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Review

On the relation between monocultures and ecosystem services in the Global South: A review

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A R T I C L E I N F O

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A B S T R A C T

The countries of the global south are characterized by high levels of biodiversity. In addition, these countries have suffered -and will suffer- even more ecological pressures due to agricultural production, mainly monocultures. When considering areas of high biodiversity with highly intensive agricultural systems, the scientific literature highlights the role provided by Ecosystem Services (ES) both *to* monocultures and *from* monocultures to their contexts. In this sense, the objective of this paper is to provide a Systematic Literature Review (SLR) to understand the relationship between monocultures and ES in the global south. Furthermore, in this research we provide a context analysis to broaden the understanding of the implications of monocultures in this region. We provide correlations between trends in monocultures harvested areas and forest cover in the countries identified through the SLR. Our SLR identified information from 15 countries and 11 monocultures. We found several negative correlations between harvested area and forest cover, mainly in megadiverse countries. In addition, we depicted trade-offs and synergies related to monocultures. We conclude that more research is needed in this regard, especially since there is great interest in monocultures for economic development in the global south, and this area will support world food production in the future.

1. Introduction

Originally, countries of the global south are characterized by healthy ecosystems with high levels of biodiversity. However, ecosystems such as forest, grassland or aquatic ecosystems in the global south have suffered -and will suffer even more- pressures due to increasing demand of agricultural production and commodities from the global north (Barbier, 2004; Defries et al., 2010; Potapov et al., 2022). While the global south heavily depends on its agriculture, there are structural weaknesses and thus inefficiencies, as the southern agricultural sector has not yet fully undergone an agrarian transition that happened in the north (Carlson, 2018). To enhance efficiency and meet a growing demand of food commodities, monocultures are often the preferred agricultural production system. When considering areas of high biodiversity with highly intensive agricultural systems such as monocultures, the scientific literature highlights the important role of ecosystem services (ES) both, *from* and *to* monocultures. As the ES are the benefit provided by ecosystems –and agroecosystems (Zhang et al., 2007), this paper aims to shed lights on the relation between agricultural production systems and the surrounding ecosystems by analyzing which ES are used by monoculture production systems as well as their implications on them. With this paper, we address the need to consider monocultures more carefully and we contribute to the current state-of-the-art on the relation between monoculture and ES by providing comprehensive existing evidence regarding this relation.

1.1. Land use and ecosystem change

By cultivating land, humans have increasingly altered ecosystems to advance socioeconomic development (Li et al., 2020). Agriculture is an important activity generating agricultural commodities, income and employment alike. However, an increasing demand for agricultural commodities by a steadily growing global population has led to a widespread detrimental transformation of natural ecosystems

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(O'Connell et al., 2018). Thus, >75 % of the Earth's ice-free land has been transformed by human-led occupation (Ellis and Ramankutty, 2008), shifting the global trend from mainly wild to mainly anthropogenic land use in the last 300 years (Ellis et al., 2010). Seminal scientific contributions have drawn attention to current trends in land use and the simultaneous decline in the capacity of the world's ecosystems to provide ecosystem services (Foley et al., 2005, 2011; Tilman et al., 2011).

While land use such as agriculture has become more efficient in commodity production due to modern practices and technological advance, it has also caused significant detrimental environmental impacts (Foley et al., 2005; Tilman et al., 2011). According to Gibson et al. (2011), biodiversity diminishes in degraded forests where agriculture is considered a significant driver of change – however, the extend of loss in biodiversity varies considerably by geographic region. Between 1985 and 2005 the world's croplands and pastures expanded by 154 million hectares (about 3 %) (Foley et al., 2011) – a trend that will likely continue as the demand for agricultural comodities is expected to increase by about 50 % by 2050 (Gibbs et al., 2010). This also means that agriculture undergoes a significative process of intensification.

As stated by Lambin and Meyfroidt (2011), agricultural intensification could also indirectly affect land use in other areas than where the food is demanded. It means that the demand for food in the global market increases – a demand that has to be satisfied by some producing countries where agriculture often is a main source of income. Results reported by Potapov et al. (2022) depict that from 2003 to 2019, global cropland areas increased by 9 %, primarily due to agricultural expansion in Africa and South America. In fact, exports of agricultural commodities have been correlated to deforestation in Africa, Asia and Latin America (Defries et al., 2010). Agriculture production often occurs in the global south where countries are struggling with structural problems resulting in low agricultural productivity which often leads to converting forests to cropland to enhance agricultural output (Barbier, 2004).

Considering the high demand for agricultural commodities in the global north and the substantial supply from the global south suggest the existence of structural relation that promote unequal flows between the wealthier global north and global south countries (Givens et al., 2019). Countries in the global north have decreased their agricultural area while global south countries have faced the opposite trend (Gibbs et al., 2010). For instance, Winkler et al. (2021) found trends for increasing afforestation and cropland abandonment in the global north and growing trends in deforestation and agricultural expansion in the south. Givens et al. put these developments briefly by stating that "*Global South nations are structurally positioned as both a tap for resources and a sink for waste within the world-economic system of extraction, production, and consumption*" (Givens et al., 2019, p 2). The problem is that many global south countries are rapidly changing land use by transforming natural ecosystems to agriculture land use (Barbier, 2004), and as stressed by Creutzig et al. (2019), agricultural intensification in global south countries has produced biodiversity loss and natural habitat degradation mainly in Latin-America, Eastern Asia and Africa.

1.2. Agriculture and ecosystem services

The conversion of natural lands to agricultural uses is a significant threat to biodiversity and ecosystems (Grab et al., 2018). Within agriculture, monoculture systems are the most adopted practices (Tarigan, 2019), which often result in low biodiversity systems (Dolezal et al., 2019). Monoculture is also related to a landscape simplification – a term comprising the expansion of farmed land, the loss of plant species across landscapes, changes in biotic interactions, and high intensive management (Barrio et al., 2013; Blary et al., 2021; Dominik et al., 2017; Felipe-Lucia et al., 2020; Mori et al., 2015; Morteo-Montiel et al., 2021). Such simplification processes occur at all levels, e.g., field, farm, landscape, and region (Lemaire et al., 2015) with monocultures producing consistently negative effects on species richness compared to other uses (Kremen and Miles, 2012), and producing little natural habitat (Meehan et al., 2011). Such a complex relationship entails benefits and costs for agriculture (Zhang et al., 2007).

