RESEARCH ARTICLE

Comparative study of the environmental impact of models of conventional agricultural and agro-ecological agriculture in the agricultural phase of tomato cultivation [version 1; peer review: 1 approved with reservations, 1 not approved]

Carina Maribel Taipe Velasco¹, Ronnie Xavier Lizano Acevedo ²,
Bence Mátyás ^{2,3}

¹Ingeniería Ambiental, Universidad Politécnica Salesiana, Quito, 170702, Ecuador

²Grupo de Investigación en Ciencias Ambientales, Universidad Politécnica Salesiana, Quito, 170702, Ecuador

³Grupo de Investigación Mentoría y Gestión del Cambio, Universidad Politécnica Salesiana, Cuenca, 010102, Ecuador

V1 First published: 25 May 2018, 7:666
<https://doi.org/10.12688/f1000research.14334.1>
Latest published: 25 May 2018, 7:666
<https://doi.org/10.12688/f1000research.14334.1>

Abstract

Background: In this study, the water footprint and the carbon footprint were calculated during the activities of the agricultural phase of tomato cultivation, comparing agro-ecological production systems with conventional production systems.

Methods: We examined with six plots in total: 3 agro-ecological plots and 3 conventional plots in la Esperanza and Tabacundo, Pedro Moncayo canton, Ecuador. The water footprint was calculated according to Hoekstra's method. For the greenhouse gas emissions calculation, due to the production of fertilisers, the activity data was multiplied by the emission factor. Phytosanitary emissions were calculated using the factor given by BioGrace.

Results: For the conventional system the most representative footprint is that of blue water with 44.19 litres of water/kg of tomatoes, followed by the green water footprint with 14.42 litres of water/kg of tomato whilst the lowest value is 0.96 litres of water/kg of tomatoes for the grey water footprint.

Conclusions: The results obtained show that an agro-ecological system is the most efficient in terms of consumption of resources. Its produce also have an added value for promoting sustainability, responsible consumption and a healthier diet. The generation of eco-labels can encourage the consumption of these by expanding markets for this production system.

Keywords

life cycle assesment, food systems, agriculture, environmental impacts

Open Peer Review

Approval Status

	1	2
version 1		
25 May 2018	view	view

1. **María Fernanda Cárdenas** , National University of Colombia, Medellín, Colombia
2. **Conrado Tobon**, National University of Colombia, Medellín, Colombia

Any reports and responses or comments on the article can be found at the end of the article.

This article is included in the **Agriculture, Food and Nutrition** gateway.

Corresponding author: Ronnie Xavier Lizano Acevedo (rlizano@ups.edu.ec)

Author roles: **Taipe Velasco CM:** Methodology, Visualization, Writing – Original Draft Preparation; **Lizano Acevedo RX:** Conceptualization, Investigation, Methodology, Supervision, Writing – Original Draft Preparation; **Mátyás B:** Formal Analysis, Methodology

Competing interests: No competing interests were disclosed.

Grant information: The present research was supported by Universidad Politécnica Salesiana and Secretaría de Educación Superior, Ciencia, Tecnología e Innovación (SENESCYT) [PIC-16-BENS-005].

Copyright: © 2018 Taipe Velasco CM *et al.* This is an open access article distributed under the terms of the **Creative Commons Attribution License**, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. Data associated with the article are available under the terms of the **Creative Commons Zero "No rights reserved" data waiver** (CC0 1.0 Public domain dedication).

How to cite this article: Taipe Velasco CM, Lizano Acevedo RX and Mátyás B. **Comparative study of the environmental impact of models of conventional agricultural and agro-ecological agriculture in the agricultural phase of tomato cultivation [version 1; peer review: 1 approved with reservations, 1 not approved]** F1000Research 2018, 7:666 <https://doi.org/10.12688/f1000research.14334.1>

First published: 25 May 2018, 7:666 <https://doi.org/10.12688/f1000research.14334.1>

