

Carbon footprint from helitankers: sustainable decision making in aerial wildfire fighting

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Abstract. Carbon footprint (CF) can be a key factor stimulating innovation while driving sustainable decision making. The air transport sector and wildfires are considered to be relevant contributors to greenhouse gas emissions. Among the available resources for wildfire suppression, aerial firefighting – particularly using helitankers – is the most effective method. However the high economic costs and fuel-related emissions incurred by helitankers prevent their widespread use. This work aims to calculate the CF from helitankers in order to assess this new indicator for sustainable decision making. The CF is calculated here by a compound method based on the financial accounts of a Spanish company that owns 20 helitankers. The total cumulative corporate CF in 2012 was 5497 t CO₂ equivalents. We discuss the influence of the method, its implications and future actions for the reduction of greenhouse gas emissions. Our experience should be considered as a pilot study providing further evidence of the value of using sustainable indicators in decision making.

Additional keywords: Carbonfeel, consumption-based emissions, environmental accounting, helicopters, MC3, Scope 3 emissions.

Introduction

Climate change is a matter of major concern to modern society (Solomon *et al.* 2007). The increase in greenhouse gas (GHG) emissions is clearly having an effect on climate systems (Stocker *et al.* 2013), with potential negative feedback for the health of ecosystems (Butchart *et al.* 2010). Forest ecosystems particularly play a crucial role in this global carbon (C) cycle, acting as a net C sink and storing between 40 and 60% of all terrestrial C, including C stored in vegetation and soil organic matter (Körner 2005; Fischlin *et al.* 2007; Bonan 2008; Pan *et al.* 2011).

In this context, the goal of sustainable development must be pursued through the use of new environmental sustainability indicators (Roca and Searcy 2012), and particularly the carbon footprint (CF) (Wiedmann and Minx 2008; Peters 2010). The target of reducing CF could be a key factor stimulating innovation while driving sustainable decision making. CF is an active research topic with a large number of initiatives currently underway in several countries (Wiedmann *et al.* 2011). Current methodological advantages in hybrid approaches allow CF to be implemented in a wide range of businesses and products (Suh

and Lippiatt 2012); however, its effectiveness as a new approach to drive sustainable decision making is still under study (Majeau-Bettez *et al.* 2011). There is a need for further research to demonstrate the feasibility of these new sustainable indicators in decision making. Positive results for early adopters may lead to future regulation and consumer trust.

The aviation sector is today regarded as a key contributor to GHG emissions (Peters *et al.* 2007). This importance has led to the inclusion in the European Union's Emission Trading Scheme (Miyoshi 2014) of commercial aviation, the only part of the aviation sector for which emissions information is officially recorded and discussed. In the global context, the International Civil Aviation Organisation has agreed to develop by 2016 a specific global market-based mechanism to be implemented in international aviation by 2020 (Barbot *et al.* 2014). A review of the literature reveals several reports of helicopter emissions from fuel consumption (FOCA 2009; Linares Bejarano 2011; Merkisz *et al.* 2012; Grogan 2013), although few consider emissions from other sources such as maintenance or construction (Ricondo and Associates 2008). This increased concern reinforces the need to consider all available strategies for

sustainable development, such as the implementation of CF in decision making.

Another major source of emissions is wildfires. Fire has influenced C cycling and interacted with the climate system for the ~420 million years of Earth's history (Bowman *et al.* 2009). Wildfires spread rapidly in the Mediterranean climate owing to the generally hot dry conditions, and the interaction between human activity and nature has made them a major economic, social and ecological problem. Climate change is likely to increase the intensity and frequency of drought in many of these Mediterranean areas, creating more intense and frequent wildfires (Flannigan *et al.* 2006; Sommers *et al.* 2014). A comprehensive knowledge of fire emissions has been promoted to effectively quantify and assess the role of fire in the C cycle, and the long-term benefits of carbon sequestration projects (Meigs *et al.* 2011; Miller *et al.* 2012). This knowledge could be improved with the assessment of emissions from human prevention, detection and suppression strategies.

Wildfire prevention, detection and suppression strategies are the ongoing subject of evaluation and discussion. Fast and effective detection is a key factor in wildfire fighting (Ambrosia *et al.* 1998), and once a fire is detected, wildfire suppression becomes critical. Suppression methods vary among countries according to their technological capacity (Moore *et al.* 2003). Although a large number of factors determine the success and effectiveness of the method, aerial firefighting is considered the most successful strategy thanks to its capacity for rapid deployment (Grigel 1974). Of the available aerial firefighting resources, helitankers are particularly valuable due to their ability to (1) transport both firefighting brigades and buckets; (2) reach areas that are difficult or impossible to access by land; (3) refill buckets in small areas in lakes, rivers, reservoirs or portable tanks; (4) evacuate humans at risk, and above all; (5) deliver a swift initial strike to gain early control and reduce the risk of large wildfires. Despite these positive features, helitankers' high fuel and maintenance costs hinder their widespread use. Increasing environmental concerns about aviation emissions may lead to their consideration as unsustainable from an environmental perspective.

