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The market–society–policy nexus in sustainable agriculture

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Abstract
Intensive agriculture has led to several environmental impacts, such as soil erosion, water scarcity, and pesticide pollution. Despite the increasing research advocating greener agriculture, the transition into sustainable agriculture practices has been slower than expected. Then, why are we stuck in this transition? In this scientific essay, we aimed to answer this question not only by analyzing agricultural systems but also by the associated actors. Specifically, this scientific essay analyzed and discussed how agricultural systems integrate with the surrounding market, society, and policies. We made a literature review of the impacts of intensive agriculture on global change and an analysis of greener agricultural systems. Then, we analyzed how the market, society, and policies can influence the transition from intensive agriculture to greener agricultural systems. In addition, we complement that literature review with a survey made in Chile. Our analysis highlighted ecological intensification (EI) as the most promising production system in terms of sustainability. However, the most sustainable was not necessarily the most supported by the market and society. We found a disconnection between consumers' environmental concerns and what they support when buying foodstuff. Our survey showed that most people are aware of soil degradation and high-water consumption, but above all, they want pesticide-free and organic food attributes. The literature review and survey results suggested how policies can break the status quo of intensive agriculture predominance. Thus, we propose a market–society–policy nexus to promote sustainable agriculture. Our suggestions are: (1) Policies should support sustainable agricultural systems at the landscape level to safeguard the ecological processes involved in agricultural production. (2) Markets should standardize eco-labels, improve clarity in foodstuff information, and relate environmental benefits to consumer benefits. (3) A subsidy on sustainable food is needed to keep the regular market prices and attract new consumers, at least in the early stages.

Keywords Global change · Sustainable development · Eco-label · Ecological intensification · Land policies

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1 Introduction

The impacts of intensive agriculture on the environment have been widely studied. In 1990, David Pimentel warned that the Green Revolution approach was not proper as a strategy for food security for the ever-expanding human population (Pimentel & Pimentel, 1990). Thirty years later, we face an unprecedented global environmental crisis where intensive agriculture (based on the Green Revolution) is one of the main drivers of biodiversity and ecosystem service loss worldwide (Campbell et al., 2017; Vanbergen et al., 2020). Moreover, this situation tends to worsen as estimations predict an increase in the human population to 9.6 billion people by 2050 (Gerland et al., 2014; Gerten et al., 2020) and that food production must be doubled to meet future needs (Tilman et al., 2011). As an alternative, sustainable agriculture should be able to supply the current demand for food without compromising the relation to the "planetary boundaries" (Rockström et al., 2009) and consider farmer welfare (Eyhorn et al., 2019). Thus, agriculture needs to transition toward sustainability; however, this transition seems stuck.

The scientific community and international organizations have promoted the transition toward sustainable agriculture as an alternative to intensive agriculture (Eyhorn et al., 2019; Pretty et al., 2018; Rockström et al., 2017). However, intensive agricultural systems are often self-proclaimed as sustainable choices for the sole fact of working in a natural system. At the same time, they can vary from a single agricultural practice adoption for environmental mitigation to a whole reconfiguration. However, an ecosystem approach is usually lacking (Costanza & Patten, 1995). What is sustainable can be ambiguous, with many people asking about what it entails and implies for development theory and practice (Mensah & Ricart Casadevall, 2019; Pretty, 2008). In this context, for discussing new approaches that will integrate biological, ecological, and social processes into food production, the following question arises: Are these potential 'sustainable agricultural systems' minimizing the main negative consequences of intensive agriculture? (Question 1).

Going beyond agriculture in the field, society becomes crucial in the transition toward sustainability since they take part in how foodstuffs are produced. However, what are the consumers' perceptions of the impacts of intensive agriculture and environmentally friendly foods? (Question 2). A recent survey from WWF (2018) reported that 91% of interviewed people did not realize our food system is the greatest threat to nature. Moreover, barely a quarter of international programs promoting sustainable development consider social engagement and empowerment (Kusnandar et al., 2019). On the other hand, sustainable development has become a famous catchphrase with unclear meaning to society (Mensah & Ricart Casadevall, 2019), without a policy framework (Collins, 2021). The vagueness of this concept is reflected in foodstuff, where many items own sustainability-related labels (eco-labels, hereafter), which generate confusion in consumers (Eldesouky et al., 2020; Grunert et al., 2014). In this sense, analyzing how the foodstuff is marketed is crucial. Specifically, are eco-labels supporting a transition to sustainable agriculture? (Question 3).

This scientific essay aims to analyze, discuss, and guide decision-makers on complex issues on sustainable agricultural systems, consumers, eco-labels, and policies. We argue that these questions need to be analyzed comprehensively to trigger tangible improvements in the sustainable development of agriculture. In honor of the work of David Pimentel and other researchers, we do not want to repeat what they said decades ago. They have clearly remarked on the consequences of unsustainable practices, but a current urgency is how to face them. Thus, we aim to promote the sustainable development of society through a holistic approach that recognizes the complex nature of social-ecological systems and the challenges of politically sensitive environmental issues. We structured this essay into three sections: A literature review of the impacts of intensive agriculture on global change (Sect. 2), an analysis of our proposed three questions (Sect. 3), and a discussion on barriers and opportunities toward the transition to sustainable agriculture (Sect. 4).

