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Research article

The reliance of countries on ecosystem services acquired through large-scale land acquisition

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ABSTRACT

Large-Scale Land Acquisitions (LSLAs) phenomenon recorded a spike after the 2007-2008 global financial crisis due to increased agricultural prices. LSLAs have previously been studied through the ecosystem services viewpoint, mapping the transfer of biocapacity economic value (BEV) across countries, especially from the Global South to Global North. In this paper, the international LSLA deals involving agricultural cropland included in Land Matrix database are considered with the involved monetary flow linking countries acquiring BEV to countries ceding it. This paper aims to investigate the BEV acquired by countries via LSLAs to reveal its relevance in satisfying the needs of such nations through comparison with the same countries' domestic BEV. The same analysis is performed in terms of land area to investigate possible correlations among BEV and land area. The 2008 global financial crisis and the Covid-19 pandemic are captured by focusing on the years from 2000 to 2021. The results show that at the global level the BEV transferred via LSLAs covers a marginal relevance (below 0.2% of the domestic cropland BEV of the countries acquiring it), at the national level it can assume a major significance (up to 8620%). Historic trends reveal that such transfer is becoming more relevant for countries acquiring land via LSLAs. The large variety shown stimulates the discussion over the drivers that underpin the phenomenon and its trend over time, linking them with economic, demographic, geophysical and climatological factors. This work calls for policies to curb the reliance on BEV acquired via LSLA by seeking possible compromise across foreign and domestic environmental and socioeconomic aspects while ensuring to safeguard ecosystems and combat inequalities.

1. Introduction

The 2007-2008 global financial crisis caused a spike in the food and agricultural prices [1]. This, in turn, induced an abrupt increase in the large-scale investments in foreign agricultural land – which commonly involved investors from the Global North and land belonging to the Global South. This kind of investment is known as Large-Scale Land Acquisition (LSLA). Through this kind of international deals the countries acquiring rights on land (e.g., concession, purchase, long-term lease etc.) can obtain primary agricultural production with a much lower investment (which can derive, for instance, from both a lower labor cost and land exploitation

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rights cost) compared to a production in the acquiring country (i.e., the country acquiring exploitation rights). By pursuing the classical neoliberal capitalistic orientation which identifies the maximization of the profits as the unique objective of a company's activity, the cropland acquiring companies often become drivers of unsustainable agricultural practices, environmental impacts, and violation of human rights, despite the potential creation of job opportunities, infrastructural development, and commodity production increase [2]. When this is the case, the involved LSLAs are commonly referred to as "land-grabbing" among the media and the scientific community [3–5]. However, this label should be carefully used.

The assessment of the impact of LSLAs is gaining momentum among scholars from various disciplines and focusing on various aspects such as the LSLAs' effects on food security [6,7] or their impacts on biodiversity [8], or on critical ecosystems such as tropical forest [9,10], but also on the availability and exploitation of scarce natural resources such as freshwater. Moreover, there is growing attention about the linkages between LSLAs' and inequalities [11]. In the global land market context the impact on biodiversity covers a peculiar role, as while LSLAs are clearly linked with biodiversity loss [8], economic incentives like Payments for Ecosystem Services (PES) are meant to promote biodiversity conservation by compensating landowners for maintaining or enhancing ecosystem services [12]. However, the positive influence on biodiversity of PES incentives is non-trivial and bound to an accurate and fine-tuned design to avoid unintended negative externalities, or general ineffectiveness [13,14].

The ecosystems underpinned by the land involved in LSLAs provide a large variety of services which include, for instance, climate regulation or biomass-based resources provision such as food and fibers [15] and they should be protected accordingly. However, forest land providing climate regulation services (essentially a long-term benefit) could, for instance, be converted into cropland to generate short term economic benefits. Studying the ecosystem services means estimating the economic value of the benefits that natural ecosystems provide to humanity [16]. The correlated concept of Biocapacity (BC) refers to the capacity of land to provide biomass-based resources like food, fibers and renewable raw materials – among other services [15]. The BC concept translated into economic terms constitutes the Biocapacity Economic Value (BEV), as introduced by Ref. [17]. By using the BEV approach it is possible to determine the economic value transfer corresponding to the appropriation of foreign cropland's biocapacity perpetrated by countries acquiring land via LSLAs [11]. [11] estimated a loss of 15′000 US $ and 5′000 US $ per hectare of cropland and forest, respectively, involved in LSLAs when comparing the monetary transactions with their BEV, on a global average, suggesting that LSLAs might result in biocapacity grabbing phenomena [11].

Besides, it is also possible to estimate the BEV of the total cropland within the boundaries of each country. By attributing the responsibility for the BEV acquired to the countries driving such phenomenon it is possible to compare the BEV obtained by acquiring foreign cropland and the BEV obtained by the exploitation of domestic cropland to reveal the reliance of countries on foreign biocapacity from an ecosystem service perspective. This phenomenon has direct consequences for the geographic structure of the global production, trade, and consumption of goods, and particularly food systems [18].

