year: Start	End: Without	End: With	Total Emission (tCO2eq): Without	With	Difference
Limestone	0,12		YES	2100,465	2100,465	Linear	0	Immediate	252,0558	252,0558	0	252	0	-252
Dolomite	0,13		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Not precised	0,125		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
								Sub-Total I-1	252,0558	252,0558	0	252	0	-252

N_2O emissions from N application on managed soils (except dejection directly in pasture, see livestock)

Type of input	IPCC factor	Specific factor	Default Factor	Amount of N Applied (t per year): Start t0	Without Project: End	Without Project: Rate	With Project: 0	With Project: Rate	Emission (t CO2eq) per year: Start	End: Without	End: With	Total Emission (tCO2eq): Without	With	Difference
Urea	0,01		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Mineral N Fertiliser (except Urea)	0,01		YES	5088,96	5088,96	Linear	0	Immediate	24790,5	24790,5	0,0	24.791	0	-24791
Mineral N Fertiliser in non-upland Rice*	0,003		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Sewage	0,01		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Organic fertilizers	0,01		YES	0	0	Linear	3375	Immediate	0,0	0,0	16441,1	0	16.441	16441
*N fertilizer from upland rice should be included above (N fertilizer)								Sub-Total I-3	24790,5	24790,5	16441,1	24791	16441	-8349

CO_2 equivalent emissions from production, transportation, storage and transfer of agricultural chemicals

Type of input**	Default factor*	Specific factor	Default Factor	Amount in tonnes of product (active ingrediente for Pesticides): Start t0	Without Project: End	Without Project: Rate	With Project: End	With Project: Rate	Start	End: Without	End: With	Total Emission: Without	Total Emission: With	Difference
Urea	4,8		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Mineral N Fertiliser (except Urea)	4,8	7	NO	5089	5089	Linear	0	Immediate	35622,7	35622,7	0,0	35.623	0	-35623
Mineral N Fertiliser in non-upland Rice*	4,8		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Phosphorus synthetic fertilizer	0,7		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Potassium synthetic fertilizer	0,6		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Limestone (Lime)	0,6		YES	2100	2100	Linear	0	Immediate	1232,3	1232,3	0,0	1.232	0	-1232
Dolomite (Lime)	0,6		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Generic Lime	0,6		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Herbicides (Pesticides)	23,1		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Insecticides (Pesticides)	18,7		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Fungicides (Pesticides)	14,3		YES	986	986	Linear	0	Immediate	14092,7	14092,7	0,0	14.093	0	-14093
* from Lal (2004) Table 5 - central value -tCO2/t product								Sub-Total I-4	50947,6	50947,6	0,0	50948	0	-50948
** tonnes of N, P2O5, K2O and CaCO3														
									Total "Inputs"			75990	16441	-59549

Table 2 shows that the named inputs as part of the conventional cultivation practices account for a total of 75,990 tCO_2 eq, while the organic practices account with 16,441 tCO_2 eq for 59,549 tCO_2 eq of fewer emissions.

Thereby it is interesting to notice that the bigger part of GHG emissions in the conventional production scenario is generated for production, transportation, storage and transfer of the agri-chemicals and only the smaller part results from nitrous oxide emissions.

Again the spreadsheet of EX-ACT also gives an overview of those activities that do not have taken place in the project, but have significant impacts on emitting or mitigating GHG emissions.

Energy and fossil fuel consumption

An important emission factor from agriculture is the use of fossil fuels for production. This can be accounted for by EX-ACT and will be shown in the following.

Table 3: GHG emissions from energy and fuel consumption

Others GHG Fluxes (not related to change in carbon pools) Back to Description

Released GHG associated with Fuel consumption (agricultural or forestry machinery, generators...)