2 Literature review: agriculture and global change

Many publications of Pimentel warned about the multiple environmental impacts of intensive agriculture. Here, we summarize six environmental impacts of intensive agriculture that make it unsustainable. In addition, we make an interlink among the environmental impacts arguing that agriculture is not causing only isolated environmental impacts but global change. Intensive agriculture impacts the interlinked processes determining the planet's balance (Rockstrom et al., 2009). Thereby, we aimed to remark on the main challenges that agriculture needs to face to advance toward sustainable development.

2.1 *Soil erosion* (SE)

It is the loss of fertile soil, which occurs by multiple causes, e.g., land clearing, poor drainage, lack of conservation, intense mechanization, and others (Lal, 2010). According to Pimentel and Kounang (1998), SE is the greatest threat to providing food for a rapidly growing human population. Humans worldwide obtain more than 98–99% of their food (calories) from the land; hence, preserving cropland and maintaining soil fertility should be highly important to human welfare (Kopittke et al., 2019; Pimentel & Burgess, 2013). SE also affects soils' ability to store carbon and contribute to climate change mitigation (Lal, 2014).

2.2 *Biodiversity loss* (BL)

It is the loss or reduction of species and their interactions in the ecosystems (Valiente-Banuet et al., 2015). It is mainly related to land-use change, from natural habitats to farmlands (Sala et al., 2000). According to the Convention to Combat Desertification of the United Nations, BL has had the most negative impact globally (UNCCD, 2022). Specifically, large extensions of natural habitats have been converted to productive lands, causing biological homogenization and the deterioration of the provision of ecosystem services (Chaplin-Kramer et al., 2015; Chase et al., 2020).

2.3 *Environmental pollution* (EP)

It is referred to any substance that may drive an adverse effect on air, water, soil, or living organism (D'Surney & Smith, 2005). The use of pesticides is estimated at 2 million tons annually (Sharma et al., 2019), but less than 1% of the total applied pesticides reach the target pest (Pimentel, 1995; Pimentel & Burgess, 2011). Thus, most pesticides are released and spread, causing EP (Nicolopoulou-Stamati et al., 2016; Kansoh et al., 2020). Concerning environmental externalities, pesticides can harm benefit wildlife and soil organisms (Aktar et al., 2009; Cloyd, 2012; Goulson & signatories, 2018; Thompson, 2003) and put at risk the health of farmers (e.g., Mancini et al., 2005) and the consumers (Vogt et al., 2012). In addition, other contaminants, such as microplastics and trace elements, are of increasing concern (Rodríguez-Eugenio et al., 2018; Tian et al., 2022).

2.4 *Nutrient imbalance* (NI)

It refers to the nutrient excess or deficits (primarily nitrogen (N) and phosphorus (P)) in the ecosystems. The fertilizers reach aquatic ecosystems through runoff, leaching, or volatilization (Gomiero et al., 2011a), causing NI, which causes anoxia or "dead zones," with an economic impact on industries such as fisheries and tourism (Galloway et al., 2008; Nkoa, 2014). It has been estimated that food production without synthetic fertilizers would be enough to satisfy only half of the world's population (taking 2011 as a reference) (Dawson & Hilton, 2011). Furthermore, fertilizer efficiency tends to decline, and synthetic fertilizer production is projected to increase (Driver et al., 2019).

2.5 *Water cycle alteration* (WCA)

It will refer to drastic changes in the natural water distribution on land. WCA is strongly related to agriculture as irrigation is the primary water use sector. Specifically, it accounts for about 70% of the global freshwater withdrawals and 90% of consumptive water uses (Siebert et al., 2010). Moreover, the irrigation of crops can deplete groundwater in arid and semi-arid areas (Scanlon et al., 2012). WCA is critical under a food demand increase scenario, leading to social and environmental issues (Pimentel et al., 2004). In social terms, the per capita availability of freshwater worldwide declined by about 70% in the last century (Pimentel et al., 2010). In environmental terms, WCA can alter the planet's ecology and biogeochemistry (Vörösmarty & Sahagian, 2000).

2.6 *Climate change* (CC)

Agricultural activities have been a significant driver of CC, primarily by releasing greenhouse gases (GHG): carbon dioxide (CO_2), methane (N_2O), and nitrous oxides (N_2O). Agricultural activities are a source of atmospheric CO_2 by clearing natural ecosystems and by soil organic matter (SOM) degrading practices (Lal & Pimentel, 2008). Also, livestock farming has released significant amounts of CH_4 and N_2O (Grossi et al., 2019). Together, agricultural activities and livestock farming accounted for around 40% of CH_4 and 79% of N_2O emissions from human activities globally during 2007–2016 (IPCC, 2021). CC has deleterious impacts on agriculture, natural habitats, water resources, food supply, and people (NOAA, 2019; WWF, 2021). Consequently, taking immediate, robust, and sustained action against CC is crucial (Lubchenco & Kerry, 2021; Zurek et al., 2022).