While [11] mapped the phenomenon at the global and country levels, this paper aims to investigate and reveal the role that the BEV acquired through LSLAs plays in covering the total use of BEV by the countries acquiring land. A global and single-country dynamic perspective from the point of view of the countries acquiring cropland is adopted by analyzing the phenomenon over the last two decades. The work delves into the identification of the drivers and features of the phenomenon through a space-time global analysis spanning from 2000 to 2021. It aims to support policies aiming to curb the reliance on BEV acquired via LSLA by carefully assessing the possible compromise across foreign and domestic environmental and socioeconomic aspects also ensuring to safeguard ecosystems and combat the inequalities.

2. Method

The data underlaying the present analysis were sourced from Land Matrix [19]. Land Matrix database includes a comprehensive list of deals (for instance, leases, concessions, and purchasing contracts) that granted exploitation rights for transboundary cropland in the global market. It is the most complete and the database most frequently used in research about LSLAs [11,20,21]. However, the Land Matrix database is not free from limitations, particularly in terms of global representativeness. For example, LSLAs involving cropland in the European Union, Northern America, Australia, and New Zealand are scarcely represented or not included at all. Furthermore, only deals involving land with a size over 200 ha are listed and among the listed deals some were abandoned, while deals involving some critical areas or deals of specific types are excluded causing both potential over- and under-estimation [22]. The information retrieved from the database includes the country where the cropland object of the deal was located as well as the country in which the purchasing company was based. Moreover, the extension of the cropland and the transaction value (for instance annual total fee or rent, annual per hectare, one-time payment etc.) are provided, together with the deal starting and ending time. The analysis' temporal span was constrained by the availability of such data, which was limited to 2021 at the time of the extraction (May 2024).

Following [11], only deals resulting ongoing either partially or totally within the period considered – from 2000 to 2021 – were accounted for. Besides, only deals with all the above-listed information available were included in the analysis. This means that some deals were excluded, regardless of their relevance or size, because of the lack of comprehensive data. Since many different countries were involved in the deals, the respective monetary transactions were expressed in multiple currencies, either international (such as EUR or USD), or local currency units (LCU). As this work aimed to provide an overall global estimate as well as cross-country comparisons, this study ensured the comparability among deals and countries by converting all transactions into a common and comparable currency that is Purchase Power Parity (PPP) [23]. For each year and deal, whenever possible, the amounts were directly converted in this study. Whenever a direct conversion was unfeasible, the LCU amounts were first converted into international currencies via official exchange rates (e.g., USD/LCU), and then the international currency was converted to PPP with the available rates [23].

Finally, only LSLA deal targeting agricultural cropland were considered, excluding deals destined to agroforestry, biomass production, or livestock farming. For some deals, details about the intention of investments were available (e.g., food crops, energy crops, or non-food crops), but in many cases the detail included multiple intentions (e.g., food crops and non-food crops). While this level of detail would allow a more in-depth analysis and further insights, at present, the available information is fragmented and inconsistent, preventing the expansion of the analysis. The same happens for the information about other resources linked with the exploitation of cropland, such as water use. Indeed, only for few deals, information about water use (e.g., m^3 of water abstracted from a nearby freshwater basin) is available, preventing the possibility to further expand the analysis to encompass freshwater-related ecosystem services, potentially revealing water grabbing phenomena [2].

To link the cropland involved in each selected LSLA deal to the acquiring country this study identified the original economic driver as the ultimate investors. By backtracking – for each deal – the flow of money from the company that ultimately made the purchase up to the related shareholding companies, funds, etc., thanks to the information included in the dataset, this study attributed the responsibility of the cropland involved in LSLA to the identified original investors. Accordingly, this study bypassed any company which merely acted as an intermediary, regardless of where it was based. In case multiple companies, based in multiple countries, were identified as ultimate investors, the responsibility for the cropland involved in LSLA was allocated proportionally to the share of original investment of each company. It must be highlighted that in some cases the information to backtrack the monetary flow was truncated in correspondence with companies legally registered in the so called "tax havens" [24].

In this study the total cropland acquired via LSLA by each country was estimated following Equation (1):

$$Acquired\ land_{g,t} = \sum_i A_{i,g,c,t} \tag{Eq. 1}$$

where *Acquired land* indicates the total cropland acquired by country g in year t, and A indicates the size of the cropland, in hectares (ha), object of the deal i located in the country c and acquired by the country g in the year t.

