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LETTER

Transnational land acquisitions beyond the food and financial crises

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Abstract

Large-scale land acquisitions (LSLA) in resource-rich countries came to global attention after the food and financial crises of 2008. Previous research has assessed the magnitude of these land investments in terms of land areas acquired. In this study, we analyze the trends in the evolution of LSLA by framing the latter as virtual land trade network with land transactions occurring between 2000 and 2015, in order to shed light on the development and evolution of this system. Based on an index we introduce to represent both the number of countries and size of deals, we discover three main phases of trade activity: a steady increase from 2000 until 2007 (Phase 1) followed by a peak coinciding with the food and financial crises between 2008 and 2010 (Phase 2) and concluded by a decline from 2011 to 2015 (Phase 3). We identify 73 countries that remained active in land trading during all three phases and form a core of land traders much larger than previously thought. Using network analysis methods, we group countries with similar trade patterns into categories of competitive, preferential, diversified, and occasional importers or exporters. Finally, in exploring the changes in investors and their interests in land throughout the phases, we attribute the evolution of LSLA to the different stages in the globalization and financialization of different industries. By showing that land investments seem fully integrated as investment strategies across industries we argue for the urgency of better regulation of LSLA so that they also benefit local populations without damaging the environment regardless of their primary purpose.

Introduction

Global demand for land is growing. Currently, more than 90% of available and accessible global biomass supply is estimated to be used, while future demand for terrestrial resources, driven by a growing global population with rising consumption ambitions, is projected (if we reach 9 billion people) to surpass this biomass supply by 2050 (Haberl *et al* 2007, Running 2012, Smith *et al* 2012). In terms of land requirements, it has been estimated that global croplands, forests and urban areas would have to expand by 4% and up to 11% (from their 2000 baseline areas) to satisfy this demand by 2030 (Lambin and Meyfroidt 2011, Hertel 2017). At this rate, available land resources could be exhausted by the 2050s at the latest (Lambin and Meyfroidt 2011). For some countries already facing land scarcity problems, this would mean increasing net imports of natural resources or acquiring land abroad (Lambin and Meyfroidt 2011).

It is in this context of increasing demand for land that the phenomenon of large-scale land acquisitions (LSLA) (also referred to as land grabbing) has emerged. According to Anseeuw *et al* (2012), LSLA refer to the practice of leasing or selling land of over 200 hectares in size to governments or companies. While some have touted the benefits of such investments for enhancing agricultural self-sufficiency across the Global South, others emphasize concerns over the impacts that unregulated LSLA might have, ranging from the environmental (e.g. water grabbing, increased deforestation, and land degradation) (Rulli *et al* 2012, Clements and Fernandes 2013, Johansson *et al* 2016) to the social and economic (e.g. displacement of rural populations and impacts on livelihoods) (Anseeuw *et al* 2012, Akram-Lodhi 2015, Nolte *et al* 2016, Oberlack *et al* 2016).

Network methods have been used to treat the LSLA system as a land trade network (LTN), where the network is defined by aggregating investors by country of origin, subsequently referred to as land importers, acquiring land in host countries, or land exporters (Seaquist *et al* 2014). In the context of network analysis, the importing and exporting countries are the 'nodes' and land acquisitions connecting pairs of nodes are the 'edges' in the network. Such a topological map (where topology refers to the connectivity between nodes in a network) can be effectively analyzed in order to describe and understand the structure and behavior of a system. Global trade markets have been analyzed extensively through the use of network analysis tools as they enable the identification of patterns and communities (e.g. groupings of countries with similar trading preferences) within trade networks (Serrano and Boguna 2003, Garlaschelli and Loffredo 2005, Dalin *et al* 2012, Piccardi and Tajoli 2012, Seaquist *et al* 2014, Cingolani *et al* 2015).

