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REVIEW AND SYNTHESIS

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Environmental and social consequences of the increase in the demand for 'superfoods' world-wide

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Abstract

1. The search for healthy diets has led to a surge in the demand for functional foods or 'superfoods', which have now become popular among the middle- and high-income fractions of the society in developed regions of the world. 'Superfoods' are predominantly consumed far from their centres of origin and out of their cultural context with different environmental and social effects.
2. Here, we present a series of case studies to provide an overview of the different environmental impacts driven by superfood expansion.
3. We show that if these crops are to follow the path of other global commodities, then strong environmental impacts and large carbon footprints are expected in terms of land clearing, use of agrochemicals and transportation during times of high prices (boom) and social problems as farmers have to abandon their livelihoods when prices sink below the cost of production (bust).
4. We also showcase how a combination of management practices, consumer choices and policy changes could help in alleviating the ecological footprint of these crops.

KEYWORDS

biodiversity, deforestation, food choices, functional foods, healthy diet

1 | INTRODUCTION

Diets across developing and developed nations have shifted in the past decades towards an increase in the consumption of meat, dairy, refined grains, fruit and vegetables as people become wealthier (Godfray et al., 2018). These changes have led to an increase in the prevalence of non-communicable diseases such as type II diabetes, coronary heart disease, cancer or obesity (Pan et al., 2012; Popkin, Adair, & Ng, 2012). The implementation of dietary solutions (e.g. a decrease in meat consumption, Poore & Nemecek, 2018) to the tightly linked diet–environment–health trilemma is a global challenge. Yet it also represents an opportunity of great environmental and public health importance, given that these food choices are also causing significant increases in greenhouse gas (GHG) emissions—including 13.7 billion metric tons of carbon dioxide equivalents and 26% of anthropogenic GHG emissions (Poore & Nemecek, 2018)—and contributing to deforestation (Tilman & Clark, 2014). Furthermore, food production across the world has important effects for biodiversity and the functioning of many ecosystems (Foley et al., 2005).

In response to the increase in the frequency of diet-related diseases, the search for healthy diets has led to a surge in the demand for functional foods with multiple benefits, amongst which are 'superfoods', as a 'smart way' to improve our diets. Superfoods are yet to be presented with a precise definition, but as opposed to other functional foods that have been fortified, enhanced or altered

TABLE 1 Summary of area occupied by case study superfoods and their main environmental issues. Total area produced obtained from (FAOstat, 2018; IBGE, 2018)

Food crop	Origin	Main producers	Total global production in 2017 (tonnes)	Main environmental issues
Coconuts	Southeast Asia	Philippines, Indonesia, Sri Lanka, India	60,773,435	Land use change
Cacao	Amazon basin	Côte d´Ivoire, Indonesia, Ghana, Cameroon and Nigeria	5,201,108	Land use change, intensification
Quinoa	Andes mountains	Peru, Bolivia	146,735	Land use change, loss of traditional varieties
Açai	Amazon basin	Brazil	219,885	Land use change
Avocado	South central Mexico	Mexico, Peru, Colombia, Chile	5,924,398	Water depletion, land use change
Almonds	China	USA, Spain	2,239,697	Water depletion

in some way to increase their nutritional qualities, superfoods are thought to be inherently full of good nutrients. Recent research suggests they are a broad category of foods that share a series of characteristics: (a) they are thought to have superior nutritional qualities, (b) they are thought to be produced in a 'natural' way, i.e. with little or no technological intervention and (c) they are associated with indigenous people and traditional production practices oftentimes in remote locations (Loyer, 2016). Indeed, many of the food items we refer to as superfoods, are traditional staples used for millennia by different indigenous communities to prevent diseases but have now become global agricultural commodities, very popular among the middle and high-income fractions of the society (Loyer, 2016). This transition from local staples to global commodities, has made superfoods increasingly demanded in developed regions of the world, far from their centres of origin and out of the cultural context in which they were traditionally consumed.

Superfoods are not solely consumed because of their nutritional values, rather they are considered by consumers as being 'natural' products (Loyer, 2016), i.e. produced using traditional management practices perfected by indigenous communities for centuries, with little impact for the environment (Loyer & Knight, 2018). Thus, superfoods are not only fulfilling the dietary concerns of consumers but also their ethical ones (Loyer, 2016). However, the growing demand for many of these products, means that in many instances, they are no longer produced following traditional practices, but rather revert to intensive agricultural production practices, with important social and environmental impacts (Campbell et al., 2018). Further, in order to reach consumers, superfoods are processed, packaged and distributed, which means that their recollection/cultivation, transportation and packaging are an important source of GHG emissions (Vermeulen, Campbell, & Ingram, 2012).

Many research efforts have been devoted to analysing the environmental impacts of diets that include meat, eggs and dairy (Eshel, Shepon, Makov, & Milo, 2014), but surprisingly little research has been devoted to studying the environmental effects of the large and rapid increase in the production of these superfood items during the last decades. Indeed, research on superfoods is now only beginning to emerge, with much of it being focused on the social aspects of its increasing consumption (Loyer, 2016; Loyer & Knight, 2018). But research focused on the environmental impacts of the increase in the consumption of superfoods is yet to come.