In this study the total BEV of the cropland acquired by each country was estimated following Equation (2):

$$Acquired\ BEV_{g,t} = \sum_i A_{i,g,c,t} \cdot ES - YF_{c,t} \tag{Eq. 2}$$

where *Acquired BEV* indicates the total BEV corresponding to the cropland acquired by country g in year t. BEV is measured in terms of current US \$ PPP to ensure comparability across countries and over time. Besides, A indicates the cropland size object of the deal i located in country c and acquired by country g in the year t. Finally, ES-YF indicates the Ecosystem Service Yield Factors for cropland in country c in year t, sourced from Ref. [17]. Acquired BEV values are reported in Table S1 and Table S2 in the supplementary material. These yield factors represent the average economic value of a set of ecosystem services provided by 1 ha of a land-type in a country. They can be seen as context-dependent scaling factors that can be used for investigating ecosystem service value transfers calculated in different locations for cropland, grazing land and forest [17]. These factors stem from adjusting the biocapacity calculation [25] and, specifically combining the country-specific yield factors (YF, gha/ha), and land type-specific equivalence factors (EQF, dimensionless) with the respective ecosystem service unit values (in \$ per ha) [26]. As such, up to now, ES-YFs can only reach a country-level resolution. A resolution could significantly increase the accuracy of the estimates, but it is now not attainable. The calculated BEV represent natural capital values and can be used for environmental economic accounting and as a component of wellbeing indicators [17]. Being a land-based indicator, it does not directly capture the effects of water availability, but it does it indirectly by capturing the land productivity, which relies on water availability.

To estimate the BEV of each country acquiring cropland this study followed Equation (3):

$$Domestic\ BEV_{g,t} = DA_{g,t} \cdot ES - YF_{g,t} \tag{Eq. 3}$$

where *Domestic BEV* indicates the BEV associated with the domestic cropland of country g, in year t. Furthermore, DA indicates the domestic cropland area of country g in year t and *ES-YF* the related Ecosystem Service Yield Factor. The domestic cropland area of each country acquiring cropland was directly retrieved from the FAOSTAT database [27].

To reveal the relevance of the cropland acquired through LSLAs in terms of BEV for the economy of the cropland acquiring countries the total linked BEV and the total domestic cropland BEV of the countries acquiring BEV via LSLAs were compared. Accordingly, in this study the ratio between the total acquired BEV and the total domestic BEV was calculated as follows in Equation (4):

$$RBEV_{g,t} = \frac{Acquired\ BEV_{g,t}}{Domestic\ BEV_{g,t}} \tag{Eq. 4}$$

where *RBEV* allows to compare the BEV appropriation deriving from LSLAs with the BEV obtained through the exploitation of the domestic cropland.

Finally, to compare the ecosystem service point of view with the physical point of view and investigate the rationale underlying the LSLAs phenomenon, a similar ratio was calculated, but using the involved cropland areas instead of the related BEV (see eq. (4)), as shown in Equation (5):

$$RLand_{g,t} = \frac{Acquired\ land_{g,t}}{Domestic\ cropland_{g,t}} \quad \text{(Eq. 5)}$$

where *RLand* expresses the ratio between the area of cropland acquired via LSLAs and the area of cropland of the countries acquiring it. The domestic cropland of each country acquiring cropland via LSLAs was directly retrieved from the FAOSTAT database [27]. The analysis' temporal span is constrained by the availability of such data, which is limited to 2021 at the time of the extraction (May 2024).

The two ratios were calculated, for each year, at both global and country level.

3. Results and discussion

The comparison between cropland's BEV appropriated by countries through LSLAs and the BEV of the cropland of the same countries (through a ratio) allowed to estimate how they rely on foreign BEV to satisfy their demand. This kind of information has major implications in terms of policy because it can inform decisions makers to opt for better investments involving domestic and/or foreign ecosystem services, and especially biocapacity.

Over the whole analyzed period, the cropland globally involved in LSLAs accounted for less than 0.5% of the domestic cropland of the countries acquiring it (Fig. 1). The share of the related BEV was even lower, staying almost always below 0.2% over the whole period (Fig. 1). The first three years were severely affected by the presence, among the countries involved in LSLAs, of Singapore, together with Switzerland and France. The sharp decline in cropland share that occurred after 2003 was due to the expansion of the pool with new countries playing a role in LSLAs and, in turn, of their domestic cropland. Fluctuations can indeed be partly due to variations in the number and features (e.g., cropland area) of the countries partaking in the cropland transfer through LSLAs. This reflects in a change in the denominators of the ratio utilized to calculate the shares over the time series, partly explaining the fluctuations, and especially the sharp 2002 decline. Afterwards, the trend was almost continuously growing from 0.02% in 2003 to 0.19% in 2021. It was possible to observe a coupled trend from 2010 until 2013, after which the share in terms of land appeared to reach a plateau, while the share in terms of BEV kept growing from the lowest point in 2010 (0.08%) up to 0.17% in 2021, suggesting a possible de-coupled trend (Fig. 1). This could be due to intrinsic differences between the agricultural practices and agricultural and economic development of the countries ceding cropland, which still have a large possibility to improve (e.g., in terms of yield) and the acquiring countries, where the yield gaps are remarkably lower and the agricultural efficiency is plateauing or only slowly growing, together with the economy, and therefore, the economic output.