The first wave of global quantitative studies on LSLA has focused on appraising the scale of global LSLA and the key countries involved in these transactions. They generally assessed land deals (mostly agricultural) starting from the food and/or financial crisis of 2008 (Friis and Reenberg 2010, Zoomers 2010, Arezki *et al* 2011, Anseeuw *et al* 2013). However, most of these studies have been criticized for primarily focusing on assessing the amount of land acquired globally, only identifying top players and drawing broad global conclusions on the drivers and consequences of LSLA with limited critical discussion of data sampling, methods or results, and with little appreciation for latent, potentially informative patterns embedded in large data sets (Oya 2013, Scoones *et al* 2013, Zoomers *et al* 2016). More recently, some have attempted to identify determinants of LSLA through econometric and regression models (Conigliani *et al* 2018, Kareem 2018, Lay and Nolte 2018). Yet, in-depth insights moving beyond data analysis and contextualizing LSLA within the framework of the commodification and financialization of nature remain limited to case studies (Bottazzi *et al* 2018, Cavanagh 2018, Vos and Roth 2018, Ogwang and Vanclay 2019) or more theoretical research (Borras *et al* 2012, Margulis 2015, Teklemariam *et al* 2015, Anseeuw *et al* 2017). We thus attempt to bridge the gap between theoretical or case study research and quantitative analyses by considering transnational LSLA as a system of interconnected transactions with multiple actors. In doing so, we go beyond a simple accounting of global acquired hectares or country rankings. Moreover, we contextualize such analyses in order to highlight core issues related to the exploitation of nature and society, so that responses that mitigate these problems can be formulated.

Therefore, this paper applies quantitative network tools on a large land deal dataset (The Land Matrix Global Observatory 2016) to make an empirical analysis of when, where, and how much land trading takes place, as well as by whom. Firstly, we establish a timeline of land transactions at the global scale in order to quantify how this phenomenon emerged, changed, and is still evolving. Secondly, we analyze the spatio-temporal trends of LSLA in terms of amount of land exchanged between regions. Thirdly, we explore the trading patterns of participating countries in the network. This includes both characteristics of individual countries and the communities they form, based on the amount of land exchanged and the number of deals, as well as the number and type of partners with which each country trades land. We also for the first time analyze the evolution of investment interests by companies. We then discuss potential drivers through the lens of global economic changes and the financialization of land-based resources in order to shed light on potential areas of intervention to establish more sustainable investments respectful of the environment and local livelihoods.

Methods

Data extraction and network construction

Our global transnational LTN was constructed from the Land Matrix (LM) database extracted on 9th March 2016 (The Land Matrix Global Observatory 2016). The database includes information on 2101 deals, of which 1100 were concluded during the 2000–2015 period (either in their start-up phase, in production, or with no current activity reported) involving at least one foreign agent (government or corporation) and amounting to over 43 MHa—an area larger than Sweden. The sizes of deals considered were those contracted, and in cases where this information was not available, we considered the operational size, else the intended size of the deal. If a deal involved more than one importing country, we divided the size of land transferred equally between these countries. If the target country was also involved in the deal, it was only considered for its role as an exporter, and the total size of land was divided between the other countries. This might increase the size of acquired land by the foreign investors, but since there is rarely any information available on ownership shares, we assumed that the foreign investor would have a strong say on how to manage the enitre parcel. From these data a graph was constructed with nodes $i = 1, 2,\ldots,N$ representing the $N = 125$ countries participating in the land trade and the $L = 486$ edges (links) corresponding to the aggregated (volume) land deals between countries (figure 1). These edges are directed from the exporting countries (hosting the deals) to the importing countries (the investors in foreign land) and weighted based on the total size of land area exchanged between the two countries (in Ha).