The goal of this paper is not to define superfoods, but rather to examine the way in which the new fondness for them is modifying and impacting natural habitats around the globe. Thus, this is not an exhaustive review of the literature on superfoods, but rather an overview of the different effects these crops might have for the environment. Our aim is to show that, similar to other high-profile non superfoods (e.g. palm oil), superfoods have a deleterious effect on the environment. To this end, we present a series of case studies (summarized in Table 1) representing some of the most consumed superfoods across the planet, which reflect the different set of environmental impacts driven by the expanding superfood industry, including water depletion (e.g. avocados or almonds), soil degradation (e.g. quinoa), negative impacts for biodiversity (e.g. açai) or increasing land conversion within natural habitats (e.g. coconut and cacao).

2 | CASE STUDIES

2.1 | Coconut

The consumption of coconut *Cocos nucifera* in all its forms (water, milk, oil, sugar or flour) has greatly increased as consumers search for alternatives to the conventional forms of these staples. The main producers of the coconut industry are the Philippines, Indonesia, Sri Lanka and India (4; Figures 1 and 2). Within these countries, 70% of the production is consumed locally in the form of fresh products, while the remaining 30% is exported mostly in the form of oil, particularly to Europe and the US (FAO, 2001).

Indonesia possesses the largest area under coconut cultivation in the world; however, most plantations belong to smallholders with limited technologies and low productivities (at 50% of their potential production), and thus have lower productivities than other countries. Philippines is the largest producer with an aggregated trade value of US$ 1.113 billion between the years 2002 and 2011 (FAO, 2013). Here, coconut area is increasing due to massive planting

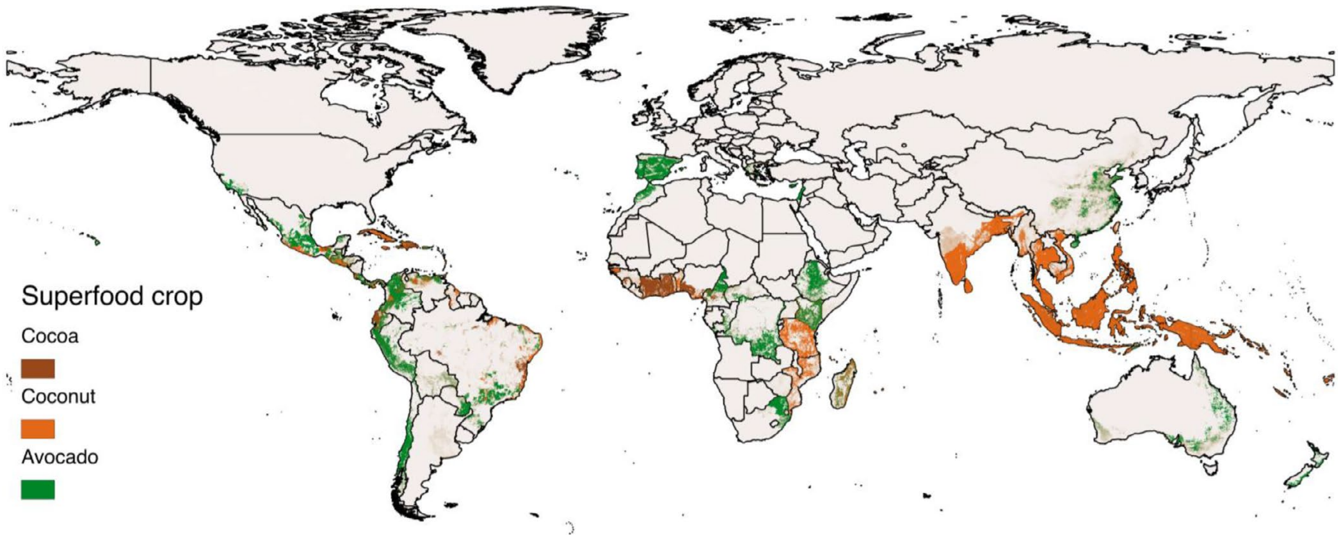

FIGURE 1 Global distribution of production areas of three of the main superfoods covered in the case studies (extracted from Ramankutty, Evan, Monfreda, & Foley, 2008)