It is remarkable that in 2008, year of the global financial crisis, the share in terms of cropland area surpassed the related share in terms of BEV. In the immediately following years the number of countries partaking in LSLAs increased, pushed by the spike in domestic prices [9,28] towards the exploitation and possible exacerbation of the socioeconomic inequalities in the countries ceding land. While 2008 crisis was detected by this analysis, it seems that the 2012-2013 crisis (European Sovereign Debt Crisis [29]), was not. This might be due to the scarce relevance of the most affected countries (Ireland, Portugal, Spain, and Cyprus) as acquiring countries – Ireland and Portugal were not even involved, while Spain and Cyprus only had a deal active. Looking at the last years it seems that the

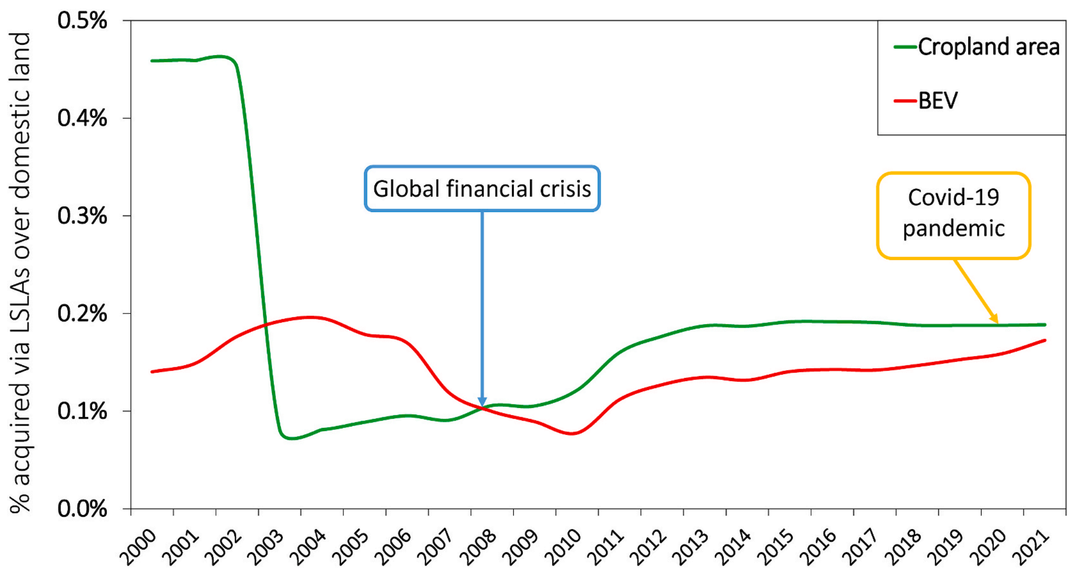

Fig. 1. The annual ratio of the BEV (red line) and land area (green line) deriving from LSLAs over the relative total domestic cropland BEV and land area of the countries acquiring land through LSLAs, expressed as share. The two major global events that occurred over the analyzed period are highlighted. Note that the pool of countries participating in the transfer of cropland through LSLAs varied across time, meaning that the denominator at the basis of the calculation of the share varied over time, partly affecting the value fluctuations.

Covid-19 pandemic affected the trend of the share in terms of BEV pushing it towards faster growth. However, more recent data will be necessary to derive sound conclusion. The global cropland area acquired via LSLAs passed from 91,400 ha in 2000 to 1.5 million ha in 2021 with a 16-fold increase (see Table S1 in the supplementary material). The corresponding transaction in terms of BEV passed from 294 million US$ PPP in 2000 to 10 billion US$ PPP in 2021 with a 35-fold increase (see Table S2 in the supplementary material).

By shifting from a global perspective to a national one it was possible to observe extremely significant variations, not only in terms of trend, but also in terms of value of the share.

Fig. 2 indicates that two distinct groups of countries can be identified by considering such shares. Other countries acquiring land via LSLAs are not shown here as the related results indicated lower relevance (see the complete results in Table S3 and Table S4 in the supplementary material).