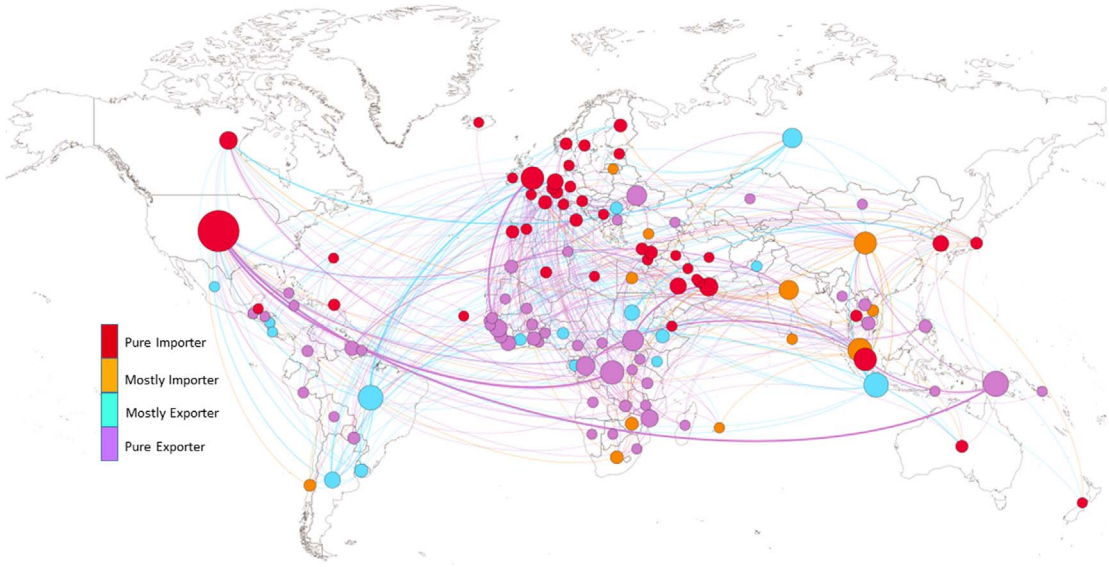

Figure 1. Land trade network including all non-domestic deals in the 2000–2015 period. The size of a node (country) represents the total amount of land exchanged (imported + exported), the color refers to the country classification from Pure Importer to Pure Exporter. The width of an edge (flow) represents the total amount of land transferred from the target to the investor country and the color refers to the target country.

Timeline of land transactions

In order to determine temporal patterns of land trade, the size of transactions and number of participating countries were considered on a yearly basis. The deals' size reflects on the amount of land that is governed differently as a result of LSLA while the number of countries is used as an indicator of the spatial distribution of LSLA. As these quantities do not correlate perfectly (figure S1 is available online at stacks.iop.org/ERL/14/084021/mmedia), they were combined into a yearly Activity Index (A_t) describing the annual intensity of land trade (equation (1)). It was defined for each year as the proportion of land traded in that year, compared with the total volume of land traded across the whole period, multiplied by the proportion of countries participating in the LTN that year (in other words, land L_t in year t with respect to the total traded land $L = \Sigma_t L_t$ during the whole period, multiplied by the number of countries C_t participating in the LTN in year t with respect to the total number of countries $C = \Sigma_t C_t$ involved in the LTN):

$$A_t = \frac{L_t}{L} \times \frac{C_t}{C}. \quad (1)$$

We visually inspected the graphical evolution of A_t to detect discontinuities in the time series (represented by the largest increase and first decrease identified), revealing changes in the state of the network in terms of amount of land exchanged and/or number of countries involved. These breakpoints were taken as boundaries representing major thresholds in the evolution of the LTN. The network was then disaggregated on the basis of these newly identified phases (figure S2).

Network metrics

For each of the three identified phases, we characterized the structure of the LTN by using eight indicators to quantify the features of each country i (table 1). By combining these metrics, it is possible to define the role each node plays in the network. This means that we are able to determine the patterns followed by each country when acquiring or leasing land (Cooper and Barahona 2010, Fortunato 2010, Newman 2010). This corresponds to a multi-criteria ranking and is therefore more informative than simply accounting for the amount of land exchanged. Countries' roles in the LTN are thus characterized by the number (figure S3) and types of partners (figure S4), number of deals (figure S5) and amount of land exchanged (figure S6).

Determining countries' roles in the network

We used role-based community detection (Cooper and Barahona 2010, Berguerisse-Diaz *et al* 2014) to classify countries based on their acquisition characteristics. This requires three steps: first, developing a measure of similarity to compare country behavior; second, simplifying the network to retain the most significant similarities; and finally, optimally partitioning countries with similar behavioral characteristics into communities whose members play the same role in the network.