This work aims to calculate the CF from helitankers in order to assess this new indicator for sustainable decision making. Our experience should be considered as a pilot study to assess the feasibility of CF in decision making.

Materials and methods

Helitanker CF is calculated using a compound method based on financial accounts (or MC3, from its Spanish acronym '*Método Compuesto de las Cuentas Contables*') (Doménech 2007). MC3 is a tiered hybrid analysis (Suh and Huppes 2005) capable of including both product and corporate CF in a comprehensive assessment (Carballo-Penela and Doménech 2010; Alvarez *et al.* 2015). This method is one of the most widely accepted approaches in Spain, and has been approved as a valid means of assessing corporate CF within the framework of the Spanish Voluntary GHG Reduction Agreement (De la Cruz Leiva *et al.* 2011). It is also endorsed by the Spanish Technical Committee of the Carbonfeel Initiative (Carbonfeel 2014). The results can be certified under international standards for both products and

companies (ISO 2013a, b). Advances in MC3 have been the subject of previous studies (Penela 2008; Carballo-Penela and Doménech 2010; Cagiao *et al.* 2011, 2012; Alvarez *et al.* 2014, 2015; Alvarez and Rubio 2015a, b), and this study applies the latest 2012 version (v. 12.3) developed within the Carbonfeel Initiative (Carbonfeel 2013). For a complete description of the process and methodological issues, see Carballo-Penela (2010) and Cagiao *et al.* (2012).

MC3 involves assessment through comprehensive corporate inventories and allows the inclusion of other indirect emissions (ISO 2006), also known as Scope 3 emissions (Greenhalgh *et al.* 2010). For example, these emissions correspond to the ones associated with the life cycle of kerosene and purchased materials such as oils and transport replacements. MC3 also enables the use of boundaries and thresholds that are unlikely to vary subjectively with each analyst – a critical factor when comparing results (Alvarez *et al.* 2014). Helitanker CF is calculated through the specific analysis of one Spanish company ('*Hispanica de Aviación SA*', hereafter HASA), with over 25 years' experience in helicopter services and specialising in helitankers for aerial firefighting. Currently, HASA owns 20 helicopters (15 are in operation) and is one of the largest contractors for aerial firefighting in Spain, in addition to operating in other countries in Europe and South America. Its operations comprise the airfield '*El Tiétar*' (4.0 ha) located in the municipality of La Iglesuela (Toledo province, central Spain); the helibase '*La Guancha*' (0.4 ha) located in La Guancha (Tenerife province, Canary Islands); and its administrative offices (0.2 ha) located in Pozuelo de Alarcón (Madrid province, central Spain). The boundaries of the analysis are defined in terms of (1) physical boundaries (area controlled by HASA), (2) organisational boundaries (operations directly controlled by HASA) and (3) operational boundaries (divided into four management areas: (a) Helitanker maintenance, (b) Helitanker operations, (c) Airfield and helibase, and (d) General administration). Detailed consumption and financial data from 2012 are classified into three main inventories: (1) land-use inventory – owned or controlled land area classified into the five main categories defined by the Eggleston *et al.* (2006a), (2) waste inventory – all residues produced in tons, classified according to the Commission Decision (2000)–, and (3) consumption inventory – fuel and electricity consumption in physical units besides annual financial reports in €, both allocated to the consumption categories in MC3–. In many cases specific invoices must be broken down in order to assign them correctly to the different MC3 consumption subcategories. GHG emissions include direct, all upstream indirect, land-use and waste management emissions. Carbon dioxide, methane and nitrous oxide emissions are evaluated and expressed in terms of CO₂ equivalents (CO₂eq).

Results

According to MC3, the total cumulative corporate CF of HASA in 2012 was 5497.12 t CO₂eq. This result can be classified according to different criteria. The ISO 14064 classification divides total emissions into three categories: Direct GHG emissions – 2898.23 t CO₂eq (52.7% of total emissions); Energy indirect GHG emissions – 21.00 t CO₂eq (0.4% of total emissions); and Other indirect GHG emissions – 2 577.89 t CO₂eq

(46.9% of total emissions). Table 1 shows the inputs and emissions according to this classification and the MC3 category (which is not a main category in the ISO 14064) classification.