The first one was composed by Singapore (not shown in Fig. 2 a, b for being out of scale), Malta, Luxembourg, Saudi Arabia, and United Arab Emirates. These countries shared a common trait, i.e., the limited availability of land suitable for crop cultivation. This limitation is due to either climatic conditions that impede crop cultivation in part of the countries' territory (for instance, Saudi Arabia [30]), or to the physical absence of land due to the small size of the countries (e.g., Singapore, Malta, and Luxembourg). Moreover, the other common trait for these small-sized countries is the very high population density [31]. All these features put together have multifaceted consequences. First, urban settlements cover a significant part of the country's territory which cannot be exploited by agriculture to provide crops or by large industrial infrastructures for industrial production. Second, the economy was oriented towards services and financial sectors which are highly information-intensive and rely more on labor than on materials (see Malta for instance Ref. [32]). As population's livelihood can be sustained either by domestic or imported production, where the domestic production cannot suffice, the market outsources the production in foreign territories, and rely on international trade [33–35]. However, the reliance on international trade can expose to multiple risks such as price shocks and, generally, a de facto dependency on one or multiple foreign countries. This is especially significant when the self-sufficiency level of a country is critically low, as in the first group of countries identified [36]. Countries could opt for avoiding market risks and outsourcing cropland-based agricultural production by acting directly on the foreign territory from which the cropland-based agricultural production will be provided through LSLAs. This cause-effect relationship became clearly visible after the global 2008 financial crisis (Figs. 1 and 2) which resulted in inflated prices and triggered countries toward LSLAs, to elude the international trade. Besides, the existence of specific crops highly demanded by countries acquiring cropland but cultivable almost exclusively elsewhere fuels the creation of this sort of dependency and, in turn, the development of LSLAs. Oil palm cultivation is a classic example [37], but other crops such as cocoa and coffee are typically involved too.

Singapore stood out from the group since it was the only country whose role within LSLAs was detected form the first year analyzed, when the share identified reached 34% (see the complete results in Table S3 and Table S4 in the supplementary material). Besides, the share rapidly and steadily grew until reaching 8620% in 2021 – meaning that the BEV acquired via LSLAs by Singapore was more than 86 times the BEV provided by Singapore's domestic cropland. Malta and Luxembourg showed a remarkable growing trend too, though with a more recent initial year and lower share values. For instance, Malta's activity was detected only from half-way through the period analyzed (2010) with an initial share of 34%, whereas the Luxembourgish one was even more recent, starting in 2016 with an initial share of 22%. Specifically, at the end of the period considered Malta's appropriation of BEV via LSLAs equaled 84% of its

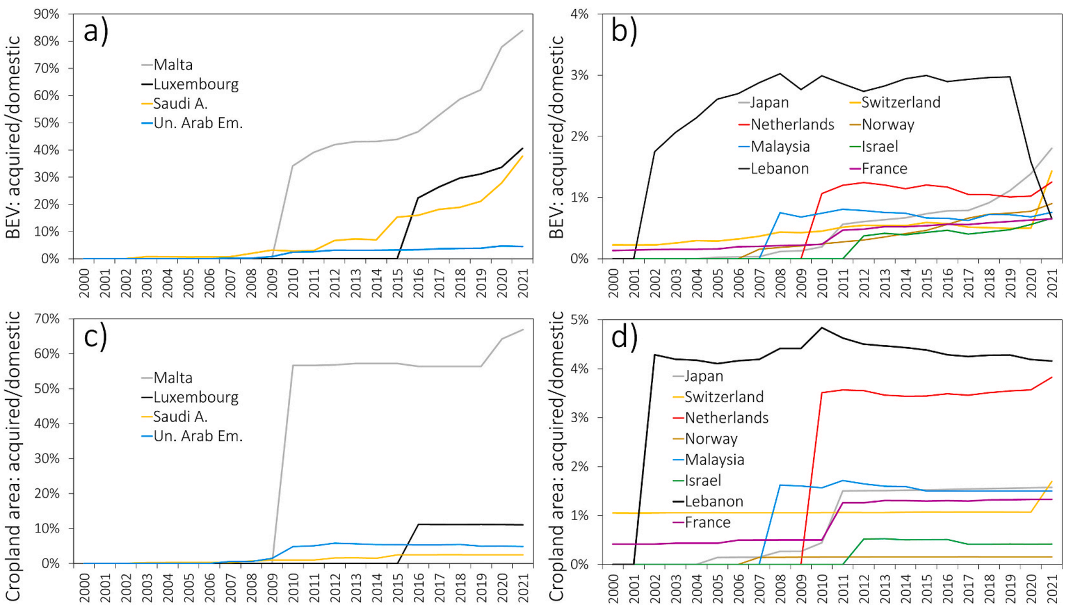

Fig. 2. The ratio between acquired BEV on the domestic cropland BEV (a, b) together with the relevance of the related acquired and domestic cropland (c, d), expressed as share. Singapore is not shown since it was significantly out of scale compared to the other countries.

domestic cropland BEV whilst for Luxembourg it reached 41% (Fig. 2a). Saudi Arabia's activity in LSLAs was recorded since 2003 and after a slow growth up to 2014, its share of BEV acquired via LSLAs over the domestic one grew faster, reaching 38% in 2021. British Virgin Islands were involved in the acquisition of cropland via LSLAs as well, being attributed large amounts of cropland BEV acquired via LSLAs. This would suggest its inclusion among the countries of the first group. However, data gaps limited the possibility to provide complete results for such territory, and the authors decided to exclude them from the figures. For a few other countries, data was limited as well. See the complete results in Table S3 and Table S4 in the supplementary material.