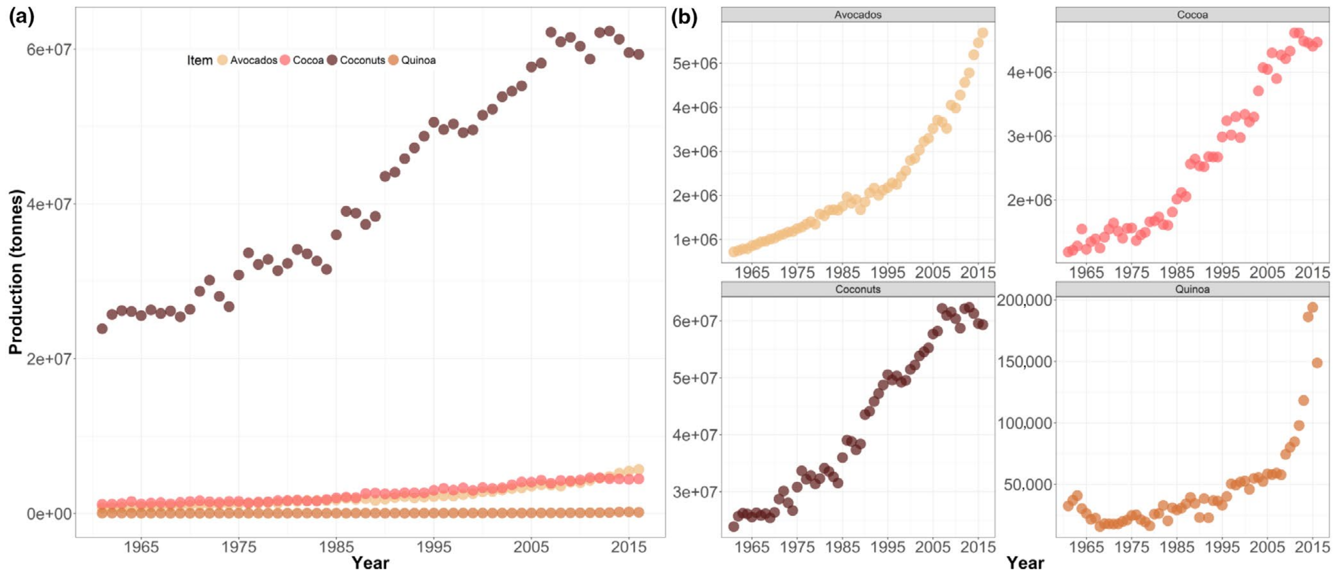

FIGURE 2 Evolution of global production in time for four of the main superfoods covered in the case studies in the period between 1960 and 2016 showing (a) all crops together for comparison and (b) each individual crop. Note that *y*-axes in (b) are different for each crop (source: FAOSTAT, 2018)

and replanting and has tripled since the 1960s, now representing >3.5 million ha, or 25% of the agricultural land in the country in 2016 (FAOstat, 2018).

In many cases, coconuts are grown as a monoculture, with the associated problem that as trees age they become less productive and the cost of maintaining and harvesting coconuts becomes extremely high. Thus, farmers need to plant more coconut trees by replacing other native trees, which can affect soil properties, increase soil erosion and alter soil nutrient composition leading farmers to rely on chemical fertilizers to increase productivity, in some cases subsidized by local governments (e.g. in North Sulawesi, Waney, 2002). However, although using fertilizer increases yields, the rise in the price of labour outweighs these gains and, as a result, profits are lower than in more traditional systems (Waney, 2002). This adds to the financial problems faced by 60% of coconut farmers who currently live under the poverty line with incomes far below the cost of inputs and subject to the variations in the global coconut oil market (Edo, 2017). Additionally, relying on monocrop farming can be extremely risky for farmers, particularly in the face of ongoing climate change and the increasing virulence of extreme weather events (e.g. Typhoon Haiyan that struck Philippines in 2013 destroying 33 million coconut trees, http://www.fao.org/news/story/en/item/212957/icode/). The increasing prevalence of extreme weather events is further amplified by the ongoing mangrove deforestation across SE Asia (Richards & Friess, 2016), which diminishes coastal protection ecosystem services in the area and protection of coconut plantations in particular.

Further, the increase in coconut monocultures can have other undesired side effects. Research conducted in the Palmyra atoll showed that seabirds avoid coconut palm trees as nesting sites within monodominant stands, favouring other tree species. As a consequence, accumulated excrement deposition in these areas decreases with important consequences for local soil conditions (including important decreases in nitrate and phosphate, Young, McCauley, Dunbar, & Dirzo, 2010). These changes to soil nutritional quality are now visible in the nutritional content of plant species growing in areas around the palms. Yet the changes do not stop there. The decrease in the nutritional value of plant species affects the consumption by herbivore species that can consistently detect leaves with lower nutritional content (Young et al., 2010). This is just an example of the broad implications and cascading effects that changing land use can have for natural ecosystems.

Generally, the expansion in coconut palm surface is dwarfed by that in oil palm, which has increased by 260% in the past two decades (FAOstat, 2018). However, the demand for two coconut-derived products marketed as superfoods, oil and water, has greatly increased during the past decade, currently representing markets worth 2.1 billion and 800 million USD respectively (Sri Lanka Export Development Board, 2018). This trend is set to continue as the demand for these products continues to increase, particularly in Europe and North America. At this point it would be interesting that the coconut industry used the knowledge derived from the many studies conducted on the environmental impacts of oil palm expansion in order to avoid the environmental damage caused by the former. These could include creating a stakeholder alliance to promote best practices within supply chains, similar to the Roundtable for Sustainable Palm Oil (RSPO), which certifies plantations following sustainable production practices. However, as is the case with oil palm, plantations under these certification schemes need to be subject to frequent evaluations to assess the relative performance of the different practices (Morgans et al., 2018) in order to adapt and change them.

2.2 | Cacao

Cocoa *Theobroma cacao* powder and dark chocolate have been shown to contain high antioxidant capacities and great nutritive values (Crozier et al., 2011). This crop is mostly produced in Côte d´Ivoire (where land under cocoa has increased by an order of magnitude since the 1960s), Indonesia (where cocoa cover has increased by >250% since 1961) and Ghana (whose production has recovered after a strong decrease during the 1980s, FAOstat, 2018), with Cameroon and Nigeria providing most of the rest of the production (Figures 1 and 2). Cacao production currently employs 60% of the agricultural labour force in Ghana, for whom this industry represents 70%–100% of their income (Ntiamoah & Afrane, 2008). This crop, originally from the Amazon (Motamayor et al., 2008), had a great value for societies there, yet its major producers are now located in West Africa and Asia, with no tradition of consumption and thus who export most of their production.