In this context, agriculture plays a vital role in the transformation of ecosystems through a process of supply and demand for ES (Zhang et al., 2007). The concept of ES in agriculture has been widely used in environmental research and is important for bridging scientific knowledge production and support for decision-making. Although ES is a contested concept, it could be understood as the contributions (or benefits) provided by nature (or agroecosystems) to people's quality of life (Maes et al., 2018; Pascual et al., 2017; Pires et al., 2020). In addition, ES benefits can be classified into the following three categories: 1) material benefits (i.e. substances, objects, or other material elements from nature), 2) non-material benefits (i.e. nature's effects on subjective or psychological aspects underpinning people's quality of life, both individually and collectively), and 3) regulating benefits (i.e. functional and structural aspects of organisms and ecosystems that modify environmental conditions experienced by people and/or regulate the generation of material and nonmaterial contributions) (Díaz et al., 2018). The ES framework enables an understanding of the relations between ecosystems and agricultural production.

Agriculture and ES are in an intricate relationship as sustainable agriculture provides positive effects on the ecosystems (e.g. promotion of biodiversity, soil conservation) and unsustainable agriculture generates negative effects on ecosystems, so-called trade-offs (Shah et al., 2019). To be more specific, trade-offs in this context refer to conflicts that emerge between the increasing need of exploiting ES (such as production of agricultural commodities such as food, fiber or bioenergy) and the negative implications on regulating ES (such as water purification, soil conservation or carbon sequestration) (Power, 2010).

Therefore, measuring ES supply, demand and trade-offs in general and from monocultures in particular is of utmost importance but often problematic because they are not easily identifiable (Moreau et al., 2019). Monoculture agriculture promotes material ES which are generally less regulated and yield un-marketed services compared to other non-intensive systems (Chabert and Sarthou, 2020). But scholars pinpoint to the benefits of regulating ES as a driver of crop production and the resilience of social-ecological systems (Raudsepp-Hearne et al., 2010). For instance, monocultures decrease the capacity of ecosystems to provide beneficial functions such as pest control (Grab et al., 2018; Larsen, 2013; Rivera-Pedroza et al., 2019) or pollination (Aizen et al., 2019; Enríquez-Acevedo et al., 2020; Jackson et al., 2007; Kremen and Miles, 2012; Reed et al., 2017). Therefore, it is necessary to find a balance between ecosystem conservation and agriculture to promote sustainable development in large-scale production areas (Araujo et al., 2021), because ES is one of the most important public goods provided by agriculture (Antle and Stoorvogel, 2006).

1.3. Problem statement

As mentioned before, monocultures produce landscape simplification resulting in a decrease in ES. Considering this, a significant body of literature explores the relationship between ES and agriculture (both ES *to* and *from* agriculture), particularly with monocultures. However, even more work is needed to understand and consolidate the dynamics of ES regarding monocultures in the global south where in particular a tremendous increase in agricultural production over the coming 40 years is expected (Foley et al., 2011). Therefore, the aim of this paper is to consolidate and systematize existing knowledge on the relationship between monoculture and ES through a systematic literature review. We thus address the research question: *How is the relation between monocultures and ES in the global south*? We highlight ES demand (ES *to*) and supply (ES *from*) in the context of monoculture production in the global south. Therefore, the contribution of the study is twofold: 1) this is the first study reviewing literature regarding demand and supply of ES in monocultures and 2) this research add concerns regarding the land use transformations due to monocultures in the global south.

2. Methods

To identify the implications delivered by monocultures in countries located in the global south, we first carried out a Systematic Literature Review (SLR) to get an overview of existing knowledge on the relationship between monocultures and ES, and second, we put the findings of the SLR into the corresponding country's context. We considered the economic status of each country, the extent of agriculture, the specific monocultures in their performance, and some implications on forest ecosystems as a proxy of the ecological impacts of monocultures.

For the SLR, we used the Search, AppraisaL, Synthesis and Analysis (SALSA) analytical framework provided by Grant and Booth (2009). The first step Search is an exhaustive search process for systematically finding all papers that appear when using the overall search terms. Second, the Appraisal step is to refine the search by inclusion/exclusion criteria, for further Synthesis and data processing. Finally, the process of Analysis and implications of the results.

Beginning the analysis with the *Search*, we used the SCOPUS database and we provided search criteria based on our research problem. That is, we consolidated the search by analyzing monocultures, ecosystem services and the global south. Nevertheless, to focus our search, we split those concepts with Boolean operators in the following form: *"crop production" OR "agriculture" AND "ecosystem services" OR "nature contributions" AND "monoculture" OR "intensive agriculture"*. We performed the search in December 2021 resulting in 320 articles.

Although currently there is an academic debate regarding the need to reframe the concept of ES towards a concept such as Nature Contribution to People (Díaz et al., 2018; Ellis et al., 2019), different scholars call for continue with the initial term (Braat, 2018; Kenter, 2018; Maes et al., 2018), and even to use them in a complementary way (Kadykalo et al., 2019; Pires et al., 2020). For this reason, we used ES and nature contributions as complementary searching criteria. We did not include global south per se in the search, as this would enhance the likelihood to miss relevant studies. In addition, to delimitate our analysis, we understood monocultures as the prevalent presence of a crop with a high level of specialization on a single crop production within an agricultural region (Franco et al., 2022). Moreover, we considered the global south not as a global location per se, but as a "reference of an entire history of colonialism, neo-imperialism, and differential economic and social change through which large inequalities in living standards, life expectancy, and access to resources are maintained" (Woon, 2013. pp. 13).