Introduction

Greenhouse gas emissions from agriculture continue to rise on a global scale, although not as fast as emissions from other human activities. Having better information at a national level on emissions from agriculture^{1,2}, live-stock, fisheries and forestry can help countries identify opportunities to reduce them, whilst pursuing objectives of food security, resilience and rural development and gaining access to global financing for implementation³. The agricultural sector is the sector that uses the most water, globally representing around 69% of all extraction, with household consumption at approximately 10% and industry at 21%⁴. The water footprint of a product is the total amount of water used to produce the goods or the service we use. In this study we calculated the green, blue and grey water footprint. The green water footprint is the amount of water in the root zone of the soil and evaporated, transpired or incorporated by plants. The blue water footprint is the amount of water that comes from surface or groundwater and is evaporated, incorporated into a product or taken from one body of water (for example irrigated agriculture have a blue water footprint). The grey water footprint “is the amount of fresh water required to assimilate pollutants to meet specific water quality standards” (see [Water Footprint Network website](#)). The agro-ecological agriculture is farming that “centers on food production that makes the best use of nature’s goods and services while not damaging these resources” (see [More and Better report on a viable food future](#)). It links ecology, culture, economics and society to create healthy environments, food production and communities in order to maintain the sustainable development (see [Groundswell international page on agroecological farming](#)). While the conventional agriculture also known as industrial agriculture, “refers to farming systems which include the use of synthetic chemical fertilizers, pesticides, herbicides and other continual inputs, genetically modified organisms, concentrated animal feeding operations, heavy irrigation, intensive tillage, or concentrated monoculture production. Thus conventional agriculture is typically highly resource and energy intensive, but also highly productive” see [USDA factsheet on conventional farming](#). In this study, emissions and water requirements for tomato cultivation in conventional production systems and agro-ecological production systems were calculated in the La Esperanza and Tabacundo parishes, Pedro Moncayo canton.

Methods

The present study examines the carbon and water footprint of product during the activities of the agricultural phase of tomato cultivation (between 2nd June and 5th of September 2017) in La Esperanza and Tabacundo, Pedro Moncayo canton, Ecuador. The average temperature was 20 °C, the humidity was 66% and the total precipitation was 320,8 mm in the examined period (<https://en.climate-data.org/location/719640/>). Three agro-ecologically managed plots (GPS decimal degrees: Plot 1: Latitude: -0.811193, Longitude: -78.6955; Plot 2: Latitude: -0.809214, Longitude: -78.6362; Plot 3: Latitude: -0.811429, Longitude: -78.6318) and three conventionally managed plots (GPS decimal degrees: Plot 4: Latitude: -0.809021, Longitude: -78.6273;

Plot 5: Latitude: -0.805316, Longitude: -78.6114; Plot 6: Latitude: -0.805312, Longitude: -78.6114) were analyzed in this study. For information about the size of the experimental areas and the applied fertilizers please see [Dataset 1](#). The water footprint was calculated as established by Hoekstra *et al.* (2011)⁵. For agro-ecological production systems, the green water footprint and blue water footprint were calculated. They lack a grey water footprint since they do not incorporate synthetic fertilisers, whereas for the conventional system the green water footprint, blue water footprint and the grey water footprint were calculated. Agro-ecological systems:

$$\text{Water footprint} = \text{Green Water Footprint} + \text{Blue Water Footprint} \quad (\text{m}^3/\text{ton})$$

Conventional case:

$$\text{Water Footprint} = \text{Green Water Footprint} + \text{Blue Water Footprint} + \text{Grey Water Footprint} (\text{m}^3/\text{ton}) \quad (\text{Hoekstra et al., 2011})$$

For the Carbon Footprint calculation, the equation given by greenhouse gases (GHG) Protocol, World Resources Institute and wbcSD (2011)⁶ was used:

$$\text{kgCO}_{2eq} = \text{Activity Data} * \text{Emission Factor} * \text{GWP}$$

For the (GHG) calculation in the conventional plots, due to the use of fuels, the equation given by the IPCC⁷ belonging to the all-terrain category was used. This equation allows one to obtain CO₂ emissions according to the type of fuel- be it diesel or petrol- as applicable for each case.

$$\text{Emission} = \sum_j \text{Fuel}_j * \text{EF}_j$$

Source: IPCC (2006a)

where:

Emission: total emissions expressed in KgCO_{2eq}

Fuel: fuel consumption TJ

EF: Emission factor ($\text{KgCO}_{2eq} \text{ TJ}$)

j: fuel type

For the greenhouse gas emissions calculation, due to the production of fertilisers, the activity data was multiplied by the emission factor. Phytosanitary emissions were calculated using the factor given by BioGrace⁸. Regarding greenhouse gases, due to direct emissions of N_2O , the contributions of nitrogen in managed soils were taken into account and for the study the equation given by the IPCC⁹ was adapted so that for the case studies it was applied as follows.

