CARBON FOOTRPINT OF THREE DIFFERENT IRRIGATION SYSTEMS

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ABSTRACT

The use of irrigation equipment and machines in agriculture causes a large amount of greenhouse gas (GHG) emissions. This study aims to evaluate the GHG emitted during the life cycle of three irrigation systems, with the purpose of assessing their Carbon Footprint. A Life Cycle Assessment (LCA) methodology has been used, according to ISO international standard 14067. The irrigation techniques chosen for comparison are dripline systems and hose reel machine equipped with both travelling rain gun and spray boom. The analysis was carried out using the software Simapro, with the support of the Ecoinvent Database. Results show that, under the assumed scenario, dripline systems are the irrigation technology with the highest GWP, while travelling boom system has the lowest one. The high impact of dripline systems is due to their short lifetime, since they have to be replaced annually. The hose reel equipped with boom seems to be the most sustainable system, in terms of GWP per m3 of distributed water, because of both its long lifetime and low working pressure.

Keywords: LCA; Environmental Impacts; Water Footprint; hose reel; dripline;

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1. Introduction

Agriculture manipulates ecosystems to produce food and fiber. This principle is common both to early and modern agriculture. However, modern agriculture went through a massive increase of food production, which doubled in the last 35 years (Pimentel, 1992). This increase in productivity has been achieved thorough the introduction of new cultivation technologies and techniques, to respond the continuous global increase of food demand. The increase of agriculture production requires a vast amount of resources and it causes a vast series of environmental impacts, which represent a threat to the natural ecosystems of the world. Some of these are related to resources depletion, Eutrophication of marine ecosystems and, last but not least, contribution to global warming (IPCC, 2007). Therefore, to maintain agricultural sector and food production sustainable, it is necessary to identify the technologies and techniques with lower environmental impacts. Irrigation plays an essential role in crop cultivation and yield rates boost, and at the same time, it is one of the agricultural techniques with the highest environmental impacts. This study assesses the contribution of irrigation technologies to climate change. Although poorly understood, climate change is an urgent threat to agriculture and food security. The irrigation sector will be strongly affected by climate change, as well as by changes in the effectiveness of irrigation methods (Tilman, 1999). Therefore, it is necessary to identify irrigation techniques, which make an efficient use of water and have a low environmental impact in terms of climate change contribution. Efficiency of water system is extensively studied in literature but very few works assess the impact of irrigation in terms of contribution to climate change.

This study analyses the carbon footprint (CF) of three widely used irrigation technologies: a hose reel machine equipped with both, travelling rain gun and boom and dripline systems. A CF assesses the total amount of Greenhouse gas emissions of a defined population, system or activity, considering all relevant sources, sinks and storage and therefore their Global Warming potential, measured in Kg of CO2 equivalent (Wright et al., 2011).

2. Materials and methods

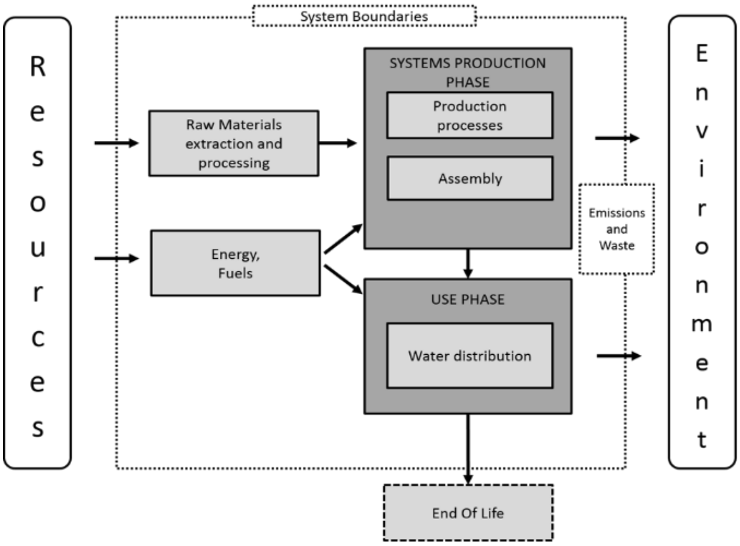


Figure 1: System Boundaries

The methodological framework adopted in this study is based on a life cycle assessment (LCA) of the two irrigation systems, in accordance with the standards ISO 14040 and ISO 14044. The aim is to provide a cradle to field analysis, which comprises the environmental burdens of the systems' production and use phases. Production phase encompasses all the impacts due to machines industrial manufacturing from raw material extraction and processing, to production and assembly of the various components. Use phase considers the impact due to the energy flows during water distribution to the field. System boundaries are presented in figure 1. The disposal scenario of the two irrigation systems is out of the scope of this study. This is because it has been difficult to source consistent data about the disposal of the systems once they complete their economic life.