In the *Appraisal*, we implemented the inclusion/exclusion criteria to determine the final sample (Maier et al., 2021; Palomo-Campesino et al., 2018). We provided a set of inclusion/exclusion criteria comprising the identification of monocrops, reported ES supply or demand and finally of being geographically located in the global south (see also Fig. 1). Applying a stepwise approach, we first scrutinized the initial 320 papers' titles and abstract for the inclusion criteria (monocultures and ES demand or supply) leaving us with 87 papers. Next, we read the remaining papers and only kept the ones that were centered around monocultures and ES reducing the sample further to $n = 40$ papers. Finally, only studies investigating monocultures and ES in the global south were kept resulting in a final sample of 27 papers (Supplementary material 1). The articles' metadata such as authors, year of publication, keywords, type of crop, ES demand, and ES supply were processed.

Next, we carried out the *Synthesis* step. First, we used text mining to support the interpretation of texts from the selected articles, and to highlight graphically the frequencies of key concepts (i.e. keywords and abstracts) from all included articles (Mengist et al., 2020). In general, the concepts were considered as a proxy for the relation between agriculture and the environment. We proceeded to support our understanding of the relation between ES and monocultures (Fig. 2) where demand are defined as positive contributions of the ecosystems, their ecological functions, of biodiversity as well as human-made contributions like irrigation. Supply are defined as trade-offs and synergies. Synergies are understood as the positive implications produced by the crop (e.g., benefits for ecosystems) and trade-offs as the negative implications (e.g., ecosystem disservices).

Finally, in the *Analysis* step, we identified the specific crop in each paper, its ES demand (i.e., whether the paper identified that the crop used ES for its development), and supply (i.e., whether the crop ultimately produced other ES or trade-offs, impacts or synergies on ES). We classified ES in three categories, namely material ES, non-material ES and regulating ES (Díaz et al., 2018; Pascual et al., 2017).

While highlighting ES particularly related to monocultures is a valuable outcome, merely mentioning ES demand and supply in isolation from a particular country's context is insufficient to address the research problem. Therefore, we wanted to complement our review with

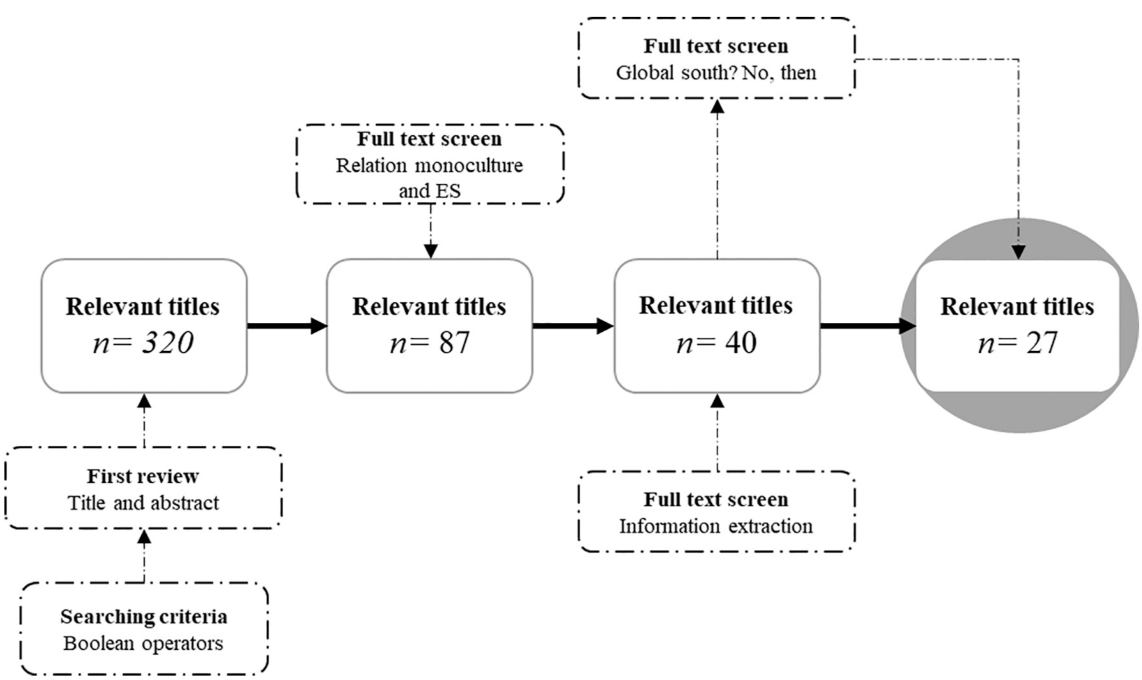

Fig. 1. Steps followed to perform the systematic literature review.

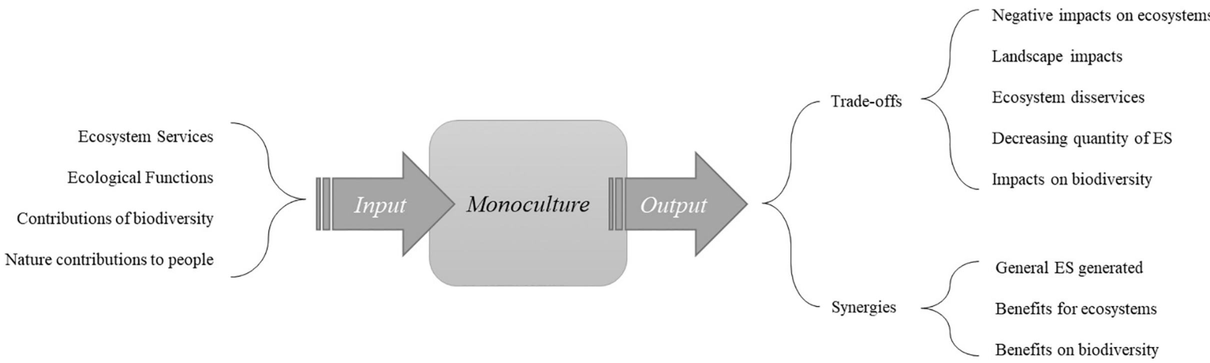

Fig. 2. Criteria for considering both the ES inputs *to* and the outputs *from* monocultures (based on Zhang et al., 2007).