2.7 Global change overview

A summary of the reviewed environmental issues and the associated agricultural practices is represented in Fig. 1a. This figure is a simplified conceptual framework, although agricultural practices involve multiple interconnected environmental impacts that alter the planet's balance (exemplified in Fig. 1b).

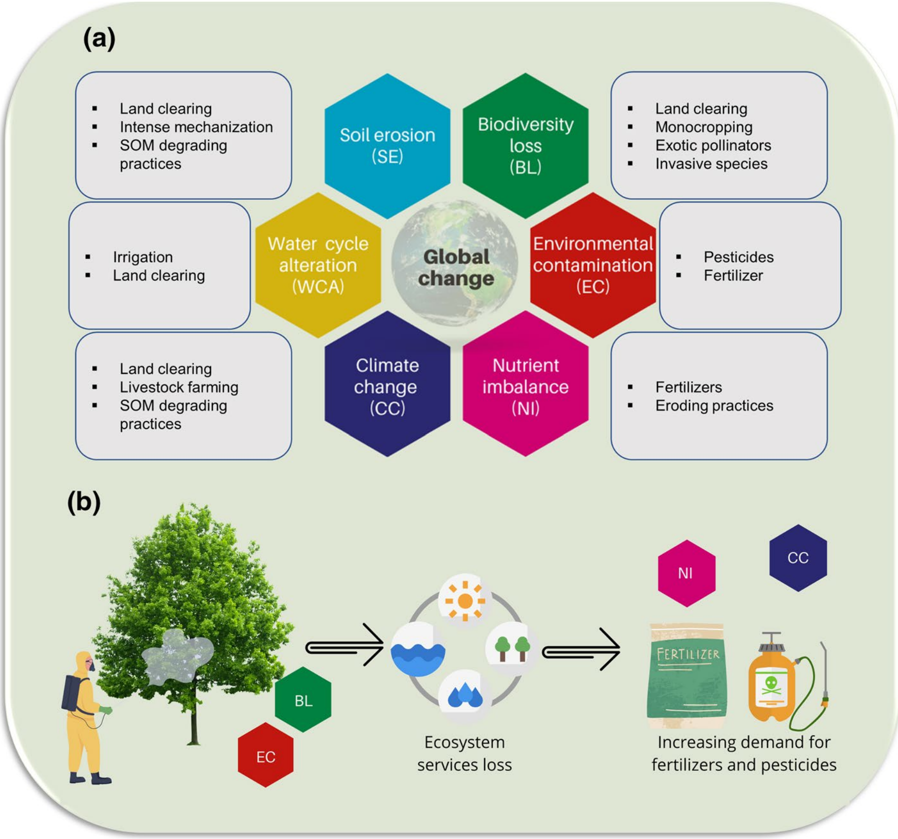

Fig. 1 Conceptualization of the planetary processes (in hexagons) affected by agricultural practices or processes (in the rounded squares) (**a**), and an example of how these ones are interlinked (**b**)

The reviewed global change proxies are environmental issues that can decrease agricultural productivity. Such a result would lead to intensifying industrial systems deepening the vicious cycles of soil and water degradation (IPES-Food, 2016). Specifically, under the traditional intensive agriculture paradigm, the short-term solution strongly focuses on increasing the agricultural surface and demand for agricultural inputs (e.g., agrochemicals or fertilizers) and natural resources. However, this solution is unviable long term because it is subject to environmental impacts (Geiger et al., 2010; Pingali, 2012; Tilman, 1999). In this sense, Gerten et al. (2020) stated that half of the current global production depends on not transgressing the planetary boundaries that ensure the biosphere's integrity.

3 Key questions

3.1 Are 'sustainable agricultural systems' fixing or mitigating the main negative consequences of intensive agriculture?

Due to the environmental externalities of intensive agriculture, the scientific community has called for a transition toward sustainable agricultural systems (Doré et al., 2011; Rockström et al., 2017; Tittonell, 2014). Today, however, many agricultural systems are considered sustainable, such as agroecology, integrated agriculture, precision agriculture, and organic agriculture among others (Gomiero, 2016). What is sustainable in agriculture can range from adjustments to efficiency to redesigning the farm management system (Vanbergen et al., 2020). However, other authors have argued that without an ecosystem approach, it cannot be considered sustainable (Costanza & Patten, 1995).