While the demographic, geographic, and ecological features of these countries explain part of the high level of the shares, the economic side can explain part of this phenomenon too. The role of the economy was revealed in Fig. 2c, which highlights how the growth of the share for the BEV was decoupled from the share of the related land area in most cases. Besides, by representing global financial activity hotspots, some of these countries might in some cases act as a mere financial intermediary without disclosing information on the original subject which actually perpetrated the LSLAs. This underscores the critical importance of enhancing transparency within the financial sector to effectively assign responsibility for BEV appropriation via LSLAs. Attributing responsibility for BEV appropriation through LSLAs to these "financial paradises" could be an entry point for policies aiming to incentivize information disclosure by these nations, thereby paving the path towards a more precise attribution process, and towards a more accurate mapping of the dynamics. Ultimately, this would allow a higher level of control, supporting the design of more efficient policies aiming to safeguard the ecosystems and to combat the inequalities deriving from the transfer of ecosystem services across the global international land market.

The second group included a large variety of countries belonging to all continents, though most are European (Fig. 2b). A common trait among the countries of this group cannot be identified. Interestingly, Lebanon is affected by both reduced area and scarce cropland availability due to climate, traits that affected countries in the first group. A large variability in terms of trend among these countries was revealed, together with a remarkable difference compared to the first group (Fig. 2a and b). Most countries' activity on LSLAs started around the middle of the analyzed period although the trend was heterogeneous (Fig. 2b). Only few countries showed a steady significant growth (e.g., Japan, Norway, and France), while most showed a variable trend including even decreasing periods (Fig. 2b). These fluctuations were mainly driven either by economic factors (e.g., PPP or exchange rates fluctuations) or changes in the domestic cropland size – besides the mere change in the cropland area acquired via LSLAs. For instance, the Swiss trend can be completely explained by the economic trend in the country where the cropland was acquired (Liberia in this case), while the Lebanese trend can be explained by considering the variation of the domestic BEV, especially over the last couple of years. Instead, the Malaysian trend was mainly influenced by fluctuations in the domestic cropland area, whereas the main driver for the French and Japanese growing trend was the increasing total cropland area (and BEV) acquired via LSLAs – which involved multiple countries – together with variations in economic factors occurred in such countries.

The effect of the global financial crisis on the reliance on foreign BEV acquired via LSLAs was evident at the disaggregated level too (Fig. 2). The spike in terms of investments, i.e., in terms of land acquired via LSLAs, occurred right after 2008 for most countries. The spike in terms of BEV was comparable and synchronous.

The effect of the Covid-19 pandemic was evident at the country level as well. Indeed, for countries of the first group, a sharp increase in terms of BEV was detected, whether it was linked to underlying increase in cropland area (e.g., Malta) or not (e.g., Luxembourg, Saudi Arabia, and United Arab Emirates). For countries belonging to the second group a similar general behavior was detected, with the notable exception of Lebanon. This showed a dramatic decrease in terms of BEV compared to a marginal decrease in terms of cropland area, possibly due to the peculiar national economic shocks that incurred a dramatic increase of the inflation rate [38], worsened by the Beirut blast [39]. These economic dynamics were disproportionate compared to, Romanian ones – Romania is the country from which Lebanon acquired cropland via LSLAs – explaining such particular trend and showing the tight relationship between biocapacity and economy. Conversely, a general intensification of the decoupled growing trend was evident for the rest of the countries from group 2, whether it was linked with a growth in terms of land (e.g., Netherlands and Switzerland), or not (e.g., Malaysia, Israel, and Norway) (Fig. 2).

As for the first group of countries, a tendency towards a decoupling between BEV and land area was revealed also for most countries of the second group (Fig. 2d). This asymmetric growth revealed that the cropland appropriation is progressively becoming more economically relevant in terms of BEV for countries acquiring cropland. However, there were no corresponding growing benefits for the countries where the land is located. On the contrary, LSLAs could have negative consequences for such countries, for instance, if the agricultural development is outpaced by population and economic growth. Indeed, a growing domestic demand for agricultural products (i.e., the related BEV) coupled with the inaccessibility to further cropland within their national boundaries – since part of it was ceded through LSLAs – could push the countries ceding rights on cropland via LSLAs towards a reliance on international market (thus to exposure to risk, and possibly higher prices) or even to participate in LSLAs as buyers, to satisfy the increased demand for biocapacity-based commodities and related BEV. This would evidently result in a paradoxical phenomenon, as already detected in some cases in market sense [40,41]. This is evident in our results where Malaysia was among the countries acquiring land, while being among the countries ceding most land, especially for the cultivation of oil palm. Other developing countries were found to be involved too (see supplementary material). The decoupling trend also means that preventing new LSLA deals from being concluded would not be enough to reduce the overall BEV loss.