One of the main properties that define the cacao industry is the boom-and-bust cycles it follows as prices rise and fall and geographical centres shift. Cacao distribution has constantly changed during the past decades, yet cacao expansion is consistently done at the expense of tropical forests and has led to the conversion of large expanses of areas within biodiversity hotspots (Yann, Heiko, & Teja, 2009). At first, cacao is planted under the shade of thinned rainforests and benefits of the shade and fertile conditions there. However, as trees mature and become less dependent on shade, many of these shade trees are removed, which is thought to also improve yield (Yann et al., 2009). Nevertheless, removing shade has important negative effects for biodiversity (Clough, Dwi Putra, Pitopang, & Tscharntke, 2009) and it leads to an increase in pest pressure, which raises the need to use chemical pesticides (Yann et al., 2009). In an attempt to increase the productivity of the crop in Ghana, the national government initiated a program to provide pesticides and fertilizers at no cost, which led the production to more than double in 2 years, an increase that was accompanied by important negative environmental consequences (Ntiamoah & Afrane, 2008). Additionally, the adoption of Amazon hybrids that do not require shade, have led many farmers to grow cocoa under full sun conditions. However, because of lack of knowledge on how to cultivate these varieties and shortage of financial investments, many cocoa farms grown in this way, suffer from early degeneration and death of trees (Wessel & Quist-Wessel, 2015). As cocoa trees age and their yield decreases, production shifts to new frontier regions, where forestland is transformed (as this is the cheapest way to establish new plantations, Yann et al., 2009), or farmers shift to other more profitable crops (e.g. rubber or oil palm) that carry their own environmental issues (e.g. land use change, soil degradation, negative impacts for biodiversity; Abood, Lee, Burivalova, Garcia-Ulloa, & Koh, 2014).

The increasing demand for cacao in its different forms (nibs, powder, chocolate bars) anticipates a new boom in its production in the upcoming years. This will mean that large tracts of forests will be converted, first to agroforestry systems, and then to cacao monocultures. These monocultures will suffer an intensification of production through the use of fertilizers and pesticides and will then be abandoned 40–50 years after establishment, when their production decreases. However, at that point their biodiversity value will be greatly diminished, as a result of the process of intensification of the agricultural practices (Steffan-Dewenter et al., 2007).

At present, there is little land available within producing countries to allow for a much larger expansion, which means that production will have to be met by increasing the yield of already existing cocoa farms by intensifying productivity (Wessel & Quist-Wessel, 2015), with the associated impacts this might bring (e.g. an increased use of pesticides and chemical fertilizers, increased pest resistance, increased GHG emissions, soil erosion, freshwater depletion or eutrophication; Balmford et al., 2018; IPES Food, 2016). There is, however, potential for improvement as Ghana and Côte d´Ivoire have recognized cocoa plantations as one of the main areas in which to focus their activities to address forest degradation and deforestation while submitting their REDD+ reference levels to the UNFCCC

Secretariat (National REDD+ Secretariat, & Forestry Commission, 2017; Republique de Cote D´Ivoire, 2017). This program seeks to reduce carbon emissions related to the expansion of cocoa production into forested areas by intensifying productivity through appropriate agronomic practices. These practices include the restoration of abandoned plantations (e.g. restoring shade trees as important carbon reservoirs, Dawoe, Asante, Acheampong, & Bosu, 2016) or the use of high yielding varieties in an attempt to reduce further expansion, although the latter pose their own problems (e.g. high pesticide use or loss of traditional varieties, freshwater depletion, eutrophication Balmford et al., 2018; IPES Food, 2016; Thrupp, 2000).

The consequences of these boom-and-bust cycles are not just environmental, but also include socio-economic effects, such as an increase in the migration rates from rural to urban areas during times of low prices resulting in a shortage of labour (Wessel & Quist-Wessel, 2015). Increasing population, in particular in urban areas, will lead to an increasing demand for food crops, which coupled with the potential effect of climate change (to which monocultures of selected productive varieties tend to be more vulnerable) and the lack of suitable land might lead to conflicts between cocoa and other potential food crops.

2.3 | Quinoa

The consumption of quinoa *Chenopodium quinoa* Wild., a local grain from the Andes, has suffered a comeback after it was neglected for decades following the Spanish conquest, representing an added market value of 131 million USD in 2012 (Furche et al., 2015). Today, quinoa is found in many US and European households due to its remarkable properties as the only plant that contains all essential amino acids, trace elements and vitamins and the fact that it is gluten-free (Giuliani, Hintermann, Rojas, & Padulosi, 2013). Its production has increased in the past four decades by 252% and 612% and the area it occupies by 124% and 440% respectively in the Andean regions of Peru and Bolivia (11, Figure 2).