some country-level context to provide inferences supported on literature and in our results regarding the implications of monocultures on the environment in the global south. To that end, firstly, we correlated key aspects such as countries' Gross Domestic Product (GDP) and forest cover given that these are key variables in global south countries related to agriculture and environment relation (c.f. Lambin and Meyfroidt, 2011). Forest cover was considered as a general proxy to prove the environmental dimension (forest as important providers of ES), for two reasons. By one hand, forest could be considered as the structure that supports ecological functions and final ES to people (Potschin et al., 2016); on the other hand, because of the literature that documented the implications produced by monocultures on forests (Gibson et al., 2011; Tenius Ribeiro et al., 2019; Winkler et al., 2021). Secondly, we highlighted historical changes in the harvested areas of the crops identified in the SLR, and we correlated this history with trends in forest cover in order to provide specific analysis between monocultures and forests cover. We provided a further context of biodiversity in each country based on the National Biodiversity Index provided (NBI) by the Convention on Biological Diversity in the Global Biodiversity Outlook 1 (https://www.cbd.int/gbo1/annex.shtml).

For the correlation analysis, we took 2005 to 2019 as the tame-frame. We considered 2005 as a starting point because then the seminal report of the Millennium Ecosystem Assessment was published and this report established a strong link between ecosystem services and agriculture (Ch. 26 Cultivated Systems). Therefore, the following variables were included in the analysis: i). GDP trend over 15 years/country (million USD), ii). Trends in harvested area in for each crop identified in the SLR over 15 years (millions hectares); iii). Trend of forest cover area in the same period (millions hectares). We used FAO statistics (2021) for harvested area per crop/country and WDI (2021) for forest cover and GDP per country. The frame 2019 was used because data were complete for all the countries to that date.

3. Results

3.1. General characteristics of the literature and context

We found literature information for 15 countries from the global South where: six countries were from Latin America, two from Africa and seven from Asia (Fig. 3). China was the country with the most

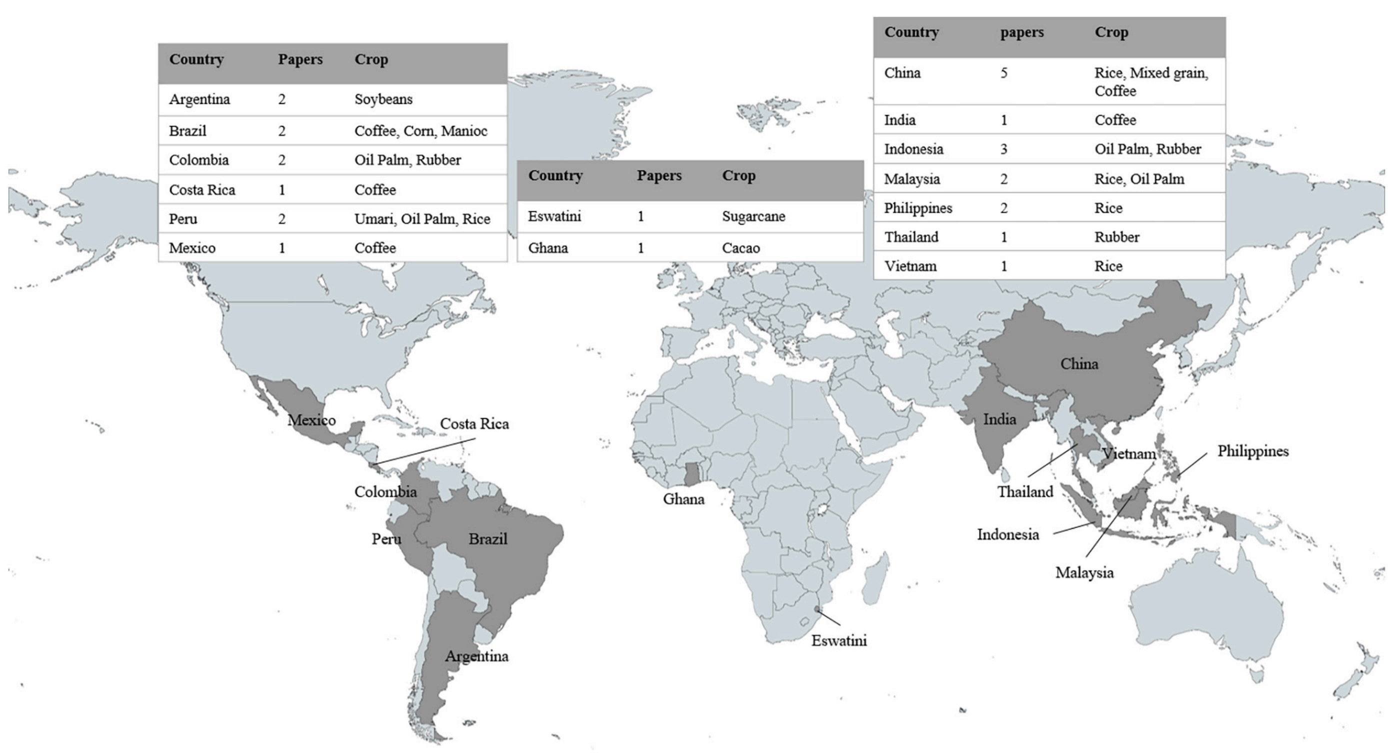

Fig. 3. Overview of the SLR: crops identified by country and frequency of papers per country.

studies (five in total), followed by Indonesia with three studies. In addition, we found eleven monocultures: soybeans, coffee, corn, manioc, rice, mixed grain, oil palm, rubber, sugarcane, cacao, and umari.