To first compare countries, we normalized each one of the eight network metrics (table 1) to lie between 0 and 1 and collect them into an eight-dimensional feature vector $C_i = (k_i^{in}, k_i^{out}, s_i^{in}, s_i^{out}, n_i^{in}, n_i^{out}, x_i, y_i)$ for each country i, to enable direct comparison between country pairs. We then quantified the dissimilarity between countries i and j as the distance between the

Table 1. Country indicators and network metrics used for the analysis of the land trade network (e.g. Newman 2010 for details on network metrics). In the last two rows , w_{ij} denotes the amount of land transferred from country i to country j.

Characteristic	Indicator	Unit	Network metric	Formula
Number of partners	Import partners	Number of countries	in-degree k_i^{in}	
	Export partners	Number of countries	out-degree k_i^{out}	
Number of deals	Import deals	Number of land trade deals	in-deals n_i^{in}	
	Export deals	Number of land trade deals	out-deals n_i^{out}	
Area of land traded	Imported land	Hectares	in-strength s_i^{in}	
	Exported land	Hectares	out-strength s_i^{out}	
Type of partners	Authority centrality (high if country imports large amounts from heavy exporters)	Index [0, 1]	authority x_i	$x_i = \alpha \sum_{j=1}^{N} w_{ji} y_j$
	Hub centrality (high if country exports large amounts to heavy importers)	Index [0, 1]	hub y_i	$y_i = \beta \sum_{j=1}^{N} w_{ij} x_j$

two feature vectors C_i and C_j (the standard Euclidean distance was used). The greater the dissimilarity, the greater the difference in characteristics between the two countries. Figure 2(a) shows that the set of countries and their dissimilarities can be visualized as a complete (i.e. all-to-all linked) network, where nodes are the countries, and edges are weighted with the dissimilarities between country pairs.

To simplify the network to unveil important relationships, we then removed strong dissimilarities (i.e. weak similarities). Following Berguerisse-Diaz *et al* (2014), we extracted the minimum spanning tree (MST) from the complete network, namely the subset of edges having the minimal possible total dissimilarity, with the constraint of connecting all nodes (i.e. a path from any node to any other node exists in the MST, see figure 2(b)). However, to guard against omitting significant relationships between country pairs, a procedure was then implemented to re-introduce potentially important edges in an augmented minimum spanning tree (AMST), as shown in figure 2(c). In brief, the direct link between countries (i, j), previously removed when extracting the MST, is re-introduced into the AMST if its weight is considerably smaller than the total weight of the path connecting (i, j) in the MST. 'How smaller' is based on a threshold value f that has to be fine-tuned (we set $1 \leqslant f \leqslant 5$): large threshold values come closer to reproducing the MST, while the original complete network tends to be restored for small values.

Finally, communities (countries with similar characteristics) were identified using modularity maximization (e.g. Fortunato 2010), in which a modularity value $Q \leqslant 1$ expresses the degree of partitioning between modules. In general, community detection entails grouping countries into modules based on similar role features. This was separately applied to all three phases, and for all values of the threshold parameter f associated with the network simplification procedure described above. The value $f = 3$ maximized Q to 0.769, 0.755, and 0.598, for each phase respectively. The result is a partitioning of countries into communities (figure 2(d)). We examined the characteristics of each community and classify them based on how intensely, frequently and with whom they engaged in land transactions (competitive, diversified, preferential, and occasional participants in the land trade) and their most dominant function (land exporters or importers).

Classification of investors and investment interests

The LM database includes information on the investors involved in land deals and on their intentions (The Land Matrix Global Observatory 2016). For the 1100 concluded deals between 2000 and 2015, we followed the LM intention classification and analyzed the five categories: agriculture, forest plantation, biofuels and renewable energy, industrial parks, tourism and conservation. We also considered deals where the intention was unknown and classify them in an additional category.