Quinoa was traditionally planted using crop rotation but the large increase in its demand has led farmers to favour intensive monocultures and heavy machinery, increasing soil erosion and degradation (Giuliani et al., 2013) with multiple other side effects. For instance, quinoa cultivation has taken over pastureland previously occupied by llamas and alpacas that naturally fertilized soil and, consequently, farmers now rely on conventional fertilizers (Giuliani et al., 2013). In addition, the use of heavy machinery has favoured the populations of several pests in the subsoil demanding a pest control management (Jacobsen, 2011). In order to ensure a continuous production, farmers now leave fallow periods ranging from 6 to 8 years (Kerssen, 2015), which increases soil erosion and the depletion of nutrients. Further, monocultures favour the use of a reduced number of varieties, which reduces crop genetic diversity and increases vulnerability to biotic and abiotic stresses. At present, four varieties cover 90% of the entire production (Avitabile, 2010), although there are at least 20 commercial varieties existing only in Peru (Apaza, Cáceres, Estrada, & Pinero, 2015). This process of intensification is particularly risky in the case of the Andean region, given that soils in the area are sandy and volcanic and characterized by high salinity, shortage of organic matter and low moisture retention abilities (Vallejos Mamani, Ayaviri Nina, & Navarro Fuentes, 2011) and subject to extreme (dry and wind-dominated) climate conditions.

Production increases also raise concerns regarding socio-economic, equity and sustainability issues in the area, such as land tenure or collective action through the conversion of previously collectively owned lands to private crops (Narloch, Pascual, & Drucker, 2012; Winkel et al., 2012). Although quinoa production has clearly improved living conditions for many farmers (Bellemare, Fajardo-Gonzalez, & Gitter, 2018), increased their access to education and more varied diets and has reversed migration flows (Avitabile, 2010), it still faces many challenges such as adapting to climate change in the face of declining genetic diversity.

Finally, quinoa too is susceptible to market vagaries as rising prices increase competition, and ultimately lead to a plunge in prices with the environmental and social impacts this carries. These include a decrease in quinoa consumption within local diets due to prohibitive prices in favour of less nutritious food items (e.g. rice or wheat, Jacobsen, 2011) that lack the essential micronutrients found in quinoa. Indeed, the export of quinoa has steadily increased since 2001, now representing 90% of production, while domestic consumption has decreased (Jacobsen, 2011).

2.4 | Açai

Another superfood item that has been become increasingly popular are açaí fruits from the palm *Euterpe oleracea* Mart. This palm, originally from the Amazon basin used to naturally grow in lowland floodplains. However, the increase in the demand for its fruits, rich in antioxidants, and the dramatic increase in its price has led to the rapid expansion of açaí plantations, now intensively managed to increase fruit production (Brondizio, 2008). The once-identified as an example of a non-timber forest product that could be used to promote conservation in the Amazon area (Weinstein & Moegenburg, n.d.) is causing considerable changes in forest structure due to its intensive management (Freitas, Vieira, Albernaz, Magalhães, & Lees, 2015). The government of the state of Pará, responsible for most of the açaí production, has proposed a management of plantations with a mean density of 200 stems/ha, which entails a progressive thinning of forested areas (Homma et al., 2006). This thinning is projected to lead to a reduction of 50% in native tree species diversity and 63% of pioneer species and a consequent homogenization of the plant community (Freitas et al., 2015). Although, the changes in floristic composition already taking place are not observable using satellite images (Brondizio, Moran, Mausel, & Wu, 1996), structural complexity and bird diversity are greatly affected (Moegenburg & Levey, 2002). In particular, the intensity of harvest affects avian frugivore species whose diversity is reduced by 22% under a high-intensity harvest regime (where 75% of the fruits are removed) as compared to a low intensity harvest (where 40% of fruits are removed). In addition, açaí stem density has an effect on bird community composition by supporting larger populations of frugivorous birds than non-frugivorous birds (Moegenburg & Levey, 2002). Further, the resulting changes unleashed by açaí on forest structure also translate into important impacts on some of the ecosystem services the crop relies on (e.g. pollination, Campbell et al., 2018), which ultimately threaten the long-term sustainability of its production. As the demand for açaí products continues to increase, research has concluded that the exploitation of açaí is not, at present, a model that merges forest conservation and rural development (Weinstein & Moegenburg, n.d.). More research on the effect of different management practices on biodiversity and ecosystem functions supported by the highly diverse and unique rainforests in the Amazon is needed to ensure that the increasing demand offers an opportunity to develop a production scheme that supports both forest conservation and rural livelihoods in the area.

Together with production, major problems of the increasing production of açai berries are packaging and processing methods. In the case of açai, the pulp needs to be extracted, the puree is then packaged and needs to be immediately frozen. This temperature needs to be maintained during transportation all over the world which increases its ecological footprint.

An opportunity arises to transfer part of the pressure suffered by Amazonian floodplains to the Atlantic forest, where berries from the related species *Euterpe edulis* are now being harvested for pulp production. *Euterpe edulis* has been traditionally managed to extract hearts of palm, palmito, which requires killing the plant. This intense harvesting led this species to be placed in the list of species threatened with extinction of the Brazilian flora (Ministério do Meio Ambiente, 2008). However, a shift from heart extraction to berry harvesting represents an opportunity to provide yearly cash for producers and to manage the species under a wide range of conditions (e.g. forest or agroforestry systems, Dias Trevisan, Fantini, Schmitt-Filho, & Farley, 2015). *Euterpe edulis* is a key species in the fragmented Atlantic rainforests providing food resources to a wide variety of taxonomic groups (Keuroghlian & Eaton, 2008; Mauro & Alexandre, 2002) and that facilitates the recovery of degraded areas (Melito, Faria, Amorim, & Cazetta, 2014). Further, pulp production requires the separation of the seed which can be used to replant degraded areas (Dias Trevisan et al., 2015), aiding in the forest recovery of one of the most threatened biodiversity hotspots (Ribeiro et al., 2011).