We described the agricultural systems according to their current contribution to different sustainability-related terms (Table 1). Then, we categorized them using a 5-point Likert-type scale (Sullivan & Artino, 2013) according to their approaches rather than considering their actual participation (details in Supplementary information: Supplementary material 1). Categories were set up under qualitative analysis based on research synthesis, reviews, meta-analyses, and our judgment as environmental agriculture researchers. We prioritized results informing the performance of agricultural systems in the long term. However, cases of these agriculture systems can widely vary as they entail different practices in different agricultural zones. We finally estimated a Sustainability Index (SI) to systematize the performance of the agricultural systems in sustainability terms (from 1 to 5 as the minimum and maximum sustainability, respectively) (details in Supplementary information: Supplementary material 1 and Table S1).

Table 1 Sustainability analysis of agricultural systems

Agricultural systems	Description	Sustainability dimension										
		Environmental protection						Social			Economic	
		SE	BL	EC	NI	WCA	CC	FW	Fsec	FS	Y	P
Agroecological practices	Agricultural practices aiming to produce significant amounts of food, which valorize in the best way ecological processes and ecosystem services (Wezel et al., 2013).	green	light green	green	green	light green	green	green	green	light green	yellow	orange
Ecological intensification	Management strategies integrating the ecosystem functions into commercial farming systems without detriment to natural capital (Pywell et al., 2015).	green	green	green	green	light green	light green	nd	yellow	light green	light green	light green
Integrated agriculture	Farming method that combines management practices from conventional and organic agriculture (Gomiero et al., 2011a).	yellow	yellow	orange	red	yellow	yellow	nd	yellow	orange	light green	light green
Intensive agriculture	Agricultural method aiming to maximize yield by practices developed in the Green Revolution, such as monoculture, agricultural mechanization, and the use of synthetic agro-chemicals.	red	red	red	red	red	red	nd	yellow	orange	green	light green
Organic agriculture	System that uses methods respectful of the environment from the production stages through handling and processing (Scialabba, 2002).	yellow	yellow	light green	red	light green	light green	nd	yellow	orange	yellow	green
Precision agriculture	System carefully tailoring soil and crop management to fit the different conditions found in each field. It is based on information and technology (Gomiero et al., 2011b)	yellow	red	light green	light green	green	yellow	nd	light green	yellow	green	light green
Agricultural biotechnology	Agricultural biotechnologies involving advanced DNA-based methodologies and genetic modification (FAO, 2011).	red	red	orange	orange	yellow	red	nd	red	orange	green	yellow

SE = soil erosion; BL = biodiversity loss; EC = environmental contamination; ND = nutrient imbalance; WCA = water cycle alteration; CC = climate change; FW = farmer welfare; FS = food safety; Fsec = food security; Y = yield; P = economic profitability. Categories are as follow: nd= not defined; red squares = very negative; orange = negative; yellow = neutral; light green = positive; green = very positive.

We found that agroecological practices and ecological intensification are the agricultural approaches with the best performance in sustainability terms (SI = 3.89 and 4.06, respectively). This result is explained as they include the linkage with the ecosystems by promoting the provision of ecosystem services. Small farmers have especially adopted agroecological practices to enhance food security, but their participation in the global market is scarce (Altieri & Nicholls, 2012). Agroecology focuses more on food diversity instead of maximizing the yield of a few crops. Thus, there is a debate about whether or not agroecology can feed the world (HLPE, 2019). However, hunger is a challenge involving more than the agricultural system and production, for example, inequality and food loss. In fact, despite the current high production levels, acute food insecurity still affects millions of people (WFP, 2021).

On the other hand, ecological intensification (EI) safeguards food production with accompanying environmental benefits; however, farmers rarely adopt the approach (Kleijn et al., 2019). One limitation is that EI is not designed by reasoning at a single crop or agricultural field but embraces the complexity of the landscape (Tittonell, 2014). EI approach shares similar characteristics with agroecology, but EI has a particular interest in production. In this sense, a recent meta-analysis found that enhancing biodiversity in agricultural systems would support crop yield and ecosystem services in 63% of the cases (Tamburini et al., 2020).

Organic agriculture obtained a SI of 3.56. Organic agriculture is more profitable and environmentally friendly than intensive agriculture (Reganold & Wachter, 2016), although a meta-analysis including 742 agricultural systems stated that organic agriculture requires more land, causes more eutrophication, uses less energy, but emits similar GHGs emissions as a conventional system (Clark & Tilman, 2017). Despite working with the environment, organic agriculture is based on environment-friendly practices at the farm level. Thus, the optimization of ecosystem services is limited (Tittonell, 2014; Vanbergen et al., 2020). Therefore, beyond organic farming, we should promote biodiversity-friendly landscapes (Tscharntke et al., 2021). Such optimization of the provision of ecosystem services is also lost in integrated agriculture (SI = 3.33), where the incapacity of certifying as organic can also reduce profits.