Moreover, we found that 915 investors from multiple economic sectors were actively acquiring land during this period. Information on these investors was gathered from the cited sources for each deal in the LM database, complemented by information publicly available on the internet. We classified the investors based on their main sector of activity: agribusiness, wood companies (includes logging and processing), energy companies (includes oil and gas), industrial companies (includes construction companies), services (includes consulting firms and import/export companies), financial institutions, governmental institutions and NGOs. Some reported investors were private individuals without a clear affiliation, these were added to those companies where no information could be found and classified as unknown.

Results

Global dynamics: three phases of land trade activity

We identified three distinct phases of land trade activity based on a temporal analysis of the amount of

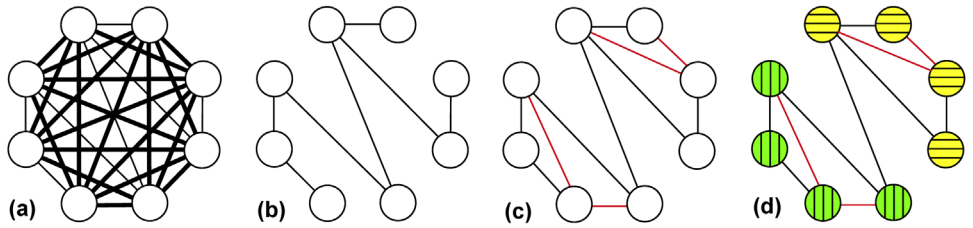

Figure 2. A pictorial description of the procedure for role-based community detection: (a) the complete (all-to-all linked) network where nodes are countries and links are weighted with the dissimilarities in land trade behavior (thinner links denote smaller dissimilarities, i.e. larger similarities in trade behavior). (b) The minimum spanning tree (MST), which is the minimal-weight subgraph connecting all nodes (countries), contains the most important pairwise similarities. (c) The augmented minimum spanning Tree (AMST) complements the MST with a few significant additional edges (in red). (d) Community detection, conducted on the AMST, partitions the nodes (countries) in modules with strong intra-module similarity (here two communities shown in green versus yellow).

land exchanged and of the number of countries involved (figure S1), which we combined to define the Activity Index (see Methods). Phase 1 extends from 2000 to 2007 and involves 93 countries that exchange about 8 MHa of land via 186 trade partnerships. Figure 3(a) shows that the Activity Index increased slowly from 2000 up until about 2005 after which it begins to accelerate. Phase 2 starts with the abrupt acceleration in land trade in 2008, and covers the period up to 2010. In this phase, 105 countries exchange more than 21 MHa of land via 257 trade partnerships. Finally, Phase 3, from 2011 onwards, is a phase of declining land trade as demonstrated by a monotonically decreasing Activity Index. It involves 95 countries which exchange about 13 MHa of land through 221 trade relations.

We identified a common core of 73 countries (58% of the countries) that actively participated in the LTN across all three phases (figure 3(b)). Moreover, the strong activity observed in Phase 2 (figure 3(a)) is also marked by the addition of 25 new countries, 10 of which remain during Phase 3 as well. Finally, in Phase 3, even though the trade activity decreases (figure 3(a)), seven new countries join the LTN (figure 3(b)). In terms of trade configuration (here denoting trade flows and directions between every two partners), diversity in trading partners is large, as a considerable number of trade relations are only active during a single phase (20% in Phase 1, 28% in Phase 2, and 22% in Phase 3) while a mere 8% of the 486 existing relations persisted through all phases (figure 3(c)).

Regional dynamics: towards the globalization of African land and the expansion of Asian investments

At the regional level, we found that all three phases were clearly distinct in trade configurations. Phase 1 is characterized by similar amounts of export flows (around 20% each) from Latin America, Asia and Europe, while Africa exports the most land at 33% of the global total, and Oceania only contributes 5% (figure 4(a)). We also note that flows are often confined to proximate geographical locations, as 58% of the trade occurs either within regions (as defined in figure 4(d)), especially in Asia, or between neighboring regions (Latin America–North America, Africa–Europe, Oceania–Asia).