GHG emissions associated with inputs transportation is not included here! But in "Inputs"

OPTION 1 (Based on Total consumption over the whole duration of the project)

Total Liquid Fuel Consumption (m3)	Gasoil/Diesel	Gasoline	Associated tCO2eq
Without Project	0	0	0
With Project	0	0	0

OPTION 2 (Based on Annual Fuel consumption at the beginning and according to dynamic changes)

Type of Fuel	Default value t CO2 /m3	Specific Value	Default Factor	Annual Fuel Consumption (m3/yr) Start t0	Without Project End	Without Project Rate	With Project End	With Project Rate	Emission (t CO2eq) All Period Without	Emission (t CO2eq) All Period With
Gasoil/Diesel	2,63		YES	97,47	97,47	Linear	97,47	Linear	257	257
Gasoline	2,85		YES	454,275	454,275	Linear	454,275	Linear	1295	1295
Gas (LPG/ natural)	0,002		YES	0	0	Linear	0	Linear	0	0
Butane	0,008		YES	0	0	Linear	0	Linear	0	0
Propane	0,006		YES	0	0	Linear	0	Linear	0	0
User defined-1	jet fuel	2,705	NO	1696,41	1696,41	Linear	0	Immediate	4589	0
User defined-2	LLDPE	6,000	NO	239,895	239,895	Linear	239,895	Linear	1439	1439
User defined-3		3,366	NO	0	0	Linear	0	Linear	0	0
	t CO2/t dry matter			Annual Consumption in t dry matter						
Wood	0,010		YES	0	0	Linear	0	Linear	0	0
Peat	0,003		YES	0	0	Linear	0	Linear	0	0

OPTION1 + OPTION2	Sub-Total Without	6140,7	Sub-Total With	1551,9	Difference	-4588,8

A-R / non Forest LUC / Annual / Perennial / Irrigated Rice / Grass / Organic Soils / Livestock / Inputs / **Other investments** / Indicators / Chain Value / Soil / Climate / Eco

We consider that for production and harvest purposes carried out on-farm 125.66 l/ha jet fuel (for fungicide application), 7.22 l/ha diesel, 32,65l gasoline and 17.77 kg/ha of plastic material (LLDPE) will be used. The total GHG emissions from fuel and energy consumption during production thus account for 6,140 tCO_2-e. In organic production systems there would be no jet fuel consumption, while the other named parts of fuel consumption would have to be examined for every case of organic cultivation individually. If we here assume for simplicity that they would be otherwise identical to the conventional scenario, then organic producers release on the total area of 13500 hectare 4588 tCO_2 eq per year less

Another upcoming issue of energy consumption in banana production systems is the increased use of water pumps for drip irrigation, packing plants, draining systems and cableways, that strongly influences energy and water consumption and can be increasingly found in company supported farming systems, as argued by FAO (2003) exemplary for the case of Ecuador.

The EX-ACT application allows for the differentiation of exactly these elements, including the resources used for construction of buildings, various forms of irrigation equipment or the burning of different kinds of fuels, wood or peat.

Calculating GHG emissions from value chain stages downstream from production

While the previous sections took a closer look to different aspects of the production stage, EX-ACT does not offer yet a similar sub-differentiation of all other value-chain stages. Instead EX-ACT is for value-chain aspects, similarly as other approaches, at the moment a pure accounting framework, equipped with tier 1 emission coefficients for diffferent activities in order to calculate emissions from parts of the value chain.

Table 4: Overview of the value chain module

Project Summary	
Name	Dole Costa Rica Banana value chain
Continent	Central America
Climate	Tropical Wet
Dominant Soil Ty	HAC Soils

Area (Initial state in ha)		
Forest/Plantation		0
Cropland	Annual	13500
	Perennial	0
	Rice	0
Grassland		0
Other Land	Degraded	0
	Other	0
Organic soils/peatlands		0

Duration of the Project (years)	
Implementation	1
Capitalisation	0
Total	1
Total Area	
Mineral soils	13500
Organic soils	0
Total Area	13500

Components of the Project	Flux in tCO_2eq	Production t of product	Flux in tCO_2eq	Production of product	%age for human use Without	%age for human use With	Food loss (t) Without	Food loss (t) With	Actual consumed quantity (t) Without	Actual consumed quantity (t) With
Deforestation	0		0							
Forest Degradation	0		0							
Afforestation and Reforestation	0		0							
Non Forest Land Use Change	0		0							
Agriculture										
Annual Crops	0	618030	-37665	####	100%	100%	24721.2	18900	593309	453600
Agroforestry/Perennial Crops	0	0	0	0			0	0	0	0
Irrigated Rice	0	0	0	0			0	0	0	0
Grassland	0	0	0	0						
Organic soils and peatlands	0		0							
Other GHG Emissions										
Livestock	0	0	0	0			0	0	0	0
Inputs	75990		16441							
Other Investment	6141		1552							
Total	82131	618030	-19672	####					593309	453600