For the conventional systems, the equation was reduced to:

$$\text{N}_2\text{O} - \text{N}_{\text{Contributions}} = (\text{F}_s\text{N} + \text{F}_c\text{R}) * \text{EF}_1$$

Source: IPCC (2006c)⁹

And for the agro-ecological systems:

$$N_2O - N_{\text{contributions}} = (F_o N + F_c R) * EF_1$$

Source: IPCC (2006c)⁹

The calculation of indirect emissions of N₂O for managed soils was carried out by means of adapting equation 11.9 of the manual (IPCC, 2006c)⁷ to the case study, thus the applied equation was: Conventional systems:

$$N_2O_{(ADT)} - N = (F_{SN} * Frac_{GASF}) * EF_4$$

Source: IPCC (2006c)⁹

Agro-ecological systems:

$$N_2O_{(ADT)} - N = (F_{ON} * Frac_{GASM}) * EF_4$$

Source: IPCC (2006c)⁹

For the calculation of greenhouse gas emissions due to the use of fertilisers, the results of direct and indirect emissions of N₂O were taken into account. Regarding the emissions from applying phytosanitary products, this section was considered only in the conventional plots since they apply pesticides for the prevention of pests, such as fungicides and insecticides. To perform the calculation, the amount employed in kg/hectare (ha) and the emission factor given by BioGrace⁸ were taken into account.

Results

Water footprint

Figure 1 shows the water requirements for each plot. Regarding the conventional system, the highest values of green and blue water footprints corresponded to plot 5 with 34.42 and 87.54 litres of water/kg of tomatoes, respectively. For the agro-ecological systems, the plot with the highest green and blue water footprint was plot number 1 with 16.46 and 42.54 litres of water/kg of tomatoes, respectively. In relation to the grey water footprint, the highest value was found for plot 5 with 2.59 litres of water/kg of tomato.

In relation to the green water footprint, on average an agro-ecological system requires 9.07 litres of water/kg of tomatoes. For the blue water footprint, it requires 32.04 litres of water/kg of tomatoes (Figure 2). For the conventional system the most representative footprint is that of blue water with 44.19 litres of water/kg of tomatoes, followed by the green water footprint with 14.42 litres of water/kg of tomato whilst the lowest value is 0.96 litres of water/kg of tomatoes for the grey water footprint.

These results show that conventional cultivation consumes 18.45 litres more water for every 1 kg of tomatoes in the La Esperanza and Tabacundo parishes of the Pedro Moncayo canton (Figure 3).

Carbon footprint results

Table 1 shows that the highest generation of emissions was in plot 2 for the agro-ecological system and plot 4 for the conventional

Figure 1. Results of water footprint per plot.

Figure 2. Averages Water Footprint per component: conventional or agro-ecological system.

Figure 3. Total water footprint based on a conventional system or agro-ecological system.

Table 1. Carbon Footprint Results (GHG - green house gases).

kg CO ₂ /ha	Agro-ecological system			Conventional system		
	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
Fuel (diesel or petrol)	0	0	0	616.57	274.45	765.93
GHG fertilisers (production)	184.61	767.60	41.25	278.62	278.62	30.43
GHG fertilisers (use)	546.98	584.63	148.42	47.52	129.21	17.20
Phytosanitary control	0	0	0	2.92	13.27	38.13
Total kg CO₂/ha	731.59	1352.23	189.67	945.63	695.55	851.69

system The average emissions for the agro-ecological system in the study area was 757.83kg of CO_2/ha whilst it was 830.96kg of CO_2/ha for the conventional system. In the agro-ecological system, the greatest generation of emissions is due to the use of biofertilisers with an average of 426.68kg CO_2/ha , whilst for the conventional system it is due to the use of fuel with a 552.32kg CO_2/ha on average.

Dataset 1. Experimental setup

<http://dx.doi.org/10.5256/f1000research.14334.d203750>

Area of the lands, total crop production (Kg), fertilizer application rate on total crop production, concentration of NPK in each solid fertilizer, mount of NPK (Kg), Liquid fertilizer application rate on the total crop production, Concentration of NPK in each liquid fertilizer, Amount of NPK in liquid fertilizer (Kg), GPS coordinates.

Dataset 2. Calculated water footprint for each plot

<http://dx.doi.org/10.5256/f1000research.14334.d203751>

Green, blue and grey water footprint in l (water)/kg(tomato).

Dataset 3. Calculated carbon footprint for each plots

<http://dx.doi.org/10.5256/f1000research.14334.d203752>

Total GHG emission (kg CO₂ eq): Fuel (CO₂, N₂O), fertiliser production (N, K₂O, P₂O) fertiliser use, phytosanitary.