2.5 | Avocados

The increase in the demand for avocados *Persea americana* Miller, particularly in Europe and the United States, is also showing important environmental impacts. This crop is produced mainly in Mexico (where production has increased by an order of magnitude and area occupied has increased in 18,000 ha since 1961), Peru, Colombia and Chile (FAOstat, 2018).

Rising prices for this crop are leading farmers in areas of central Mexico, responsible for 40% of global avocado exports (Figures 1 and 2), to thin out pine forests to plant avocados underneath and even to completely clear forested areas (Chávez-León et al., 2012). In order to keep up with the increasing demand for this nutritious product, the surface occupied by avocado in the country increased by 40%, the value of its production tripled and exports increased by 1,000% between 2000 and 2010. Initially, avocados were planted in agricultural areas (e.g. corn fields), yet once all these areas below 1,800 m were occupied, avocado plantations started to take over forested areas. During the past three decades, the expansion of avocado has led to the loss of 690 ha of forest per year (Chávez-León et al., 2012), particularly in the region of Michoacán, whose pine forests also annually host migrating populations of the monarch butterfly *Danaus plexippus* L. Here, in the period between 1993 and 2000, >100,000 ha of forest and >320,000 ha of jungle were transformed to avocado production, and as a consequence this greatly increased the use of fresh water and agrochemicals (Chávez-León et al., 2012; Gonzalez-Estudillo, Gonzalez-Campos, Napoles-Rivera, & Ponce-Ortega, 2017).

Avocado production is also raising important issues in Chile due to its high water requirements. Chile, one of the top 33 water-stressed countries (Luo, Young, & Reig, 2015) has multiplied by 10 its area devoted to the crop since 1961 (3,000 ha in 1961 as compared to >30,000 in 2017, FAOstat, 2018), which has already raised concerns among local smallholders in the province of Petorca. In this region in particular, water restrictions are in place since 1997 due to the low water retention capacity of soils. This adds to the large requirements of the avocado plantations where a single tree needs 187.4 L/day during the irrigation period (January–March; Castro Rios & Espinosa Toro, 2008). In addition, changing climate in the area is leading to a decrease in rainfall, with rain being concentrated in small periods of intense precipitation, which means water is not retained in the soil. These and other problems contribute to the increasing socio-economic issues raised by avocado and other superfoods (Box 1).

BOX 1 How avocado production fuels extortion rackets

In the case of Mexico, and the state of Michoacán in particular, socio-economic problems driven by superfood expansion are exemplified by the extortion payments that many farmers are being urged to pay to some of the drug cartels operating in the area where avocado plantations are established, as failure to do so translates into material damages (Aranda, 2014). In the area of Michoacán, reports suggest that extortion of avocado farmers is the main income for criminal groups like the Knights Templar (Aranda, 2014). Here, dispossession of lands by these criminal groups and money laundering in connivance with major public figures is currently reorganizing the economy.

2.6 | Almonds

Due to their high protein and fibre content, almonds are seen as healthy snack alternatives and almond milk is increasingly demanded as a vegan alternative for milk. As opposed to other superfoods, mostly produced in developing tropical regions, almonds are mainly produced within the USA and Spain (although production here is an order of magnitude smaller than in the US). The USA is also their main consumption centre (72% of the production remains there, FAOstat, 2018) thus; transportation in the case of almonds might have a smaller effect, yet its impacts arise from its intensive use of other inputs. Almonds demand large amounts of water, which is leading to a decrease in their yields in California (e.g. 15% decrease between 2011 and 2018, USDA, 2012), where 80% of US almonds are produced, and that has been suffering important droughts in the past 5 years. Additionally, almond production requires large amounts of fertilizers and pesticides as well as great numbers of honeybee hives, which are transported across the country every year to fulfil the pollination needs of the crop. Every year during almond blooming 1.7 million hives, or 85% of the available commercial honeybee hives in the US are transported to the almond-producing regions of California, with the consequent emissions due to transportation. Thus, although the carbon sequestered in almond trees could compensate part of the emissions they generate, the area they occupy has greatly increased in the past decade and so have all their inputs (USDA, 2012).

3 | TOWARDS A SUSTAINABLE SUPERFOOD INDUSTRY

If 'superfoods' are to follow the path of other global commodities (e.g. coffee) then strong environmental impacts and large carbon footprints are expected in terms of land clearing, use of agrochemicals, machinery and transportation, exacerbated in the case of 'superfoods', produced far away from consumption centres.

Generally, when new commodities enter the increasingly globalized food market, their demand increases very rapidly. This is the case in recent years for different superfoods, which could easily lead to an intensification in their production within their countries of origin, with implications for food security, local livelihoods and the environment. Yet, making informed decisions about the production of these crops requires that the context of the local food system be taken into account, given the critical role that many of these crops play for local communities (Ickowitz, Powell, Rowland, Jones, & Sunderland, 2019). Indeed, superfoods originate in most cases within complex and diverse crop agricultural systems. Transforming such production systems to commercially oriented intensive agricultural systems will have profound impacts on landscapes, livelihoods, diets, carbon footprints and biodiversity amongst others (Gonzalez, 2011). Thus, if intensification is to be part of the way the demand for superfoods is fulfilled, producers will need to ensure that environmental and social impacts are minimized, as avoiding them will be impossible given the scale of the demand. When policies and programs are implemented that fail to consider these important dimensions, there is a risk that they will do more harm than good. However, a combination of improved management practices, consumer awareness and policy changes might alleviate these impacts.