Fig. 2a indicates a worrisome trend for the first group of countries which can be expected to be progressively more relying on BEV acquired through LSLA. Domestic ecosystems are thus preserved – at least from agricultural expansion, but the avoided burden is shifted abroad to foreign ecosystems through LSLA. Since LSLAs risk to degrade the involved ecosystems reducing their productivity, these countries might end up seeking for more and more cropland acquired abroad, exacerbating the current dependency. This worrisome future outlook should be carefully addressed by the policymakers of the acquiring countries to ascertain the soundness of current and possible future LSLAs to ensure a long-term ecosystem protection, and not only profitability. While the same could be said for the second group of countries, Fig. 2b indicates a less worrying trend for them. In this case, policymakers could also consider the option of investing in domestic ecosystem restoration (and increase domestic BEV generation) to alleviate the dependence on foreign BEV. On the other hand, policymakers in the countries ceding land can use the BEV estimates (local vs foreign) to ascertain whether current or future deals are generating (or are expected to generate) an adequate economic value from the loss of BEV, thus identifying the existing trade-off between the (short term) economic development and (long term) ecosystem protection.

In 2014 – the most recent year for which the original BEV yield factors were available – the BEV of the cropland globally involved in LSLAs accounted for about 0.13% of the GDP from agriculture, forestry and fisheries of the countries acquiring land via LSLAs (note that disaggregate accounts for the sole agriculture are not available) [27,42,43] (Table 1).

Moreover, it is remarkable that considering the second group of countries this share doubles to reach 1%, and further increases if considering the sole first group of countries, reaching 2% (Table 1). Furthermore, the share varied greatly across countries. For example, the BEV of the cropland acquired via LSLAs by Singapore in 2014 equaled more than three times Singapore's agricultural GDP (Table 1). Besides, the share was remarkable for Malta, for which it accounted about 16%. Once again, this study provided a picture of the extent to which cropland's BEV acquired via LSLAs can contribute to the economy of countries acquiring it. It should also be noted that agricultural production could even just undergo a first or further processing in the countries acquiring land via LSLAs before being exported and, finally, consumed elsewhere. Another significant difference existing between the two groups of countries can be revealed by comparing the countries' per capita GDP (PPP). Indeed, the countries belonging to the first group rank significantly higher compared to the second ones [44]. This means that more developed countries tended to rely more on cropland's BEV acquired via LSLAs compared to less developed ones. A future advancement, with updated yield factors, could refine and expand this kind of analysis allowing a better understanding of this trend over time.

Overall, the existing socioeconomic disparities between countries acquiring and countries ceding cropland seem to be at the basis for the advantageousness of LSLAs for the former, and this advantage has been generally steadily growing. Furthermore, the recent major geopolitical events such as the Russo-Ukrainian conflict (after 24 February 2022) and the Israeli-Palestinian (after 7 October 2023) are expected to further disrupt the global food systems with consequences in terms of food security [45] which, in turn, might affect the dynamics underpinning the cropland (and related BEV) transactions occurring in the context the global land market. Future analyses are expected to investigate these aspects following the approach utilized in this paper.

4. Limitations and future directions

Besides productive land, water is a critical resource that is commonly involved in LSLAs. The underlying database presents, for very few deals, information about water usage (e.g., m^3 of water abstracted from a freshwater basin). While water availability is another kind of ecosystem service, the scarce level of available data limits the possibility of capturing this flow of ecosystem services linked to LSLAs. A higher overall economic benefit is likely to be linked to the ecosystem services transferred via LSLAs and data generation on water usage is pivotal to reach a higher level of understanding of this phenomenon and the development of more fine-tuned policies, ideally to also manage potential water grabbing phenomena [2].

The available data also includes, for very few deals, details about the intention of investments (e.g., food crops, energy crops, or non-food crops). The current level of patchiness prevents further informative analysis and investigation to more comprehensive

Table 1

The per capita GDP [44], acquired cropland BEV (this study), GDP (agriculture, forestry, and fisheries) [42,43], and the ratio between the BEV acquired via LSLAs and the GDP (this study). Per capita GDP figures are expressed in 2014 PPP $ whereas other data are expressed in billion 2014 PPP $. "Other countries" indicates countries acquiring land not included among the two groups. See details in the supplementary material. *Luxembourg BEV data refer to 2016, year of the first involvement in LSLA. See the supplementary materials for details on the "Rest of the countries acquiring land".