Fig. 1 shows the structural composition of the total CF according to MC3 categories. The main source of emissions is the Direct emissions' category, followed by the Materials category (32.0% of total emissions). In the Direct emissions' category, the consumption of kerosene accounts for the highest contribution (50.4% of total emissions). In the Materials category, the consumption of transport vehicles has the highest

Table 1. Inputs and carbon footprint of *Hispánica de Aviación SA* (t CO₂eq) by scope and MC3 category

Scope/MC3 category (units)	Input	Emission
1. Direct emissions		
1.1. Petrol (L)	34 626.98	85.57
1.2. Gasoil (L)	15 902.56	41.57
1.3. Kerosene (L)	757 975.02	2771.09
2. Indirect emissions		
2.1. Electricity (Kwh)	110 541.33	21.00
3. Other indirect emissions		
3.1. Materials (€)	3 745 030.96	1756.36
3.2. Services and contracts (€)	2 051 443.60	471.11
3.3. Agricultural and fishing resources (€)	30 658.68	5.96
3.4. Forestry resources (€)	3 325.57	8.37
3.5. Water footprint (m ³)	697.44	1.71
3.6. Land use (ha)	41.02	-14.50
3.7. Waste and discharge (t)	5.61	0.47
3.8. Scope 1 and 2 life cycle emissions		348.41

percentage (27.7% of total emissions), followed at a distance by furniture and oils (1.4% and 1.3%).

Data from the four management areas are shown in Fig. 2. The total CF from each of General administration and Helitanker maintenance is 995 t CO₂eq (18% of total emissions). Helitanker operations have the highest contribution (3326 t CO₂eq, or 61% of total emissions), with the lowest being from Airfield and helibase (186 t CO₂eq, or 3% of total emissions).

The mean annual flight distance covered by each of the 15 helitankers in operation is 34 000 km (±11 895 km standard deviation). These results added together for all helitankers totalled a corporate distance of 509 995 km in 2012. Taking into account the total corporate emissions, the average emissions are 10.8 Kg CO₂eq km⁻¹.

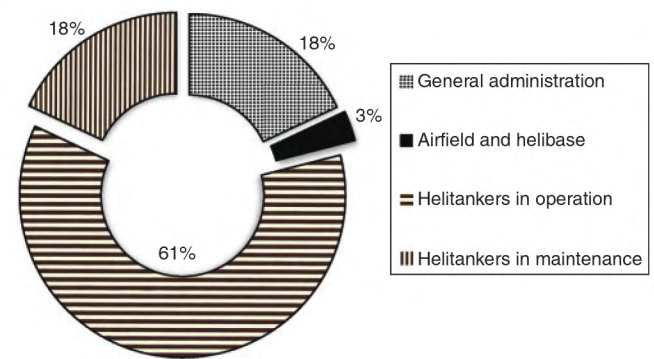


Fig. 2. Structural composition of the carbon footprint of *Hispánica de Aviación SA* according to management areas.

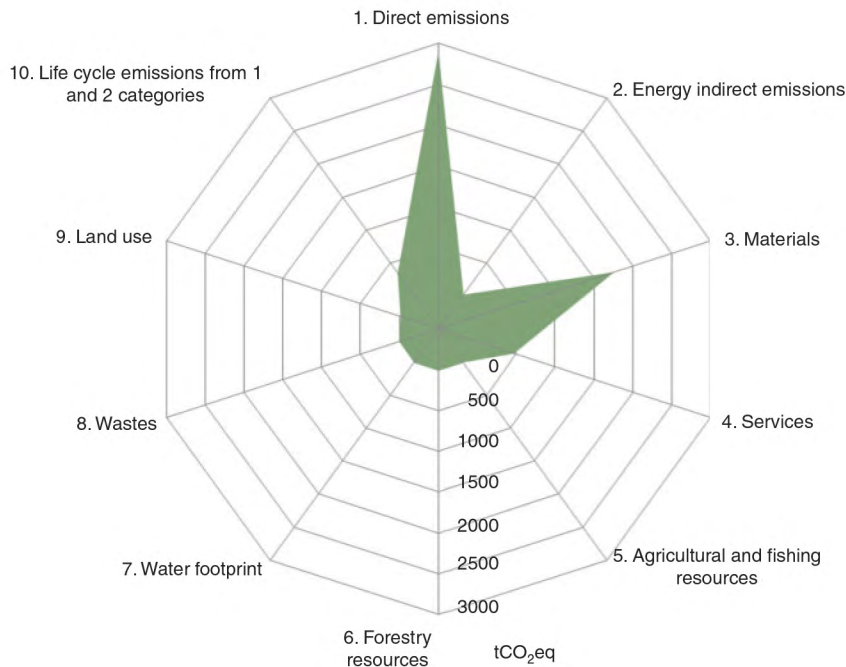


Fig. 1. Structural composition of the carbon footprint of *Hispánica de Aviación SA* according to consumption categories.