3.1 | Improving production environments—Towards agroecological systems

In the context of fulfilling the increasing demand, some management practices can minimize the potential impacts of a non-sustainable intensification, while they could otherwise represent substantial opportunities for food security of locals and climate change adaptation and mitigation, including diversification of crops, agroforestry practices, agroecological practices or sustainable intensification (Godfray & Garnett, 2014).

For instance, coffee and cocoa on average have a carbon footprint of 8.3 (van Rikxoort, Schroth, Läderach, & Rodríguez-Sánchez, 2014) and 8.0 kg CO_2 e/kg (Ortiz-Rodríguez, Villamizar-Gallardo, Naranjo-Merino, García-Caceres, & Castañeda-galvís, 2016). However, different management practices, such as the diversification of crops within a farm or the inclusion of a diverse set of shade tree species, can reduce their carbon footprint (van Rikxoort et al., 2014). In particular, a departure from monocrop exploitations to more diverse systems where multiple crops are produced, and particularly agroforestry systems that include shade tree species, might be an opportunity to ensure win–win scenarios for agricultural production and biodiversity, while safeguarding the long-term sustainability of the production. Although agroforestry practices also need improvement in order to decrease their impact, including their emissions, for example a comparison between conventional and agroforestry cocoa systems in Colombia showed they had equivalent CO_2 emissions (Ortiz-Rodríguez et al., 2016).

There are also opportunities for sustainable intensification, including ecological, genetic (through plant breeding processes) and market intensifications, defined by fairer and more efficient markets (Conway, 2012; Godfray & Garnett, 2014). Ecological intensification refers to the optimal management of the ecosystem services and functions provided by natural ecosystems to improve agricultural productivity, thus reducing the use of agricultural inputs. Nonetheless, ecological intensification requires more research aimed at understanding the relations between land use and ecosystem service provision (Bommarco, Kleijn, & Potts, 2013). Further, in order for growers to adopt these alternatives, researchers need to provide evidence on the economic benefits of these practices at scales that are relevant for them (Kleijn et al., 2019).

Given that superfoods are in many cases grown and manufactured in countries far from where they are consumed, it is very difficult to trace their supply chain. The existence of sustainability third-party certifications based on independent audits, thus represents a great opportunity to ensure that all the products consumed have a sustainable origin that has been tracked (Bain & Hatanaka, 2010).

Several of these endeavours exist in the case of superfoods (e.g. Rainforest Alliance cocoa, Fairtrade, Sustainable Certified Coconut Oil Production). In many cases, these certifications aim at improving the productivity and the quality of crops following standards for a sustainable productivity, while improving farmer quality of life through greater access to healthcare for example. Nevertheless, these sorts of approaches have sometimes been criticized, as they do not always address problems that farmers might be facing such as low productivity, a general lack of infrastructure or the use in some cases of child labour. Further criticism, suggests that in some cases farmer livelihoods and environmental sustainability might not always be the primary goal of sustainability certifications, but rather ensuring the provision of raw material at the cost of preventing farmers from diversifying their economies to more profitable crops (Odijie, 2018). Equally important is the fact that although certification raises the price paid to farmers, there is less evidence that is actually translated into a rise in farmer incomes given the high costs of the certification process. Indeed, certification processes are often costly and burdensome for farmers, preventing the ones with fewer resources from benefitting without external financial support. This is compounded by the fact that not all of the certified produce is sold at a premium due to lack of demand, which means farmers pay the costs of certification but are not receiving a premium price for their whole production (Elliot, 2018). Likewise, certification is not tailored to the unique production systems and conditions faced by different farmers growing the same crop in different locations and thus might not be as effective outside of the regions it was developed for.

3.2 | Consumer behaviours and dietary changes

The EAT-Lancet Commission is a group of 30 world-leading scientists working on defining a healthy and sustainable diet (Willett et al., 2019). The Commission has recently concluded that the transformation of our food system to a sustainable food production by 2050 will require a (a) 75% reduction in yield gaps, (b) a global redistribution in the use of nitrogen and phosphorus fertilizers, (c) the recycling of phosphorus, (d) radical improvements in the efficiency of fertilizer and water usage, (e) a rapid implementation of agricultural mitigation options to reduce greenhouse gas emissions, (f) adoption of land management practices that shift agriculture from a carbon source to sink, (g) a fundamental shift in production priorities and (h) a dramatic shift in the current dietary trends (Willett et al., 2019). Indeed, even though producers can certainly improve their practices to limit their impacts on the environment and achieve this transformation, consumer behaviour is critical in demanding more sustainably produced food. Great changes can therefore also be achieved through dietary shifts at the level of the consumer (Poore & Nemecek, 2018). As a matter of fact, the need to reach a sustainable consumption through changes in consumer behaviour is one of the Sustainable Development Goals (SDGs) set by the United Nations (UN General Assembly, 2015), and consumer awareness and behavioural changes are increasingly being seen as one of the approaches to contribute to sustainability and mitigation of climate change (Niles, Esquivel, Ahuja, & Mango, 2017).