Value Chain Segments

Upstream segments — Downstream segments

Item	Unit	Emission (tCO2/ unit)	Post Harvest (unit/year) Without	Post Harvest (unit/year) With	Processing (unit/year) Without	Processing (unit/year) With	Transport (unit/year) Without	Transport (unit/year) With	Retail (unit/year) Without	Retail (unit/year) With	Consumption (unit/year) Without	Consumption (unit/year) With	Waste mng (unit/year) Without	Waste mng (unit/year) With	Calculated emissions (tCO2/year) Without	Calculated emissions (tCO2/year) With
Food loss - annual crop	t		6180.3	4725.0					6180.3	4725.0	12360.6	9450.0				
Electricity	MWh	0.605			8609.2	6581.9									5208.5	3982.1
Diesel	m3	2.896			3034.5	2320.0									8788.0	6718.6
Corrugated board	t	1.170			43812.1	33495.5									51260.2	39189.8
Plastic (LLDPE)	t	1.720			852.9	652.1									1467.0	1121.5
															0.0	0.0
Electricity	MWh	0.605					96530.1	73799.8							58400.7	44648.9
Diesel	m3	2.896					8819.3	6742.6							25540.7	19526.5
Refrigerants*	n/a	1.000					13194.9	10087.9							13194.9	10087.9
Heavy fuel	m3	3.366					122629.5	93753.5							412770.9	315574.1
Ethylene	t	1.720					228.7	174.8							393.3	300.7
															0.0	0.0
															0.0	0.0
															0.0	0.0
															0.0	0.0
															0.0	0.0
Sum of emissions (tCO2/year)			0	0	66724	51012	510301	390138	0	0	0	0	0	0	577024	441150

* For refrigerants Luske (2010) only reports t CO2/ton of transported banana. Thus we cannot calculate with an emission factor here. Thus under "transport" the 13194 and 10087 tCO2 per year are inserted. To make sure that these numbers are copied identically into the Emission table, I inserted a 1 under the Emission factor

EX-ACT calculated in the value chain module the amount of GHG emissions per t of output. Thus also different productive farming systems as in our case can be compared. Thereby EX-ACT does not take into account the total quanitiy produced. Instead the total quantity consumed is the reference category and hence food losses along the complete value chain as well as production quantities that do not qualify for human consumption from the start, are substracted from the total product quantitiy. E.g. in our case we assume food loss of 1 percent each during post harvest handling and retail, while we assume 2 percent of food loss when the product reached already the consumer[9]. E.g. instead of 618030 t of conventional banana that qualified for export commercialization only 593309 t are in the end consumed.

The lower part of table 4 displays then all considered emission related aspects along the value chain. While we have detailed data on post harvest, processing and transport, we are instead missing information on the value chain stages retail, consumption and waste management.

[9] The numbers of food loss are greatly ad-hoc, though Luske (2010) states similar low numbers for all stages until consumption.

Table 5: GHG emissions at different stages of the value chain: Focus Processing/packaging and transport

Item	Unit	Emission factor (tCO2/ unit	Processing (unit/year)		Transport (unit/year)		Calculated emissions (tCO2/year)	
			Without	With	Without	With	Without	With
Food loss - annual crop	t							
Electricity	MWh	0.605	8609.2	6581.9			5208.5	3982.1
Diesel	m3	2.896	3034.5	2320.0			8788.0	6718.6
Corrugated board	t	1.170	43812.1	33495.5			51260.2	39189.8
Plastic (LLDPE)	t	1.720	852.9	652.1			1467.0	1121.5
							0.0	0.0
Electricity	MWh	0.605			96530.1	73799.8	58400.7	44648.9
Diesel	m3	2.896			8819.3	6742.6	25540.7	19526.5
Refrigerants*	n/a	1.000			13194.9	10087.9	13194.9	10087.9
Heavy fuel	m3	3.366			122629.5	93753.5	412770.9	315574.1
Ethylene	t	1.720			228.7	174.8	393.3	300.7
							0.0	0.0
							0.0	0.0
							0.0	0.0
							0.0	0.0
							0.0	0.0
Sum of emissions (tCO2/year)			66724	51012	510301	390138	577024	441150

Table 5 display GHG emissions form the major considered value chain stages from production until transport to retail location. Emissions from the production of corrugated board are the strongest factor during processing/packaging contributing 51260 tCO_2-e in the case of conventional production quantities and with 39189 tCO_2-e the proportional smaller amount of emissions for fewer organic production quantities of bananas. All aspects of processing/packaging account p.a. for emissions of 66734 tCO_2-e (conventional) or 51012 tCO_2-e (organic) respectively.