In our SLR, we found 145 different keywords used by the included papers whereof 25 % related to the following six categories: Agricultural intensification (four times), Agroforestry (five times), Biodiversity (seven times), Ecosystem Services (15 times), Trade-offs (four times) and Bats (four times). In addition, through a word cloud (recurrence of words in the 27 Abstracts), we found overview of where the monocultures were embedded (Fig. 4). We highlight the specific importance given to concepts such as ecosystem services, ecosystems and agriculture (and concepts related such as systems, rice, yield, farming, plantations etc.). In addition, it is important to point out the prominence of words that appeared repetitively throughout all the papers such as forest, biodiversity, natural, soil or even proximity, which represents that the monocultures of this review were embedded in environments with important ecological characteristics.

In addition, when analyzing study area description of the papers, the authors mostly described their study area with outstanding natural context no matter the landscape transformations by the crops. To cite some examples, authors mention: areas with remnant native grasslands (Hodara and Poggio, 2016), with dense vegetation (Tenius Ribeiro et al., 2019), mountains dominate region (Rigal et al., 2020), subtropical mountain region (Liu et al., 2020), preserved savannas (Lavelle et al., 2014), host of rich biodiversity (Marquardt et al., 2013), or even Peruvian amazon (Dominik et al., 2017).

3.2. The demand: ES to monocultures

The review allowed us to identify important ES for some crops. We found six main ES –or ecological functions or benefits such as water supply, nutrient regulation, pest control, shade, pollination and species richness (sometimes-called biodiversity). Water supply was linked to all crops as a necessary service. Although not all studies identified ES demands, we identified that crops of great importance such as rice depend on nutrient regulation, pollination and pest control. Coffee, for example, needs pollination, pest control, shade, weed suppression, soil moisture and soil erosion protection, and sugarcane requires pest control for its cultivation.

In that sense, Burkhard et al. (2015) researching about ES in rice stated that rice crops are highly dependent on regulating ES. They summarized for example that nutrient regulation ensures successful yields. In addition, Amira et al. (2018) mention that in rice fields, foraging by wetland birds can suppress plant pests (i.e. species richness that is beneficial for crops). This is supported by Zhang et al. (2012) who stressed the importance of neighboring ecosystems that provide reproductive habitat for rice pollinators and biocontrol agents. Now regarding coffee plantations, Rigal et al. (2018) found that shade (provided by other tree species) produce lower inter-annual variation in coffee yields, and improve coffee quality; Davidson (2005), mention that shade provide microclimate for coffee, reducing water stress, and Meylan et al. (2017) found that shade affect coffee flowering and cherry development. Now, regarding sugarcane ES demand, the SLR showed that the foraging function of bats is useful to suppress populations of insect pests in this agricultural system (Mtsetfwa et al., 2018).

3.3. The supply: ecosystem services and monocultures

In general, we found a total of 23 ES (or ecological functions) from monocultures. These were four material ES (food, timber, charcoal and raw materials), four non-material ES (scenic beauty, tourism, identity, and medicinal use) and 15 regulating ES/functions (carbon sequestration, erosion control, habitat for species, nutrient regulation, pest control, soil fertility, soil moisture, species richness, water regulation, water quality, air purification, climate regulation, net primary productivity, oxygen, and pollination). We identified that some monocultures provided benefits and others provided trade-offs. According to the recurrence of these supply in the papers, we found negative involvement mainly in regulating ES, and more synergies in material and non-material ES. We highlight synergies related to CO_2 sequestration, climate regulation and O_2 production, and we stress the negative implication on species richness (or biodiversity).

3.3.1. ES from monocultures: synergies

As a first element, is not novel to mention that material ES in the form of food, raw materials or fiber production is the main contribution of monocultures. However, this review found that monocultures produce several ES beyond materials ES. One interesting aspect found was the identification of non-material ES from rice crops such as tourism (Liu et al., 2020), scenic beauty or identity (Burkhard et al., 2015). In addition, regulating ES were widely highlighted. Regarding water, studies on coffee (Meylan et al., 2017), grain (Wang et al., 2015), palm oil (Lavelle et al., 2014), and rice (Zhang et al., 2012) found positive contributions for water regulation. Now, for soil quality, some studies stressed the contributions on soil erosion control made by coffee

Fig. 4. Words cloud whit the most recurrent words in the abstracts of all the 27 papers.

(Meylan et al., 2017), rice (Liu et al., 2020), and umari (Wood et al., 2016); improvements in carbon stock in topsoil was reported by palm oil (Labrière et al., 2015). Moreover, climatic regulation, air purification, oxygen generation and CO_2 sequestration were reported in palm oil, rubber plantations and rice (Lavelle et al., 2014; Liu et al., 2020; Nattharom et al., 2021; Zhang et al., 2012). Other positive contributions of monocultures were net primary production in grain (Li et al., 2020), and contributions for pollination by coffee (De Beenhouwer et al., 2013), or even maintenance of bats species richness in palm oil plantations (Cely-gómez et al., 2021).

3.3.2. ES from monocultures: trade-offs

Although literature depicts some positive outcomes from monocultures since the ES perspective, it is important to mention the negative implications. Let us begin with material ES. In the SLR, we only found that coffee and cacao produced negative implications in food production and also produced a trade-off regarding the production and use of timber (De Beenhouwer et al., 2013). Now, related to regulating ES, we found many trade-offs. What is important to stress is the negative implications on biodiversity, species habitat or species richness. This is an implication mentioned in almost all the crops. See for instance cacao (Wade et al., 2010), coffee (Anand et al., 2010; Davidson, 2005), corn (Tenius Ribeiro et al., 2019), grain (Wang et al., 2015), oil palm and rubber (Marquardt et al., 2013; Mumme et al., 2015), rice (Dominik et al., 2017), soybeans (Hodara and Poggio, 2016), and umari (Wood et al., 2016). In addition, there were further trade-offs on regulating ES identified (Table 1). The implications on non-material ES were mentioned in cacao crops, which has been highlighted for affecting the use of medicinal plants (De Beenhouwer et al., 2013).