Conversely, we find that Phase 2 is characterized by heavily globalized land trade whereby the proportion of intra-regional trade becomes minor (figure 4(b)). Africa dominates exports (51%, including 3% intra-regional trade), while Latin American shares decrease and Oceania's shares increase from Phase 1. Europe and Asia considerably increase their acquisitions of African land, compared to Phase 1, while North America focuses on Oceania.

Finally, we find that Phase 3 (figure 4(c)) marks a return to intra-regional trading, especially in Asia (21%) and Europe (10%), while African land continues to be transferred globally at a very large rate. Africa becomes nearly the sole investment region for North America, and a major one for Asia. Moreover, Latin America's contribution to the LTN remains the same although its main partners are now Asia and Oceania, which becomes a mostly importing region.

Country dynamics: shared behaviors beyond simple country rankings

The changes in configuration reveal changes in the land import and export behavior of most countries throughout the three LSLA phases (see Methods). We classified countries into distinct groups of four communities (competitive, diversified, preferential and occasional) across two behaviors (importers and exporters) (figure 5), based on the role-based community detection. Competitive countries are those that are presented as outliers for all metrics (figures S3–S6). Diversified countries exchange land in a few deals with many partners while the preferential countries have fewer partners with whom they exchange land in more deals. Occasional countries are those that only participate in few deals.

The distribution of the competitive, diversified, preferential and occasional communities across phases reveals important distinctions between importers and exporters. In Phase 1, the largest group is the preferential for both exporters (22% of countries) and

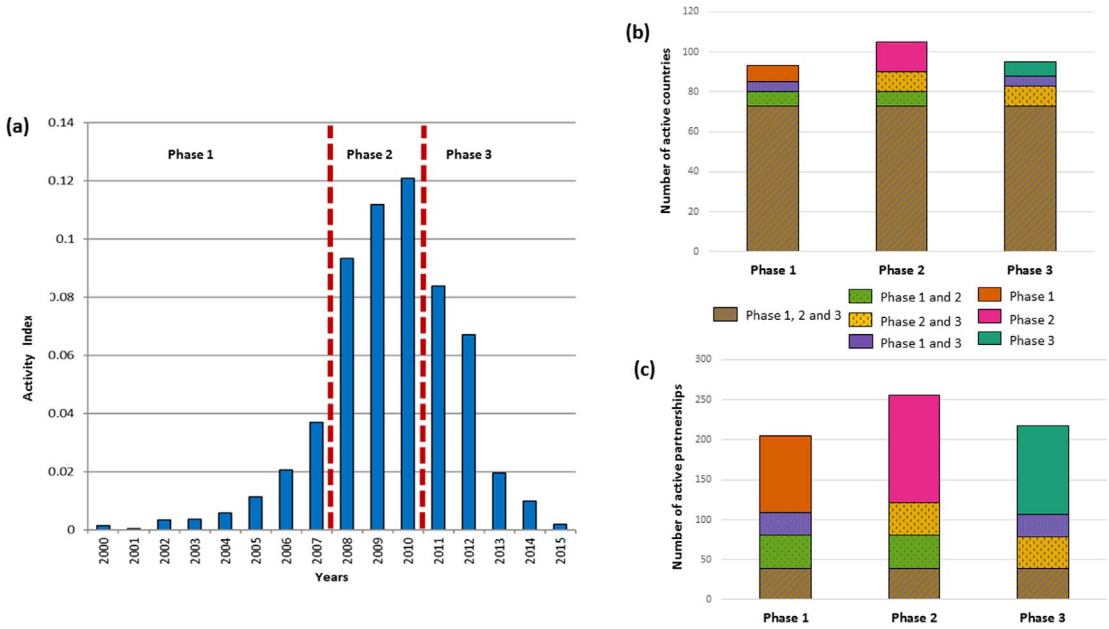

Figure 3. (a) The evolution of the Activity Index A_t (combining the share of yearly exchanged land with that of yearly active countries over 2000–2015) and breakpoints placed at the largest yearly increase of A_t, and at the beginning of the downturn; (b) the number of countries actively participating in the land trade network during the three phases; (c) the number of active trade partnerships in the three phases. The same shading in different phases denotes the same set of countries (b) and partnerships (c).