Discussion

The relevance of this study is reinforced by the possibility of including new environmental criteria such as CF in sustainable decision making. The results can be analysed from different points of view. First, we evaluate the method's characteristics and influence. Second, we assess the results to understand their implications and to identify future actions.

The strengths and weaknesses of MC3 have already been outlined by *Alvarez et al. (2014)*. This method offers the chance to work with easy-to-obtain data, and correctly assesses the amount of direct and indirect GHG emissions. In the current study it is worth highlighting one main strength and one weakness. One strength is the complete consideration of other indirect emissions thanks to the use of accounting reports and the use of input–output analysis for CF. Besides, it should be noted that GHG inventories from transport activities are now shifting from direct emissions to the indirect emissions in the upstream supply chain, and those caused by the use and disposal of products (*CDP 2013*). Helicopter emissions are commonly estimated following IPCC guidelines based only on fuel consumption (*Eggleston et al. 2006b*). Several examples use these recommendations (*FOCA 2009; Linares Bejarano 2011; Merkisz et al. 2012; Grogan 2013*). In our experience, these studies fail to account for emissions that should be included; specifically, 49.6% of total emissions due to all consumption and waste generated from helicopter activity.

The main weakness of the study is that the results for product CF should be considered as an approximation. Despite our improvements over former studies (*FOCA 2009; Linares Bejarano 2011; Merkisz et al. 2012; Grogan 2013*), a life cycle phase statement is required for the correct assessment of product CF (*ISO 2013a*). Manufacture and disposal life cycle emissions in addition to operation life cycle emissions should be considered in future studies. The reviewed studies show significant differences in consumption depending on the propulsion system (e.g. *Grogan 2013*), and the helitanker's emissions may vary with the service provided. Each service may produce different emissions based on the fire activity, weather conditions and terrain slopes. The functional unit should therefore be defined in terms of the type and specific service provided by the helitanker.

Our results may be of substantial interest in the field of helitanker services and to helicopter services in general. The CF results provide an analytical basis for the implementation of carbon management plans in HASA. Obviously, reductions in fuel consumption are needed in order to enhance sustainability, and here we should indicate the recommendations of *Drozd et al. (2012)*. Nevertheless, our study allows assessment in categories that are not commonly reported and could produce high effective reductions in total emissions. To give a few examples: (1) materials from maintenance services (28% of total emissions) should be evaluated in order to pursue reductions by buying products covered by environmental declarations; (2) gasoil emissions from office boiler consumption (1% of total emissions) could be reduced by replacing gasoil with natural gas or biomass fuel. Further, the comparison of consumption patterns across management areas and years revealed interesting findings (data not shown) that led to the integration of new schemes for sustainable development in HASA. Finally,

in addition to reduction measures, the company could enact compensation measures such as reforestation in permitted areas around the 'El Tiétar' airfield.

Taking into account our results for emissions per km, it may be possible to tradeoff the emissions from helicopter operation against the avoided emissions from wildfire. This simplification does not consider the distance covered by on-site operations (i.e. loading and unloading), as well as other valuable environmental assessments such as the loss of biodiversity and soil erosion, which should not be ignored in a comprehensive view of all environmental effects (*Campbell and Tilley 2014*). These features (including flood risk) are particularly relevant in the Mediterranean region where effective wildfire suppression may produce important changes (*Certini et al. 2011*). Therefore, this tradeoff could never be a criterion for decision making, but may give us further insight into the relevance of wildfire emissions and the importance of developing effective techniques for wildfire detection and suppression.

Conclusions

This study provides further evidence of the value of implementing sustainable indicators in decision making. Our experience should be considered as a pilot study to demonstrate the feasibility and practicality of integrating one of these new sustainable indicators – the CF – in decision making. Despite the focus on the participation of helitankers in wildfire suppression, these criteria may be useful in other more general aspects of helicopter services such as crew transportation and aerial reconnaissance.

In fact, the results may be of considerable interest to the air transport sector in general, and to helicopter services in particular. The differences in the helicopter emissions in the review can be explained by the assumptions of the method. MC3 was easily implemented, and provided a broad field of action in terms of reduction, compensation and communication. Thanks to the wide range of consumption categories, the results can be used as a baseline to measure the effects of future change in policies and technical measures on reducing consumption and material-associated GHG emissions. Moreover, the assessment using MC3 has raised awareness of the integration of new schemes for sustainable development. Further work is currently ongoing to assess CF by specific helitanker unit and service.

Our experience indicates the need to reinforce strategies based on the implementation of sustainable indicators such as CF. These new criteria may be useful in making decisions aimed at bringing benefits in sustainable development. Government authorities should be aware of this new capability in aerial firefighting and promote its inclusion in public procurement as a new criterion for award.

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