Finally, it is important to put into context all the positive and negative contributions of monocultures. The review showed that monocultures produce contradictory implications. On the one hand, some crops support water regulation, but at the same time they can produce trade-offs on water. The same as - for example - soil fertility or erosion control. This is an interesting result, as the analysis of the relations between monocultures and ecosystem services in the global south needs to be nuanced and contextualized. To see better this aspect, see Fig. 5 to visualize the flows on ES in monocultures according to the SLR and the proposed model.

3.4. Context analysis

Once identified the ES related to the monocultures in our SLR, the next step was to put in context those monocultures in order to provide a proxy of their performance in the global south countries. From our SLR, nine countries are categorized as upper middle income and six are lower middle income. In addition, most of the countries have a high proportion of agricultural land in relation to the country's total land area (>40 % of their land devoted to agriculture). Moreover, Malaysia, Colombia, Brazil and Costa Rica stand out for their high proportion of forested land (over 50 %). Comparing the values 2005 and 2019, Brazil, Ghana, India, Indonesia, and Mexico have increased in 1 % the share of agriculture in their GDP. Colombia and Malaysia stay constant and the rest of the countries have faced a decrease in this index. In 2020, Eswatini, India and Vietnam had the higher share of agricultural sector in their GDP (19 %, 18 % and 15 % respectively). Additionally, we found some negative correlations between GDP and forest cover in the last 15 years (Table 2).

We stress that all the countries found in the SLR have high levels of biodiversity (Table 3). According to the National Biodiversity Index (NBI), countries' NBI were mostly high (NBI > 0.6), but countries such as Indonesia (NBI = 1), Colombia (NBI = 0.93), Mexico (NBI = 0.92) and Brazil (NBI = 0.87) stand out. In these contexts of high biodiversity, important areas have been oriented to monocultures. Adding the harvested area of these crops in the 15 countries, we found that in 2019 the total harvested area reached 247,492,142 ha. The most widespread crop was rice with 110,169,795 ha, followed by soybean (72,995,222 ha), oil palm (22,194,835 ha), sugarcane (21,401,951 ha), rubber (10,371,919 ha), coffee (6,247,378 ha), and cocoa beans (4,111,042 ha).

Now, considering the crops produced by each country, we provided a calculation of the evolution of the harvested area in 15 years. We found a high increase in countries such as Argentina (19 %), Brazil (29 %), Colombia (22 %), Indonesia (33 %) or Peru (26 %), and very low in countries such as China (0.01 %), and Costa Rica or Vietnam (5 %). We highlight that Argentina, Indonesia and Brazil lost 11 %, 8 % and 7 % of forest cover respectively in the analyzed period. In addition, from Table 3 we highlight the correlations between the harvested area of the crops identified in the SLR by country and forest cover. We found that eight countries showed negative correlations, being Brazil, Colombia, Indonesia and Peru the countries with higher values ($r \geq -0.90$) and greater explanatory power in forest variation ($r^2 > 0.8$). In addition, we highlight megadiverse countries such as Brazil, Colombia, Indonesia, Malaysia and Mexico that have maintained or increased agriculture GDP share in the period 2005–2019, present negative correlations between harvested area and forest cover.

4. Discussion

4.1. Balancing ecosystem services in monocultures

As showed in our results, we support the links highlighted by Zhang et al. (2007) regarding the important relation between agriculture and ES, but mainly adding concerns on monocultures. According to our SLR,

Table 1
Trade-offs produced by the monocultures identified in the systematic literature review.

Crop	Regulating ES						
	Carbon sequestration	Erosion control	Nutrient regulation	Pest control	Soil fertility	Soil moisture	Water regulation
Cacao	Wade et al., 2010; De Beenhouwer et al., 2013	De Beenhouwer et al., 2013					
Coffee	Davidson, 2005; De Beenhouwer et al., 2013	De Beenhouwer et al., 2013			De Beenhouwer et al., 2013		
Corn					Tenius Ribeiro et al., 2019		
Grain	Wang et al., 2015						Li et al., 2020
Oil palm			Marquardt et al., 2013			Marquardt et al., 2013	
Rubber Plantations						Marquardt et al., 2013	
Rice				Burkhard et al., 2015			Zhang et al., 2012
Soybeans	Wilson et al., 2020				Wilson et al., 2020		Wilson et al., 2020