importers (16%). It is followed by the occasional (18%), the competitive (11%) and the diversified (8%) for exporters and by the diversified (12%) and the occasional and competitive, with each of these groups representing 8% of the importing countries (figure 5(a)). By Phase 2, the proportion of competitive countries doubles for both importers and exporters and it becomes the largest group of countries (figure 5(b)). The next largest groups are diversified and occasional while the preferential group becomes the smallest for both exporters and importers. The main distinction between importers and exporters occurs in Phase 3 as the largest exporter group remains competitive followed by preferential and occasional with no more diversified countries, while the largest importers group in the occasional closely followed by preferential and then diversified and finally competitive importers become the minority (figure 5(c)).

Of the 73 countries that are active during the entire period (figure 3(b)), 18 countries maintain the same trading behavior across phases, shown in blue in (figure 6). The USA, UK, China, Singapore and Malaysia remain competitive importers and Brazil, Argentina, Uruguay, Indonesia, Cambodia, Mozambique and Ethiopia competitive exporters. Ten countries (including Japan, the Netherlands and Angola) only change community in Phase 2 (most of them become competitive) as a response to the crisis and go back to their initial activity type in Phase 3 (shown in orange figure 6). Another 10 countries (incl. Canada, South Africa and Ukraine) change communities in Phase 3 (purple in figure 6) and 12 countries change communities in Phase 2 and maintain their new positions in Phase 3 too (turquoise in figure 6). These include the Congo, Tanzania and Ghana that become and remain competitive exporters. Moreover, 23 countries, including Korea, Italy and Senegal change behavior in each phase (yellow in figure 6). Amongst them, 9 countries move between being exporters to importers of land. These include India and Chile that are exporters in Phase 1 but become importers in Phases 2 and 3, while Russia, Pakistan, Gabon, Kenya and Egypt become importers in Phase 3 only. Mexico and Zimbabwe are the only countries that start as importers in Phase 1, become exporters in Phase 2 and return to importing land in Phase 3.

Finally, we find that the longest partnerships are between the 73 core countries except for the one between Norway and Mozambique that stopped in Phase 3 and that of Sierra Leone and the UK that started in Phase 2 (figure 6). Moreover, we find that 34% of the partnerships occur within regions especially between Asian countries (Indonesia–Malaysia, Cambodia–Vietnam and China–Laos). Preferential relations also occur between African and Asian countries (Ethiopia–India), African and European countries (Nigeria-UK) and Latin and North American countries (Peru-USA).

Dynamics of investors and investment intentions: new industries interested in land-based products

As most of the land deals are enacted by companies rather than governments (The Land Matrix Global Observatory 2016), we explore across the three phases to what extent different economic sectors are interested in land investments and for which purpose. We