Yet these changes largely depend on the accuracy of the information that consumers have to make informed decisions about their food choices. In the case of superfoods, the increasing demand for them as a component of healthy western diets, does not always have a scientific basis (Breeze, 2017) but rather, is oftentimes the result of marketing strategies to seek new market niches by food companies (Loyer, 2016). In the European Union, since 2007, the use of the term superfood for health claims needs to be accompanied by evidence. However, these marketing campaigns focus not only on the healthy aspects of superfoods, but also on their 'natural' origin and the associated 'romantic' stories that link them to ancient civilizations. Yet meeting current demand for most of these products means that traditional growing practices can no longer be used and an intensification of the production is required, with the environmental and social consequences this encompasses (Gonzalez, 2011). A consumer understanding and awareness of the environmental impacts of their food choices will thus also require stronger regulations of marketing practices accompanied by an increase in the number of scientific studies focusing on this unexplored area of research.

3.3 | Bridging consumers and producers through novel food networks/economic structures

Coupled with communicating the impacts of food choices (in terms of where and how they are produced, and their life cycles) there is a need to develop regulations that ensure that the information about their real benefits is accurate. In this sense, new economic structures and networks could facilitate not only consumer access to more sustainably produced food, but also ensure that food is produced promoting well-being and social justice. Indeed, consumers are choosing amongst a range of existing products that have been brought to them and that exist given the relationships between different producers and distributers (Parker, 2013). Ensuring that the environmental and social impact of our food choices is minimized will require of novel choices, including farming practices or supply chains.

For instance, an alternative to consuming superfoods with a distant origin is to consume local varieties of equivalent properties. In the case of quinoa in Europe, for example, there are Eurasian relatives for which there is evidence of consumption in the past, which could be the focus of new breeding programmes (e.g. *Chenopodium album*, Bazile & Baudron, 2015). Some other crops, like avocado, are now also largely produced in Europe and Australia, following different environmentally friendly technologies (e.g. non-tillage practices, Sayadi, Calatrava Requena, & Guirado Sanchez, 2005).

Yet consuming superfoods originating closer to the areas of main consumption has some issues of its own. First, production in those areas will likely still not be able to meet the total demand. Indeed, given the large demand for some of these products, no matter how sustainable production is, the level of production required would still be unsustainable. Second, these sort of shifts in consumption patterns could have an important effect for producers in areas of origin and their opportunities to raise their living standards and their income.

3.4 | Policy changes

Consumer choices are strong ways to shift the production of many crops, yet changing the superfood industry will also require policy action on both the supply and demand ends, which takes into account and monitors impacts for the environment as well as for producers. A full range of policy levers, from soft to hard, will be needed. Strong and coordinated governance of land will be required, which according to the EAT-Lancet commission, for example, should include implementing mechanisms of international land use governance (Willett et al., 2019). But a coordination of land policies at a global level is not a trivial question. The three Rio Conventions have addressed this issue since their creation, both as a stand-alone theme as well as included within different perspectives such as desertification and land degradation, biodiversity and climate change. National governments are also aiming at creating policies for land use and sustainability, oftentimes unfortunately through government departments that are not coordinated. A system approach is thus necessary. The SDGs and the Paris Agreement commitments that governments undertook in 2014 constitute a window of opportunity at national and international level to address land use from a more holistic and coordinated manner that could catalyse the transformation of the food systems.

4 | CONCLUSIONS

Local communities have sustainably exploited functional crops for millennia, however, their branding as a 'superfood' has turned them into global commodities in high demand. The production of many of these crops is now dominated by large corporations which favour short-term gains over long-term sustainability. Following the path of other commodities, it is expected that market forces will drive superfood production to follow boom-and-bust cycles, which could have pernicious impacts for the livelihoods of millions of local communities and farmers as they depend on the vagaries of global markets. Domination by these corporations could continue to erode local food systems which in many cases were healthy, sustainable and socially just (Gonzalez, 2011). Further, how these crops will respond to ongoing climate change in their growth centres is currently unknown, yet the decrease in their genetic variability and their management as monocultures suggests they will suffer strong decreases in production and potentially shifts in the distribution of areas suitable for their cultivation (Magrach & Ghazoul, 2015). Moreover, these superfoods might at present have a large genetic variability, which if eroded as production intensifies, might potentially lead them to lose some of their purported properties.

Serious questions remain regarding the environmental and social impacts of superfood production and consumption, and whether such products reinforce notions of cultural difference and patterns of global inequality (Loyer, 2014). More scientifically based studies are needed to quantify the effect of the rapid land use changes that origin areas are experiencing and their impact for the environment and the sustainability of the production. Fulfilling the need for the diverse diets of an ever-growing population without jeopardizing biodiversity will require important new research avenues but also an increased consumer awareness of the origin of the foods they consume and the environmental impacts of their food choices coupled with stronger regulations on marketing and distribution. Yet the challenge of achieving a sustainable food production will only be met if action is done on several fronts: from changing production practices to consumer diets and governance (Godfray & Garnett, 2014).

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CONFLICT OF INTEREST

The authors report no conflict of interest.

AUTHORS' CONTRIBUTIONS

A.M. and M.J.S. conceived the ideas, collected all relevant references and wrote the manuscript.

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