Country group	Country	Per capita GDP (2014 US $ PPP)	Per capita GDP global rank	Acquired cropland BEV (2014 US $ PPP)	GDP (agriculture, forestry and fisheries) (2014 US $ PPP)	% BEV acquired over domestic GDP
First	Malta	34,344	39	0.02	0.15	16.4%
	Luxembourg*	105,296	3	0.07	0.17	40.3%
	Singapore	84,423	4	0.49	0.16	304.7%
	Saudi Arabia	55,726	12	0.29	38.37	0.8%
	Un. Arab Em.	73,619	6	0.02	4.34	0.4%
	Group total			**0.89**	**43.18**	**2.1%**
Second	Japan	39,555	32	0.23	50.17	0.5%
	Netherlands	49,233	18	0.09	14.43	0.6%
	Malaysia	24,608	59	0.45	65.21	0.7%
	Lebanon	15,017	88	0.07	3.78	1.8%
	Switzerland	64,103	10	0.01	3.68	0.3%
	Norway	65,893	9	0.01	4.88	0.2%
	Israel	34,366	38	0.01	3.40	0.4%
	France	40,144	30	0.93	41.43	2.2%
	Group total			**1.80**	**187.00**	**1.0%**
Rest of the countries acquiring land				**2.53**	**3827.55**	
Global total				**5.22**	**4057.74**	**0.13%**

understand the phenomenon. Data generation on the type of agricultural output generated via LSLAs could instruct more in-depth analysis such as a cluster analysis across countries to investigate the existence of common traits or trends. A potential way to fill this data gap and allow further investigation could be conducting a thorough investigation by surveying local authorities that were involved in the deals or the local communities that were affected.

Ultimately, the current method captures the biological (organic) output that is linked with LSLAs while overlooking the inorganic input (e.g., water as mentioned above) and the organic inputs that are necessary for plant growth. This entails not only the soil microbiota and macrobiota, but also larger and more mobile organisms such as birds and mammals, which are all highly variable geographically. A thorough ecological investigation could generate data on the organisms potentially affected in the areas where LSLAs occur to allow the estimation of the effect on biodiversity and provide further insights into the impacts of LSLAs beyond BEV.

The availability of these kinds of data could greatly expand the potentiality of the proposed method and increase the related informativeness to support the design of more comprehensive policies to regulate and monitor LSLAs phenomena.

Finally, updated yield factors could refine and expand the proposed analysis, allowing a better understanding of the underlying temporal dynamics.

5. Conclusion

Acquiring cropland via LSLAs is a steadily growing phenomenon globally. This analysis provides insights on the relations between biocapacity grabbing and LSLAs. From an ecosystemic point of view the BEV associated with the involved cropland was growing much faster. The countries fueling this phenomenon gained considerable advantages in terms of BEV, managing to cover part of the domestic demand for agricultural products by outsourcing the production to foreign countries, which, instead, lost useful BEV. Considering that LSLA deals might last multiple decades and observing the past trends it was possible to understand that in the long run this loss could become even more relevant with countries acquiring cropland via LSLAs relying more and more on the foreign BEV, and countries ceding BEV increasingly pushed to deflect and exacerbate this phenomenon towards other countries, whether already targeted by LSLAs or not – creating a paradox and linked negative feedback. This adds up to the already well-known environmental risks tied to LSLA that can result in long-term ecological issues, such as biodiversity loss, water scarcity, and environmental degradation. This study showed that even without further additions to the cropland areas involved the loss of BEV could keep significantly growing, especially as a consequence of major geopolitical events such as the 2008 financial crisis, the Covid-19 pandemic, and armed conflicts. By accounting for the BEV of the cropland involved in LSLAs and attributing it to the acquiring countries, this study identified the main drivers underpinning such phenomenon revealing a large variety among them, with economic factors accounting as much as demographic, geophysical and climatological ones. Identifying and quantifying the reliance of countries on ecosystem services acquired through LSLAs and the linked environmental risks can represent a data-drive robust platform to inform policies to re-think or better orient investments in order to avoid unintended detrimental impacts in the targeted countries and respective communities, especially in light of the major ongoing geopolitical events that can unpredictably alter the macroeconomic dynamics and directly and indirectly affect the land market dynamics as well as the linked ecosystem services value. Countries belonging to the first group might act on two sides: i) limiting the consumption of commodities typically supplied through LSLAs and ii) investing on the development of landless agriculture such as vertical farming coupled with renewable energy production. The second group might also consider two options: i) limit the consumption of commodities typically supplied through LSLAs and ii) convert farming practices to allow domestic sourcing of commodities previously supplied via LSLAs. If none of the options is feasible – either for political willingness or socioeconomic or environmental barriers – then a much proper pricing system should be adopted to ensure a fair compensation for the BEV acquired via LSLAs.

However, a more granular and detailed dataset, as well as a higher resolution in terms of methodological framework should be pursued to further strengthen the results and provide even more roust conclusion upon which design fine-tuned policies aiming to ensure the minimization of the environmental impact linked with the exploitation of ecosystem services, either domestically or abroad.

CRediT authorship contribution statement

Fabio Sporchia: Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation, Formal analysis, Data curation, Conceptualization. **Nadia Marchettini:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision. **Elisa B.P. Tiezzi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Conceptualization. **Valentina Niccolucci:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

Data availability

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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All authors contributed to the conception and design of the study, design/methodology of the study or acquisition of data, or formal analysis and interpretation of data. All authors contributed to drafting the article or revising it critically for important intellectual content. All authors expressed their final approval of the version to be submitted. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2026.e45254.

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