Discussion

In the La Esperanza and Tabacundo parishes an agro-ecological system requires less water compared to a conventional system, since the latter consumes 18.45 litres more water to produce a kilogram of tomatoes. In terms of emissions, the agro-ecological system obviously generates less, since it does not include the use of fuels because all the activities are carried out manually.

In relation to the Water Footprint, we used the values provided by Villavicencio *et al.*¹⁰ as a referential Water Footprint for fresh tomatoes (grown in the Coquimbo Region in the Choapa basin in Chile). They found a total water footprint of 84.2l/kg for the central region whilst we found a total water footprint of 59.57l/kg of tomatoes in the conventional system and 41.11l/kg in

the agro-ecological system. Our values reflect the characteristics of the study area.

As a whole, an agro-ecological system emits on average of 757.83kg CO_{2eq}/ha whilst a conventional system emits on average 830.96kg CO_{2eq}/ha . In the latter system, the greatest generation of emissions corresponded to the use of fuel, with an average of 552.32kg CO_{2eq}/ha whilst for the agro-ecological system the greatest generation of emissions corresponded to the use of biofertilisers with 426.68kg CO_{2eq}/ha .

The results obtained show that an agro-ecological system is the most efficient in terms of consumption of resources. Its produce also have an added value for promoting sustainability, responsible consumption and a healthier diet. The generation of eco-labels can encourage the consumption of these by expanding markets for this production system.

Data availability

Dataset 1: Experimental setup. Area of the lands, total crop production (Kg), fertilizer application rate on total crop production, concentration of NPK in each solid fertilizer, mount of NPK (Kg), Liquid fertilizer application rate on the total crop production, Concentration of NPK in each liquid fertilizer, Amount of NPK in liquid fertilizer (Kg), GPS coordinates [10.5256/f1000research.14334.d203750](http://dx.doi.org/10.5256/f1000research.14334.d203750)¹¹

Dataset 2: Calculated water footprint for each plot. Green, blue and grey water footprint in l (water)/kg(tomato). [10.5256/f1000research.14334.d203751](http://dx.doi.org/10.5256/f1000research.14334.d203751)¹²

Dataset 3: Calculated carbon footprint for each plots. Total GHG emission (kg CO₂ eq): Fuel (CO₂, N₂O), fertiliser production (N, K₂O, P₂O) fertiliser use, phytosanitary. [10.5256/f1000research.14334.d203752](http://dx.doi.org/10.5256/f1000research.14334.d203752)¹³

Competing interests

No competing interests were disclosed.

Grant information

The present research was supported by Universidad Politécnica Salesiana and Secretaría de Educación Superior, Ciencia, Tecnología e Innovación (SENESCYT) [PIC-16-BENS-005].

References

- Mátyás B, Chiluisa Andrade ME, Yandun Chida NC, *et al.*: **Comparing organic versus conventional soil management on soil respiration** [version 1; referees: 2 approved]. *F1000Res*. 2018; 7: 258. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Bautista G, Mátyás B, Carpio I, *et al.*: **Unexpected results in Chernozem soil respiration while measuring the effect of a bio-fertilizer on soil microbial activity** [version 2; referees: 2 approved]. *F1000Res*. 2017; 6: 1950. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Emisiones de gases de efecto invernadero de la agricultura, silvicultura y otros usos de la tierra America Latina y el Caribe. FAO. 2014. [Reference Source](#)
- FAO. (s.f): **Agua y cultivos uso agrícola del agua.** [Reference Source](#)
- Hoekstra AY, Chapagain AK, Aldaya MM, *et al.*: **The Water Footprint Assessment Manual: Setting the Global Standard.** 2011. [Reference Source](#)
- GHG Protocol, World Resources Institute y wbcscd: **Greenhouse Gas Protocol. Product Life Cycle Accounting and Reporting Standard.** World Resources Institute. Washington DC, USA: Greenhouse Gas Protocol. 2011. [Reference Source](#)
- Davies W, Harnisch J, Lucon O, *et al.*: **CAPÍTULO 3: Combustión Móvil.** En