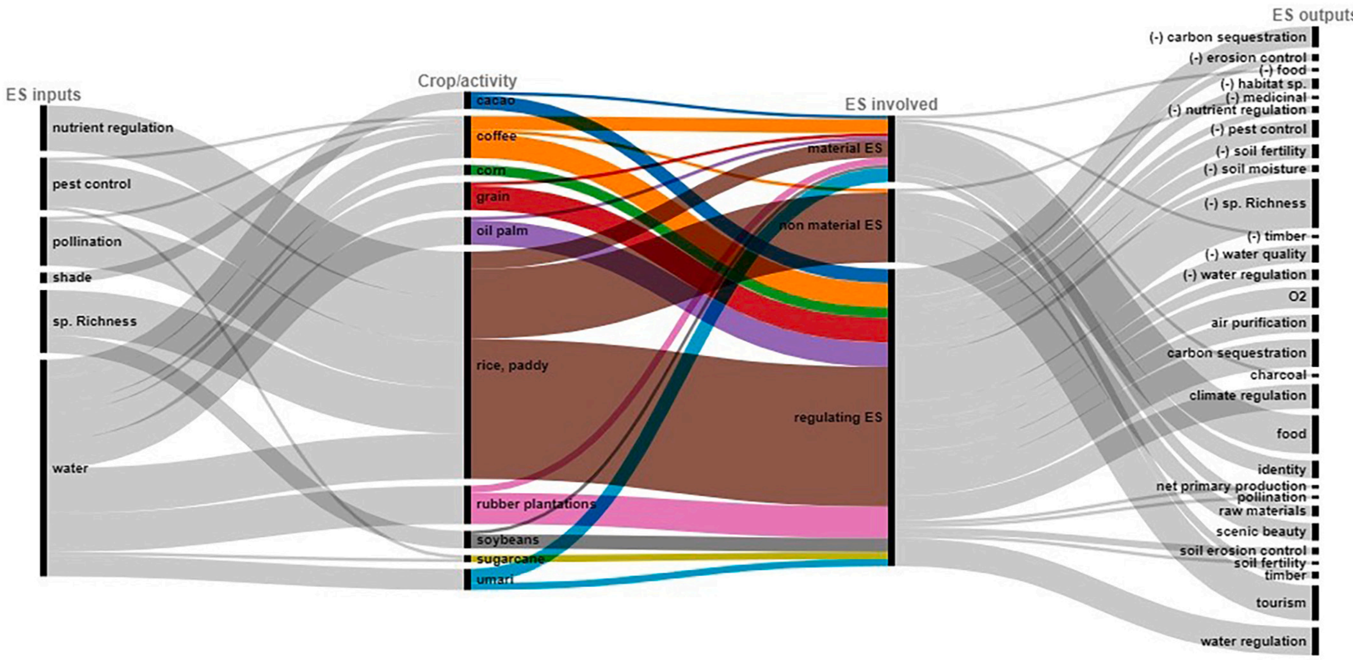

Fig. 5. ES flows *to* and *from* monocultures in the global south according to the SLR. Symbol (-) means trade-off. Diagram based on (Herbst et al., 2020).

Table 2
General information regarding GDP, agriculture and forests in the countries identified from the SLR.

Country	Income Level	Agriculture area/land area[a]	Forest area/land area[a]	Agr. forestry, and fishing (% of GDP) 2020[a]	Δ Agr. value added % GDP[b]	GDP/forest cover[c]
Argentina	Upper Middle	54 %	10 %	6 %	−2 %	$r = -0.89$
Brazil	Upper Middle	28 %	59 %	6 %	1 %	$r = -0.67$
China	Upper Middle	56 %	23 %	8 %	−4 %	$r = 1.00$
Colombia	Upper Middle	45 %	53 %	8 %	0 %	$r = -0.73$
Costa Rica	Upper Middle	35 %	59 %	5 %	−4 %	$r = 0.93$
Eswatini	Lower Middle	71 %	29 %	19 %	−18 %	$r = -0.76$
Ghana	Lower Middle	65 %	35 %	14 %	1 %	$r = -0.87$
India	Lower Middle	60 %	24 %	18 %	1 %	$r = 0.99$
Indonesia	Lower Middle	33 %	49 %	4 %	1 %	r = −0.73
Malaysia	Upper Middle	26 %	58 %	8 %	0 %	$r = 0.17$
Mexico	Upper Middle	55 %	34 %	8 %	1 %	$r = -0.94$
Peru	Upper Middle	18 %	57 %	10 %	−3 %	$r = 0.42$
Philippines	Lower Middle	42 %	24 %	8 %	−3 %	$r = 0.67$
Thailand	Upper Middle	43 %	39 %	9 %	−1 %	$r = 0.66$
Vietnam	Lower Middle	39 %	47 %	15 %	−4 %	r = 0.99

[a] Period 2005–2019. Own calculations based on the SLR and FAO stats (https://www.fao.org/faostat/en/#data/QCL) (2021).
[b] Change 2005–2020.
[c] Absolute values for 2020. Based on the SLR and WDI (https://data.worldbank.org/indicator/AG.LND.FRST.ZS) (2021).

we found that monocultures face a metabolic process, which take inputs from ecosystems and finally produce outputs to ecosystems. Those outputs some times are positive, but in most case are negative, particularly affecting regulating ES (Fig. 5). Then, our results go in line with studies which show that low complex landscapes such as croplands, provide high quantities of material ES, but low quantities of regulating ES (Araujo et al., 2021). The problem is that, when considering the scale of monoculture production in the global south, we face an amplification problem. Considering a general perspective, only the crops identified encompass about 247 million ha in the 15 countries analyzed (stressing

Table 3
Information related to biodiversity, monocultures and forest area in the SLR countries.

Country	NBI	Crops according SLR±	Trend in harvested area 2005-2015*	Trend in forest cover 2005-2015**	Harvested area/forest*
Argentina	0.615	(a), (e), (i)	16%	-11%	r = -0.67; r^2= 0.46
Brazil	0.877	(a), (b), c, d, (e), (g), (h), (i), (j)	29%	-7%	r = -0.91; r^2= 0.85
China	0.839	(a), (b), (e), (g), (j), (h), (i)	0.014%	13%	r = 0.03; r^2= 0.07
Colombia	0.935	(a), (b), (e), (g), (h), (j), (i)	22%	-4%	r = -0.91; r^2= 0.82
Costa Rica	0.820	(a), (b), (e), (g), (h), (j), (i)	5%	5%	r = 0.13; r^2= 0.01
Eswatini	0.609	(e), (i)	14%	3%	r = 0.98; r^2= 0.90
Ghana	0.646	(a), (b), (e), (g), (h), (i), (j)	0.001%	-5%	r = -0.24; r^2= 0.05
India	0.732	(a), (b), (e), (h), (j), (i)	8%	5%	r = 0.69; r^2= 0.48
Indonesia	1.000	(a), (b), (e), (g), (h), (i), (j)	33%	-8%	r = -0.93; r^2= 0.86
Malaysia	0.809	(a), (b), (e), (g), (h), (j), (i)	13%	-1%	r = -0.04; r^2= 0.002
Mexico	0.928	(a), (b), (e), (g), (h), (i), (j)	6%	-3%	r = -0.83; r^2= 0.69
Peru	0.843	(a), (b), (e), (g), (h), (i), (j)	26%	-3%	r = -0.936; r^2= 0.91
Philippines	0.786	(a), (b), (e), (g), (h), (i), (j)	14%	1%	r = 0.19; r^2= 0.03
Thailand	0.670	(a), (b), (e), (g), (h), (j), (i)	14%	2%	r = 0.81; r^2= 0.65
Vietnam	0.682	(a), (b), (e), (h), (i)	5%	14%	r = 0.81; r^2= 0.66

± Here are included all the crops identified in the SLR per country when applied. For instance, we aggregated in Argentina rice, soybeans and sugarcane. (a) Soybeans, (b) Coffee, (c) Corn (not available in FAOSTATS), (d) Manioc (not available in FAOSTATS), (e) Rice, (f) Mixed grain, (g) Oil Palm, (h) Rubber, (i) Sugarcane, (j) Cacao, (k) Umari (not available in FAOSTATS).
*Change in the period 2005–2019. Own calculations based on the SLR and FAO stats (2021).
**Based on the SLR and WDI (2021).

that there are a lot more monocrops in those countries). It means, that the trade-offs mentioned in Section 3.3 will appear not only in those 247 million ha, but in their landscape-contexts too, and particularly those trade-offs related to biodiversity loss, habitat fragmentation and species richness in the global south.