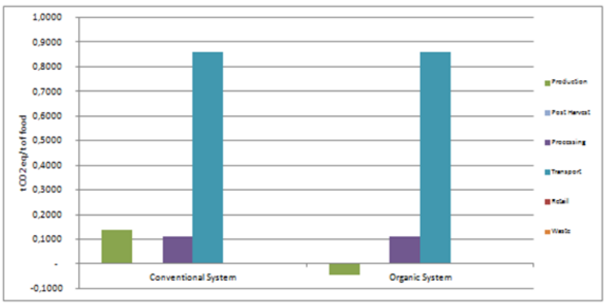
Total GHG emissions from transport are by contrast drastically higher, and proof to be the biggest source of GHG emissions in the banana value chain. They account for 510301 tCO_2-e (conventional) or 390138 tCO_2-e (organic) respectively.
The biggest element is thereby emissions from heavy fuels for ship transport (conventional: 412770 tCO_2-e, organic: 315574 tCO_2-e) as well as for electricity.

Summary of all GHG emissions along the banana value chain

Table 6: Main results of GHG emissions along the banana value chain

Total emissions (tCO2 per ton of product actually consumed)

	Without	With
Production	0,1384	- 0,0434
Post Harvest	-	-
Processing	0,1125	0,1125
Transport	0,8601	0,8601
Retail	-	-
Consumption	-	-
Waste	-	-
Total	1,1110	0,9292



Considering the fact that some elements contributing to GHG emissions have been omitted in the analysis at hand (no data on retail, consumption and waste management as well as limited data reliability in some other cases), the analysed conventional banana value chain arrangement is characterized by a carbon footprint of 1,111 tCO_2-e per t of consumed banana, while the organic value chain arrangement has with 0.929 tCO_2-e per t of consumed banana a carbon footprint that is 16% smaller.

Both value chain arrangements were not differenciated in this study concerning processing/packaging and transport (and are expected to be factually little differentiated in associated resource use and GHG emissions) and are a source of 0.113 tCO_2-e /t banana due to processing/packaging and of 0,860 due to transport.
Although transport is the overwhelming source of GHG emissions in the banana value chain, changes in cultivation practices proof to realize a considerable amount of abated emissions: While conventional production systems are a source of 0.138 tCO_2-e /t banana, organic production systems lead to carbon sequestration of 0.043 tCO_2-e /t banana.
That changes in production practices can still result in such a significant effects on the overall product footprint, is a relevant result of this approximative carbon footprint calculation.

That the decrease in production related emission per tones of bananas is as strong as displayed, is the more remarkable if one takes into account that we assumed that the organic production system is characterized by considerably lower yields (total production of 472,500 t compared to 618,030 t). Though the transportation aspect stays the most important, still agricultural production systems can make a strong difference for emission intensity.

5. CONCLUSION

The paper at hand presented a draft calculation of the carbon footprint of the banana value chain. Thereby the data source of the calculations was limited and did not intend to correspond to usual standards of completeness. Instead the case of the banana value chain was taken to show that the EX-ACT tool provides for production related activities not only a tool to claculate GHG emissions, but also helps to identify and quantify alternative more sustainable practices.

Standard carbon footprint accounting systems for value chains are missing this aspect: By providing pure accounting systems of actual implemented practices they do not provide any introduction to management practices and value chain settings that would be more sustainable for the climate. Also the EX-ACT module on value chains does not yet have this functionality.

Purpose of this paper was thus to show the necessity to develop user oriented value chain analysis tools that provide at the same time methods for GHG accounting as well as alternative scenario of climate smart practices. Only such an orientation can help value chain actors to take such scientific studies as a starting point for intervening in their existing production systems.

The approximative analysis of the banana value chain has in addition shown that also in contexts where production related emissions are only a small share of total emissions resulting from a value chain, they can still make an remarkable difference. The strong link of agricultural mitigation measures to climate change resiliance of small farmers, strengthened environmental sustainability beyond climate change aspects and increases in agricultural productivity are further strong reasons to promote adapted policy decision analysis for climate change mitigation.

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