As previously underlined, the goal of the study is to compare the environmental impact of two sprinkling irrigation machine and a dripline system, considering the impact category of Global warming Potential, measured in Kg CO2 eq. The functional unit chosen, to which all results have been reported, is the m3 of water distributed to the field.

2.1 Description of irrigation systems

The hose reel machines chosen for comparison are equipped with a equipped with a big gun sprinkler, named Explorer, with a 30 mm Ø snorkel nozzle and a 44 meters width spray boom. The horse reel has three main components: a large reel mounted on a four-wheel cart, a large semi-rigid polyethylene hose that is wounded on the reel and a cart. The cart can be fitted with a large volume gun-type sprinkler or a spray boom. The gun cart is trailed at the end of a travel line along with the rigid hose. During operation, the hose pulls the gun cart back as the hose is wound onto the hose reel. A water turbine powers the hose reel. The machines are equipped with a 400m length hose of 125 mm of external diameter.

Drip irrigation involves dripping water onto the soil at very low rates from a system of small diameter plastic pipes fitted with outlets called emitters or drippers. Pipes are usually grounded to apply water close to plant roots. The dripline system chosen for comparison is flat emitter dripline, pitch 30 cm, in two versions: 16 mm external diameter, 8 mills thickness and 22 mm external diameter, 10 mills thickness.

2.2 Life Cycle Inventories

Life Cycle inventories (LCI) are lists of the flows from and to the systems, such as inputs of water, energy, and raw materials and emissions or waste release to air, land, and water. For each of the analysed systems the inventory has been divided in two sections, relating production and use phase, to make easier a reallocation of related impacts to the chosen functional unit. The Members of AMIS, Italian association of self-propelled irrigation machine producer, have provided data regarding production phase of hose reel machines, rain gun and spray boom. Data on dripline have been gathered from technical sheets and catalogues of producers.

Life Cycle inventories regarding the use phase have been modelled considering average working conditions for the three systems (Table 1). As previously mentioned, impact of use phase is mainly due to the production and combustion of diesel burned in combustion engine, which generate the power needed to feed with pressured water the irrigation systems. The consumption of diesel has been calculated with the following formulas:

$$C=kW*CS$$

C = Diesel consumption of the pump (g/h);

kW = Power absorbed by the pump

CS = Specific consumption of the endothermic engine (g/kWh)

And

$$\mathrm{kW}=\gamma*Q*H/102*\eta$$

γ = Specific weight of water at 4 °C in Kg/m3

Q = pump flow rate in m3/s;

H = Hydraulic head in m H2O;

η = Pump efficiency (70%)

LCI Use Phase				
		Sprinkler	Boom	Dripline
Hourly consumption	l/h	4,26	1,4	0,84
Seasonal consumption	l/ha	125,99	73,99	101,64

Table 1: LCI use phase

The CF has been assessed multiplying inventory flows by the emission factor corresponding to that activity, material or process. Emission factors are form the EcoInvent database version 3 of the Swiss Centre for Life Cycle assessment. The LCIs have been analysed with the software Simapro (8.0.2, pre-sustainability-2014, UK).

3. Results

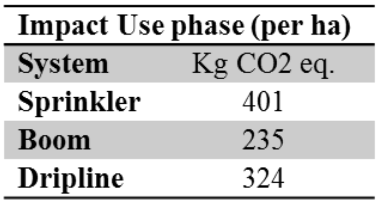
The results of the inventories analysis is presented below, starting with the production phase, use phase, and finishing with the allocation impacts to the Functional Unit. CF has been assessed using the IPCC 2013 GWP 100a method.

3.1 Impact of production phase Horse Reel systems

The total impact due to the production phase of the Hose Reel system is 7109 Kg CO2 eq. The reel cart is the component with a higher contribution to the system CF (50%), followed by the hose (42%). Production of sprinkler gun has an impact of 79,4 Kg CO2 eq. while the CF of boob production is 454 Kg CO2 eq. Hence the CF of the hose reel equipped with the boom is 5% higher (7563,35 Kg di CO_2 eq.) than the one equipped with the gun sprinkler (7188,75 Kg di CO_2 eq.).