With this, we added concerns on seminal scientific contributions regarding the more frequent biodiversity loss (Foley et al., 2005), habitat lose and fragmentation (Fahrig, 2003; Myers et al., 2000) due to land use. Moreover, we add alarms regarding the implications of monocultures in a global south-scale, given that in these countries biodiversity is outstanding. This is not a minor aspect, because of it has been highlighted that land system change (Steffen et al., 2015) and biodiversity loss (Rockström et al., 2009) are planetary boundaries that should not be trespassed.

4.2. Monocultures in the global south

The keywords we found mostly considered concepts that influence the understanding of monocultures, both in the sense of practices (i.e. agroforestry and intensification), the connection with ecosystems, their functions and services (i.e. biodiversity, bats, ecosystem services) and monoculture impacts (trade-offs). These go in line with scientific discussion on the consideration of sustainability in agriculture practices (Tilman et al., 2002; Tscharntke et al., 2005), and the more and more growing body of literature considering the importance of ES for agriculture (Kremen and Miles, 2012; Zhang et al., 2007).

Our SLR showed that monocultures are embedded in high biodiverse areas, not just for the descriptive analysis provided in Fig. 4, but also for the context of the producer countries; a context of mega diversity (Table 3). This is a trend highly recognized in literature, where biodiversity hotspots are used by agriculture as means for development and generation of capital for national industrialization (Dobrovolski et al., 2011), producing an “agricultural bomb” (Laurance et al., 2014). In particular, all the countries identified in this SLR although high biodiverse, are into the high level predictions for fauna extinction (Gonçalves-Souza et al., 2020). The aforementioned goes in line with forest cover trends in most of the SLR countries, where the change in forest cover through the period 2005–2019 was negative. Although we found that some countries had positive changes in forest cover (e.g. China, Philippines), literature also highlight the high levels of habitat loss and fragmentation in all the SLR countries (Kong et al., 2021).

One vision of monocultures according to tropical farming economics, is that natural ecosystems limit what can be harvested (Almestad, 2015). Therefore, ecosystem complexity is a problem, and then is economically better landscape simplification for improving agricultural outputs. On the other hand, other approaches have suggest that capital should flux through nature in order to increase productivity and create new opportunities for accumulation (Boyd et al., 2001). For this reason, the crops found in this SLR are those related to high landscape transformations. In this sense, there is a multidimensional problem: countries with middle-low incomes, with important levels of agricultural GDP share and high biodiversity are facing deforestation and biodiversity loss. The aforementioned reinforce the idea of the ecologically unequal exchange between wealthier nations (global north) which tend to impact the ecosystems in marginalized nations (global south) trough exports (Bunker, 1986). This is related to a challenge of sourcing northern economies trough monocultures –for example, while southern countries struggle to reduce poverty and face ecosystem degradation (LaRota-Aguilera et al., 2022). Therefore, as mentioned by Austin (2010), the relationship between deforestation and the flow of monocultures from less-developed (south) nations to more-developed nations (north) is a specific form of ecologically unequal exchange.

5. Final remarks

The overall results provided in this SLR showed a qualitative relation and fluxes between ES and monocultures in the global south. We found some high-value crops and we identified that producer countries are very high biodiverse nations. In addition, we found that the literature reviewed stress the ecological characteristics where the monocrops were embedded. We highlight that we did not provided causality relations, rather, we provided correlations as proxies to point out the implications of the growing crops areas in the countries; we were able to reinforce this relation with literature. We recommend providing local analysis for a better understanding of the ES demand-supply in monocultures.

Our results suggest to strength policy approaches to address the sustainability of agroecosystems –mainly in monoculture systems- particularly in those mega diverse countries, which face every-day ecological degradation and high need for increasing their GDPs. However, as showed in this paper, there is a difficult problem to solve: how to balance demand and supply of ES in monocultures? We consider that this problem is challenging to address if business as usual continues. The literature in general and our review in particular, allowed us to understand that monocultures produce transformations in ecosystems, synergies and trade-offs. Although monoculture still produce ES, it is very improbable that monocultures could be understood as sustainable use systems, both for their nature and for their scale. More research is needed in this sense particularly because there is a high interest on monocultures for economic development in the global south, and this area will support the global food production in the future.

Finally, we would like to mention some limitations of the present study. The first is the analysis only of literature published in English and indexed in the SCOPUS database. In addition, the few amount of countries identified is a limitation. A more detailed research should take into account context-specific information in different languages and context, and consider gray literature. This could provide valuable information to complement our results. Second, our approach was only intended to point out qualitative relationships between monocultures and ES, but quantitative information would be even revealing. Finally, it is important to provide further considerations on the role of China - in isolation - since it has been mentioned as a country that externalizes monoculture-related impacts even in more peripheral countries (Tasmim et al., 2022), and we did not address it in our work.

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Ethical statement

- Conflict of interest: The authors declare they do not have a conflict of interest.
- Authors' contributions: A. Suarez: Conceptualization, Methodology, Writing original draft. W. Gwozdz: reviewing, editing.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

The original documents analyzed in this research are included in the article/supplementary material. Data related to background information are open access provided by FAO and WDI. For more information, please contact the corresponding author.

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