On the other hand, precision and biotechnological agricultural systems (SI = 3.78 and 2.39, respectively) improve only limited aspects of environmental protection. Precision agriculture improves system efficiency, especially by using remote sensors (Cisternas et al., 2020). However, it does not promote the conservation or regeneration of the environment. Similarly, biotechnological agriculture has shown good indicators in economic and environmental terms, but it still has acute adverse effects on biodiversity loss and social impacts (Ervin et al., 2010; Hubbell & Welsh, 1998).

The higher benefits of EI over other environmentally friendly systems were also recently analyzed by Lal (2019). EI would allow benefits to farmers and society. However, several ecological processes, such as bird biological control and pollination by native insects, are not manageable through a predial scale. Thus, an optimal EI establishment will depend on the articulation of farmers in the landscape (Tittonell, 2014). In this sense, the transition toward EI practices and other sustainable agricultural systems should not rely only on farmers but on external support.

3.2 What are consumers' perceptions of the impacts of intensive agriculture and environmentally friendly foods?

In the early 1990s, consumers begin to become aware of the negative environmental impacts of food supply and production (Giddens, 1991). Since then, supply chains have gradually embraced these demands of consumers, who are now regarded as active agents in the food chain (Lowe et al., 2008). This growing demand for natural foods is linked to concerns about environmental degradation (Blandford & Fulponi, 1999; Laureti & Benedetti, 2018), and these environmental concerns or attitudes drive green purchasing behavior (Leonidou et al., 2010; Moser, 2016). For instance, Laureti and Benedetti (2018) showed that Italians concerned with soil pollution and deforestation have a higher probability of buying organic products.

Considering this background, we conducted an online survey in Chile to understand consumers' environmental concerns and preferences for environmentally friendly food. The survey was open between October and November 2021, reaching 333 respondents whose median age was 39 years old (details in Supplementary Information: Supplementary material 2).

A 79% of the surveyed considered that conventional (intensive) agriculture has negatively affected the environment. Respondents associated environmental problems caused by agriculture with 23 concepts (Fig. 2a), mainly associated with nature concepts (e.g., water, biodiversity, soil) than with agricultural practices (e.g., pesticides, fertilizers, agrochemicals). The most frequent problems (soil degradation, high water consumption, environmental pollution, and biodiversity loss) are consistent with those mentioned in Sect. 2.1. Warnings about water are related to water conflicts in Chile (Berasaluce et al., 2021, and references therein). Environmental pollution and biodiversity loss were also expected as major issues since they are commonly mentioned in environmental education programs (e.g., campaigns facing bee extinction) (Cho & Lee, 2017; Hartmann et al., 2021).

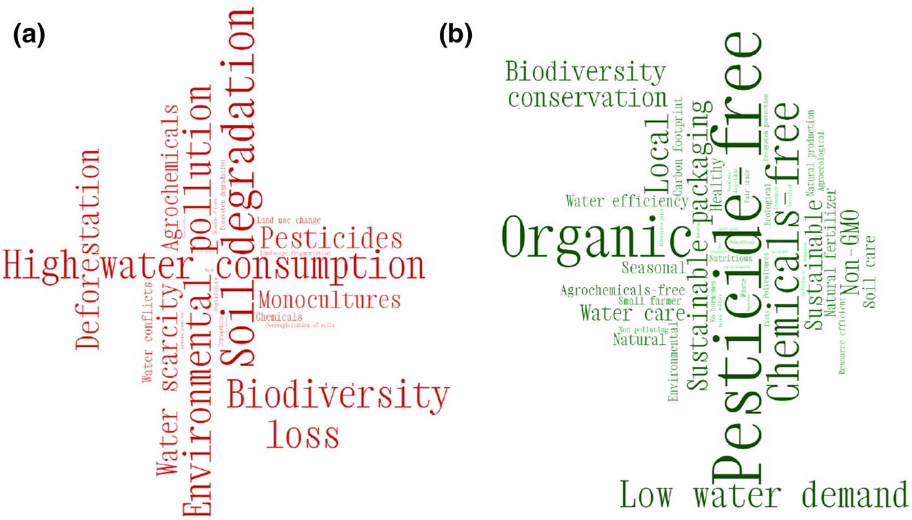

Fig. 2 Word cloud containing the respondents' concepts concerning **a** environmental problems caused by agriculture and **b** attributes of environmentally friendly food. The larger size and darker color, the higher frequency

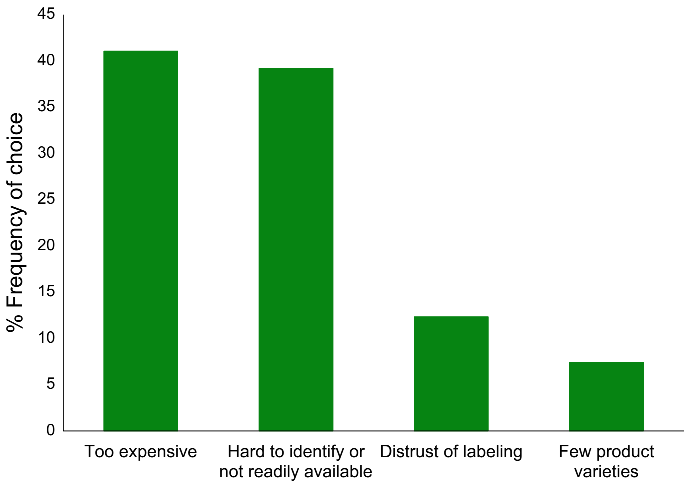

Fig. 3 Ranking of problems of buying environmentally friendly foods ($n = 333$). Bars represent the percentage of each attribute ranked as the most critical attribute according to the respondents

Surprisingly, soil degradation had the most significant concern in consumers, and climate change was not mentioned even once, even though it is a familiar concept to most people today and agricultural activities are one of the leading causes of climate change.