- Directrices del IPCC de 2006 para los inventarios nacionales de gases de efecto invernadero, Energía. Japón:IGES. 2006a; 2: 1–78.
[Reference Source](#)
8. BioGrace: **BioGrace complete list of standar values version Public**. 2011.
[Reference Source](#)
 9. Eggleston ES, Buendia L, Miwa K, *et al.*: **CAPITULO 11: Emisiones de N₂O de los suelos gestionados y emisiones de CO₂ derivadas de la aplicación de cal y urea**. Directrices del IPCC 2006 para los Inventarios Nacionales de Gases de Efecto Invernadero, Agricultura, Silvicultura y Otros Usos de la Tierra. Japón: IGES 2006c; 4: 1–56.
[Reference Source](#)
 10. Villavicencio, Riquelme y Pérez: **Huella hídrica en Tomate Fresco**. En Osorio U., Alfonso (ed). Determinación de la huella del agua y estrategias de manejo de recursos hídricos. Serie Actas N° 50. Instituto de Investigaciones Agropecuarias, Centro Regional de Investigación Intihuasi, La Serena, Chile, 2013; 211.
 11. Taipe Velasco CM, Lizano Acevedo RX, Mátyás B: **Dataset 1 in: Comparative study of the environmental impact of models of conventional agricultural and agro-ecological agriculture in the agricultural phase of tomato cultivation**. *F1000Research*. 2018.
[Data Source](#)
 12. Taipe Velasco CM, Lizano Acevedo RX, Mátyás B: **Dataset 2 in: Comparative study of the environmental impact of models of conventional agricultural and agro-ecological agriculture in the agricultural phase of tomato cultivation**. *F1000Research*. 2018.
[Data Source](#)
 13. Taipe Velasco CM, Lizano Acevedo RX, Mátyás B: **Dataset 3 in: Comparative study of the environmental impact of models of conventional agricultural and agro-ecological agriculture in the agricultural phase of tomato cultivation**. *F1000Research*. 2018.
[Data Source](#)

Open Peer Review

Current Peer Review Status: ? ✖

Version 1

Reviewer Report 28 August 2018

<https://doi.org/10.5256/f1000research.15597.r36276>

© 2018 Tobon C. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Conrado Tobon

Department of Forestry Science, National University of Colombia, Medellín, Colombia

Title and introduction

The title of the manuscript does not provide a precise summary of the paper's content, which is, it does not condense the paper's content, since this refers to environmental impacts of two types of land use, while the content is totally related to water footprint.

I suggest to change the title for a better descriptive name, although simple and brief, but including both: Carbon and water footprint.

Methods.

The authors failed to present a comprehensive methodology to calculate the components of total footprints: Green, blue and grey. A full description of the methods used to calculate these specific footprints is required in order to understand results, and whenever necessary, compare results. Moreover, they should explain why is not necessary to calculate Grey water footprint, for this specific case.

Authors should complete the methodology.

Figures.

Figures 1, 2, and 3 should be more clear, and do not requires number on the bars. That's why the Y axis exists.

Discussion

In the first paragraph of the discussion the authors again present the results, which in fact belong more to the results than to properly to the discussion component. As for the other paragraphs, the presented discussion is far too poor, and do not interpret and describe the significance of the findings in light of what was already known in this field of the science. It needs to be completed.

The authors should present a new discussion based on:

- Authors should demonstrate their ability to think critically about the reported and formulate

through the discussion session a more profound understanding of the research problem under investigation,

- To denote possible implications of the results and explore possible improvements that can be made in order to further develop the research topic
- To state how the findings from this study revealed new gaps in the literature that had not been previously exposed or adequately described.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Reviewer Report 27 July 2018

<https://doi.org/10.5256/f1000research.15597.r36277>

© 2018 Cárdenas M. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

María Fernanda Cárdenas

National University of Colombia, Medellín, Colombia

In the abstract, the presented results refer only to the water footprint calculated for the conventional system. Without the missing information, is not possible to follow your conclusions,

presented in the abstract but not in the document.

The introduction of the manuscript does not provide the reader a context to understand the importance of this study. This is, for example, the relevance of agroecology, the current politics about it, or the significance of tomatoes in particular or agriculture in general for the region where the study was carried out. I believe the earlier would enhance the study.

The study sites and their location would be clearer presented in a table or in a figure. In a table would be interesting add, besides the coordinates, some information about the field characteristics, since I suspect it has a relationship with the results obtained. Particularly, it would be interesting if helps to explain the huge differences you found among plots.

Also, and related to the earlier, it would be necessary to justify why you decided to work with 3 plots in each assessed system. This is a big concern to me due to the differences presented in fig. 1... there is no explanation in the document and is it must be statistically supported.

Fig 2. and Fig. 3 are not relevant since they are not showing new information.

Finally, it is important to review the references. I.e, #9 says IPCCc, but it actually refers to Eggleston et al. Also, the letter c does not have sense if there is no a or b.

In general, English needs to be reviewed.

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact research@f1000.com

F1000Research