3.2 Impact of production phase dripline systems

As previously underlined, two dripline models have been assessed in this study. Impact has been evaluated considering the quantity of material necessary to cover a hectare of cultivated surface. Dripline diameter is usually chosen in function of filed length and therefore two models of dripline have been analyzed to partially assess this variability. Impacts due to production phase of 16 mm Ø and 22 mm Ø dripline are respectively 222,82 and 308,08 Kg CO2 Eq. per hectare of irrigated surface.



Impact Use phase (per ha)	
System	Kg CO2 eq.
Sprinkler	401
Boom	235
Dripline	324

Table 2: Impact of use phase, per ha

3.3 Impact of use phase

CF of use phase is mainly due to diesel production process and combustion, which is necessary to power the hydraulic pumps for feeding the systems with water at a required pressure and flow rate. Table 2 shows the impact of use phase, due to the season volume of water distributed on 1 hectare. Impact due to use phase of the dripline systems is equal for the 16 mm Ø and 22 mm Ø, since differences of operating pressure can be consider negligible.

3.4 CF of analyses systems

The functional unit of this study is the m3 of distributed water, therefore all the impact of production and use phases have been reallocated, based on system lifetime, seasonal irrigation capacity and seasonal distributed water. The main difference between the three systems is that economic life of Hose reel machines is 15 years while dripline are replaced annually. Moreover, horse reel operational capability (seasonal irrigable surface) is defined by machine characteristics (hose diameter and length, operating pressure and flow rate), while dripline systems are dimensionless (virtually there are no limitations on irrigable surfaces). The two Hose systems analysed in this study have a season irrigation capability of 35 hectare when fitted with the sprinkler and 19 when equipped with the boom. Dripline refers to the quantity of pipes and drippers necessary to cover a hectare of surface. Both the systems distribute 2500 m3 of water per hectare seasonally. Figure 2 presents the CF footprint of the two systems, regarding the m3 of distributed water.

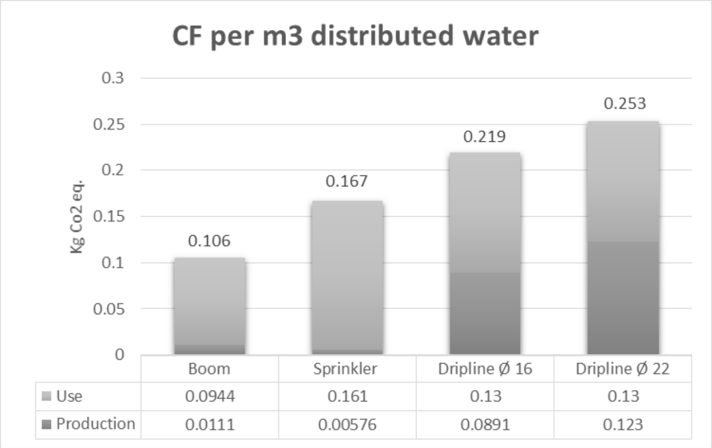


Figure 2: Carbon Footrpint per Functional Unit

The 22mm diameter dripline is the system, which shows the higher impact, with 0,253 Kg CO2 eq. per m3 of distributed water, followed by 16mm dripline with 0,219 Kg CO2 eq. per m3 and the Sprinkler Hose Reel with 0.167 Kg CO2 eq. per m3. The system with the lower impact is the Boom with 0,106 Kg CO2 eq. per m3. Impact of hose reel production phase has little contribution to the system overall CF (about 3%). On the contrary, production of Dripline systems contributes for 41% of CF for the 16 mm and for 48% for the 22 mm. This is because dripline systems used to irrigate open field cultivations are substituted annually.

4. Conclusions

The analysis performed in this study shows that the dripline system has the higher environmental impact, regarding the effects on climate change. This is because dripline are disposable systems and an assessment performed on the entire life cycle of the systems shows that this has an important influence on environment. However, this study assesses only one impact indicator. Analysis on the overall sustainability of irrigation systems should consider other indicators such as the hydric efficiency or water footprint among others.

In any case, it is not possible to define a system, which is sustainable in all conditions. Indeed, variables such as soil condition and composition, culture, climate zone and weather have a relevant influence on environmental impacts of different irrigation systems. In addition, the experience and competence of whom operate the systems is a variable that should be considered when assessing irrigation sustainability, although it is difficult to measure.

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