We also assessed the consumers' attitude to environmentally friendly products in the survey. A 97% stated that they would prefer to buy environmentally friendly food instead of conventional one if they had an equal price. Regarding the attributes of environmentally friendly food, the responses were highly heterogeneous, as respondents associated the attributes in 48 concepts (Fig. 3b). The most desired attributes (pesticide-free, organic, and chemical-free) are related to the non-use of synthetic chemical compounds on plants or food.

Contrasting Figs. 2a and b showed similarities and differences about consumers' environmental concerns and their preferences for environmentally friendly food. On the one hand, the frequency of respondents associating water scarcity and biodiversity loss as environmental problems caused by agriculture was similar to the frequency of respondents associating biodiversity conservation and low water consumption as environmentally friendly food attributes. Similarly, several studies report environmental protection concerns as a driver of organic food consumption (Hidalgo-Baz et al., 2017a, 2017b; Janssen, 2018). Nevertheless, we found that consumers' preference for environmentally friendly food would be primarily linked to nutrition or chemical food security (Fig. 3b). This result was consistent with other studies which report that consumers are encouraged to buy organic products for self-interest, especially for health (Bullock et al., 2017; Padel et al., 2005; Vega-Zamora et al., 2014).

The problem is that there is often a discrepancy between environmental concerns and the purchase of sustainable food products (Aschemann-Witzel & Zielke, 2017; van Dam & van Trijp, 2013). For instance, Hughner et al. (2007) found that although consumers reported a high willingness to buy organic products, only a tiny percentage bought them. Similarly, DEFRA (2006) found that 30% of consumers in the UK reported environmental concerns, but their concerns rarely translated into green purchasing. Therefore, other factors are more critical determinants of sustainable food purchasing than environmental concerns.

Our results showed that 41% of respondents considered price the most critical problem for buying environmentally friendly foods (Fig. 3). This result was in line with the review of Aschemann-Witzel and Zielke (2017), who found that consumers perceived price as the main barrier to buying organic foods. On the other hand, 39.2% of respondents found that environmentally friendly foods are difficult to identify or that they are not readily available in the market. This finding is consistent with previous research stating that availability or lack of identification is a major barrier to buying organic products (Bryla, 2016; Vermeir et al., 2020; Xie et al., 2015).

According to the literature, the lack of regulation on eco-labeling has caused green skepticism that lowers customers' environmental concerns, adversely impacting their purchase intentions for green products (Goh & Balaji, 2016). In addition, the great diversity of labels hinders understanding and interpreting their meaning, which may lead to the belief that labeled goods have some attributes that are not present in the product (Galarraga Gallastegui, 2002). Nevertheless, our survey showed that they were not critical factors in green purchase preferences.

3.3 Are eco-labels in foodstuffs supporting a transition to sustainable agriculture?

Eco-labels should help those consumers with environmental concerns (Sect. 3.2), find the foodstuffs from sustainable agricultural systems (Sect. 3.1), but this may not necessarily be the case.

Eco-labeling in foodstuffs is a mechanism to highlight those environmentally friendly products. The first environmental certification was The Blue Angel, which appeared in Germany in 1978. Despite resistance from the industry, Blue Angel began to build momentum regarding the environmental awareness of a wider public, becoming a driving force for the rollout of more environmentally friendly products (Blue Angel, 2018). This label and its subsequent ones have promoted products that can mitigate adverse environmental effects compared to other products in the same category.

Eco-labels can be essential in transitioning to sustainable agriculture as they have proven significant effects on consumers' attitudes (e.g., Song et al., 2019). However, are eco-labels aligned with the main environmental challenges of agriculture or related to an ecosystem approach? Such a question is hard to answer as eco-labels can be managed by government agencies, nonprofit environmental advocacy organizations, or private sector entities. They can focus on a single lifecycle stage of a product and address a single environmental issue or focus on the entire lifecycle of a product and address many different environmental issues (US EPA, 2021). On the other hand, there are more than 300 sustainability standards in the market (International Trade Center, 2021) and about 459 eco-labels in 199 countries and 25 industry sectors. In the food area, 145 eco-labels mainly focused on specific impacts such as energy consumption, emissions, animal welfare, and agricultural practices (Ecolabel Index, 2022). In addition, eco-labels are differentiated into groups and classified by the International Organization for Standardization (ISO) in the 14,020 series (OECD, 2016).

In Chile, for example, a recent national eco-label only considers waste generation considering the feasibility of package recycling but without considering the remaining environmental issues (Reyes, 2022). Similarly, organic agriculture certification labeling promotes using natural inputs but does not necessarily comprise diversification practices (Ministerio de Agricultura, 2016). In contrast, other eco-labeling such as Rainforest Alliance comprises the six environmental issues of Fig. 1 (Rainforest Alliance, 2021), but certification costs could be a major constraint to achieving it, especially to small farmers (Pinto et al., 2014). Alternatively, this could be costed by consumers but affect their preference. Nevertheless, any of these eco-labeling agencies lacks an ecosystems approach.

4 Barriers and opportunities toward sustainable agriculture

We identified several weaknesses and barriers in the agricultural system hindering the transition to sustainable agriculture from our literature review and consumer survey. However, this means there are opportunities to move forward.

Our results showed that ecological intensification is the agricultural system that best faces the environmental impacts of intensive agriculture. However, a big barrier to its implementation is that sustainable agriculture is mainly promoted at the farm scale but not on the landscape scale (Sect. 3.1), although the surrounding context is essential (Steffan-Dewenter, 2003; Thies et al., 2003). This fact may arise because the traditional definition of sustainability (WCED, 1987) has an implicit temporal dimension but lacks a spatial dimension, which is where it is put into practice. Local- and landscape-level ecological processes are involved in agricultural production, and some are scale dependent (Steffan-Dewenter et al., 2002), such as pollination by native species. Therefore, we argue that sustainable agriculture should be linked with an ecosystem approach. That is, changing the lens used for management from an intra-farm view to a landscape view (Grass et al., 2019; Tscharntke et al., 2021). In this regard, optimal landscape design is critical to promoting biodiversity in productive lands at the local scale (Arroyo-Rodríguez et al., 2020).

Promoting ecological intensification systems or sustainable agriculture is not only a technical issue but also needs to be linked with other actors. In this sense, Dokić et al. (2020) argued that policies and the market must take appropriate measures. Nevertheless, what is appropriate is a pending and critical question.

According to the enhancement of ecosystem services, policies should support sustainable agriculture at the landscape level to effectively safeguard the ecological processes involved in agricultural production and promote land management, not just supplying subsidies for individual farmers to change their practices.

Land policies should promote more diverse productive lands that work for biodiversity and people (sensu Kremen & Merenlender, 2018). We also need to promote and secure the conservation of the extant natural habitats, along with restoring disturbed lands that may balance with the current agricultural activity (Grass et al., 2019). Natural habitats are biodiversity reservoirs. While many species can thrive in disturbed habitats and productive lands, they are usually a subset of the species found in natural habitats (Barlow et al., 2007; Peh et al., 2006). Besides species composition, simplified habitats (such as crop fields) impose environmental filters to native species (Castaño-Villa et al., 2019). In this context, land-sharing and land-sparing practices are relevant (Edwards et al., 2014; Kremen, 2015; Phalan et al., 2011). To achieve this, we must reconcile biodiversity conservation and food production (Grau et al., 2013). It is fundamental to build bridges among decision-makers and authorities responsible for conservation and food production to achieve common goals, as usually, they have different goals that are often incompatible. Otherwise, no conservation action will be enough if it is not articulated with proper management of productive lands.

Regarding the consumers (Sect. 3.2), social awareness of agriculture's environmental impacts is key to supporting the transition to sustainable agriculture. However, many people do not realize that our food system is the greatest threat to biodiversity (WWF, 2018). In this sense, environmental education is crucial as environmental knowledge can overcome several barriers to consuming environmentally friendly products, such as high prices (Díaz-Siefer et al., 2015; Hartmann et al., 2021; Hidalgo-Baz et al., 2017a). Such environmental education could be implemented by government institutions and different stakeholders in the food chain, such as supermarkets, with information in their aisles.

In this essay, we discussed that linking environmental benefits to human health is crucial since consumers' concern about food is more about the impact on health than on the environment. Such a pattern was similar to that of Hoek et al. (2017). Thereby, eco-labeled foodstuff should guarantee food security and show the added value for nutrition or other health benefits (Vigar et al., 2019).

The survey also showed that environmentally friendly foods are challenging to identify or not readily available on the market. Our findings are consistent with previous studies, which have shown that the lack of information about environmentally friendly food could also be a barrier to consumers buying them (Pickett-Baker & Ozaki, 2008; Cerri et al., 2018). Therefore, eco-labeling is a vital market instrument of sustainable development strategies (Sect. 3.3).

We argue that eco-label certifiers should standardize the certification criteria to help consumers understand, such as the Open Standards for the Practice of Conservation (CMP, 2020). Eco-labels should contain visual information that allows the consumer to quickly recognize what is being certified rather than simply displaying a symbol. In this context, Chile implemented front-of-package nutritional warning labels, which decreased unhealthy foods purchased (Taillie et al., 2021), and led to several foods being reformulated by significantly reducing sugars and sodium (Reyes et al., 2020). A similar implementation could be used for foodstuffs transgressing sustainability limits. In this sense, eco-labels could have two measures: a sustainability measure, showing the product's contribution to each of the three main pillars (environmental, economic, and social), and an exclusively environmental measure, showing whether the foodstuff impacts one of the six environmental problems mentioned in Sect. 2. For example, labels should indicate whether crops contribute to deforestation or pesticides were applied to foodstuff production. Finally, a consumer subsidy is also needed in the first stages to encourage consumers to buy eco-sealed products for the first time (e.g., Gottschalk & Leistner, 2013).

Moving toward agricultural sustainability requires a joint effort to increase scientific knowledge and improve evidence-based agricultural management based on sustainable and ecosystem-linked practices, government regulation, agreements between producer associations, marketing chains, and consumer education. This change should also be driven by a public–private partnership involving all stakeholders in the agri-food chain and thinking in the common well. In this regard, the main discussion and recommendations are summarized in Fig. 4, remarking on different actors influencing the agricultural system's performance and the need to bring them together for this common purpose.

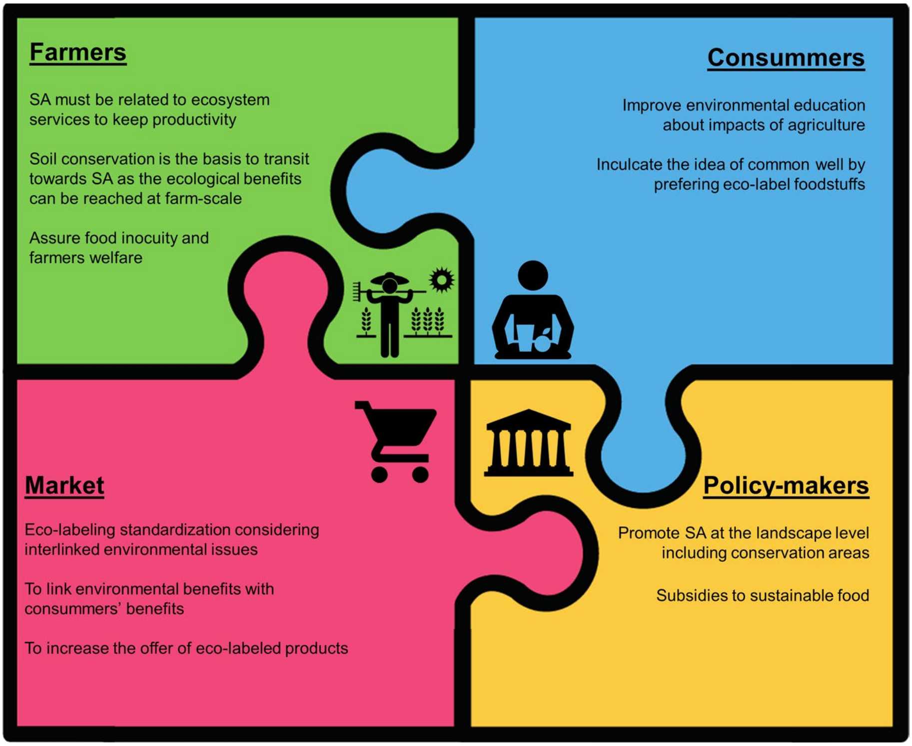

Fig. 4 Authors' key messages to transit the agri-food system toward sustainability. SA = sustainable agriculture

5 Conclusion

According to a literature review, we found interlinked planetary processes being affected by intensive agriculture. Although the need to transit toward sustainable agriculture is clear and urgent, the way we must transit is not clear. Through the analysis of different agricultural systems, we highlighted ecological intensification as an agricultural system with the potential to achieve increased yields and ecosystem services for the farm and society. However, a successful establishment of this agricultural system requires a landscape approach instead of a predial one, making it challenging to put into practice when sustainable agriculture promoting policies are mainly on a low spatial scale.

The surrounding societal issues also stick the transition to sustainable agriculture. Although consumers are concerned about the environmental effects of intensive agriculture, they mainly look for those environmental attributes that directly benefit their health. In this sense, markets could help relate other environmental benefits to human welfare. For that purpose, eco-labels can be helpful to appropriately give in know what is occurring in the field in environmental terms. However, markets should improve eco-labels standardization. Another barrier was the price, which policies can support at least in the early stage to help farmers transition agricultural systems and attract and make habits in potential consumers.

Consequently, we proposed a market–society–policy nexus to be considered to reach sustainable agriculture. In this sense, the public and private sectors should integrate their perspectives and work coordinately, reflecting the importance of education and policies. On the contrary, we concluded that transition would keep slower than needed.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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