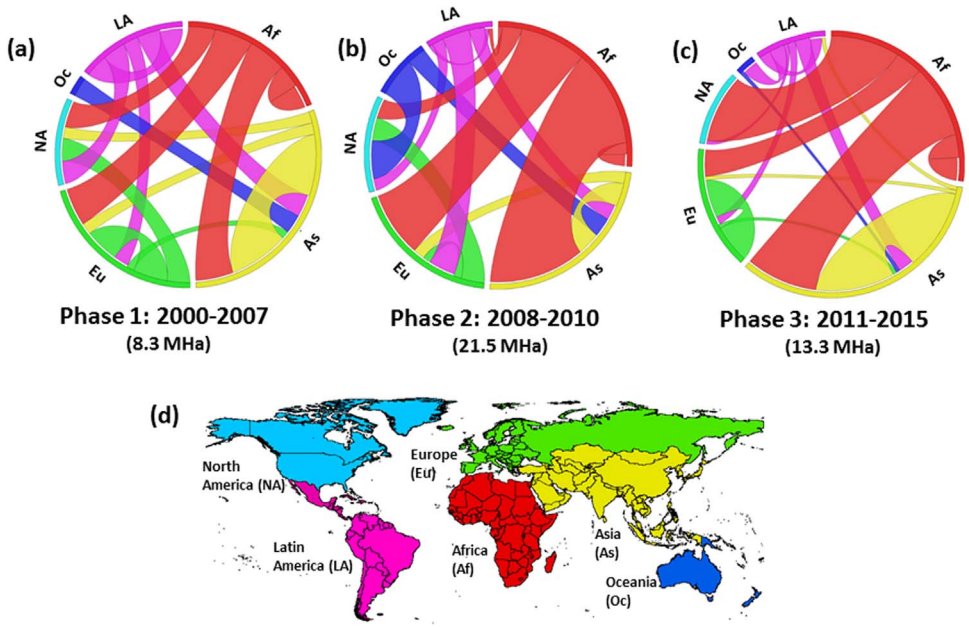

Figure 4. Regional land trade: countries are aggregated by their geographical position (regions are defined in (d) according to the UN classification (United Nations 2016). The three circles, drawn with Circos (Krzywinski *et al* 2009), refer to Phase 1 to 3 in the land trade network, with the total volume of land traded shown for each phase. The size of the links represents the proportion of exported land from the region of origin to partner regions, over the total amount of exchanged land for each phase. The color of the links represents the region of origin. For readability, the sizes of the three circles are drawn equally and thus do not represent the actual amount of total traded land. Only flows of at least 1% of the total trade are shown for each phase.

find that in Phase 1, agribusinesses are the largest investor group (acquiring 30% of the land), followed by financial institutions (23%) and wood companies (20%) (figure 7(a)). This distribution changes in Phase 2 where the majority group becomes forestry (29%) while agribusinesses and financial institutions lose in acquired shares even if there was a slight increase in absolute amounts of land acquired. During this second phase, energy and service companies as well as governmental institutions increase their share of acquired land. Moreover, private and unknown investors acquire more land during this phase than any other. Finally, in Phase 3, most groups return to their Phase 1 shares, especially agribusinesses dominating with 36% of the acquired land. This time, the wood industry moves back to fourth place, behind other industries and financial institutions that both acquire 17% of the traded land.

In terms of deal intentions, the dominance of agriculture is striking in Phases 1 and 3 representing 56% of all land acquired and even if it drops to 29% in Phase 2, it is still the largest intention during the crisis period (figure 7(b)). Biofuels and renewable energies as well as forest plantations are the other most common intentions in Phase 1 (11% and 22% respectively) and Phase 3 (9% and 17%). Phase 2 is characterized by more diversification in investment intentions, highlighted by the increase in the proportion of biofuels and renewables as well as conservation and tourism (which remains considerable in Phase 3 too). During the crisis period, the fraction of the land for which the intention is unknown is largest (19% against 6% in Phase 1 and 15% in Phase 3).

Discussion

In this study, we have presented an integrated spatio-temporal analysis of transnational LSLA at global, regional and country scales. We have identified, three main phases of trade activity in the global LTN: Phase 1 between 2000 and 2007, Phase 2 between 2008 and 2010 and Phase 3 between 2011 and 2015 (figure 3(a)). These are consistent with the findings of Nolte *et al* 2016 who identified an acceleration starting 2005 and a slow-down from 2012 by looking at the number of deals and area under contract. The rest of our analysis however is always embedded within these three identified phases, enabling us to highlight shifts in the locations and intentions of LSLA throughout time.

We have thus shown that land trade started between geographically proximate locations in Phase 1, became more global in Phase 2 and returned to more regional trade in Phase 3 (figure 4). While previous analyses present a clear North–South divide between land importers and exporters (Anseeuw *et al* 2012, Weinzettel *et al* 2013, Seaquist *et al* 2014, Coscieme *et al* 2016), we showed that land trade activity can be better understood if divided in three phases. It then appears that North–South trade only dominated land exchange during Phases 1 and 2, while we found increasing South–South trade starting Phase 2, and especially within Asia in Phase 3 and between Africa and Asia in Phases 2 and 3 (figure 4). Finally, because these trade patterns seem to follow those of merchandize trading (WTO 2015, Gasparri *et al* 2016), we further hypothesize that land exchanges could be

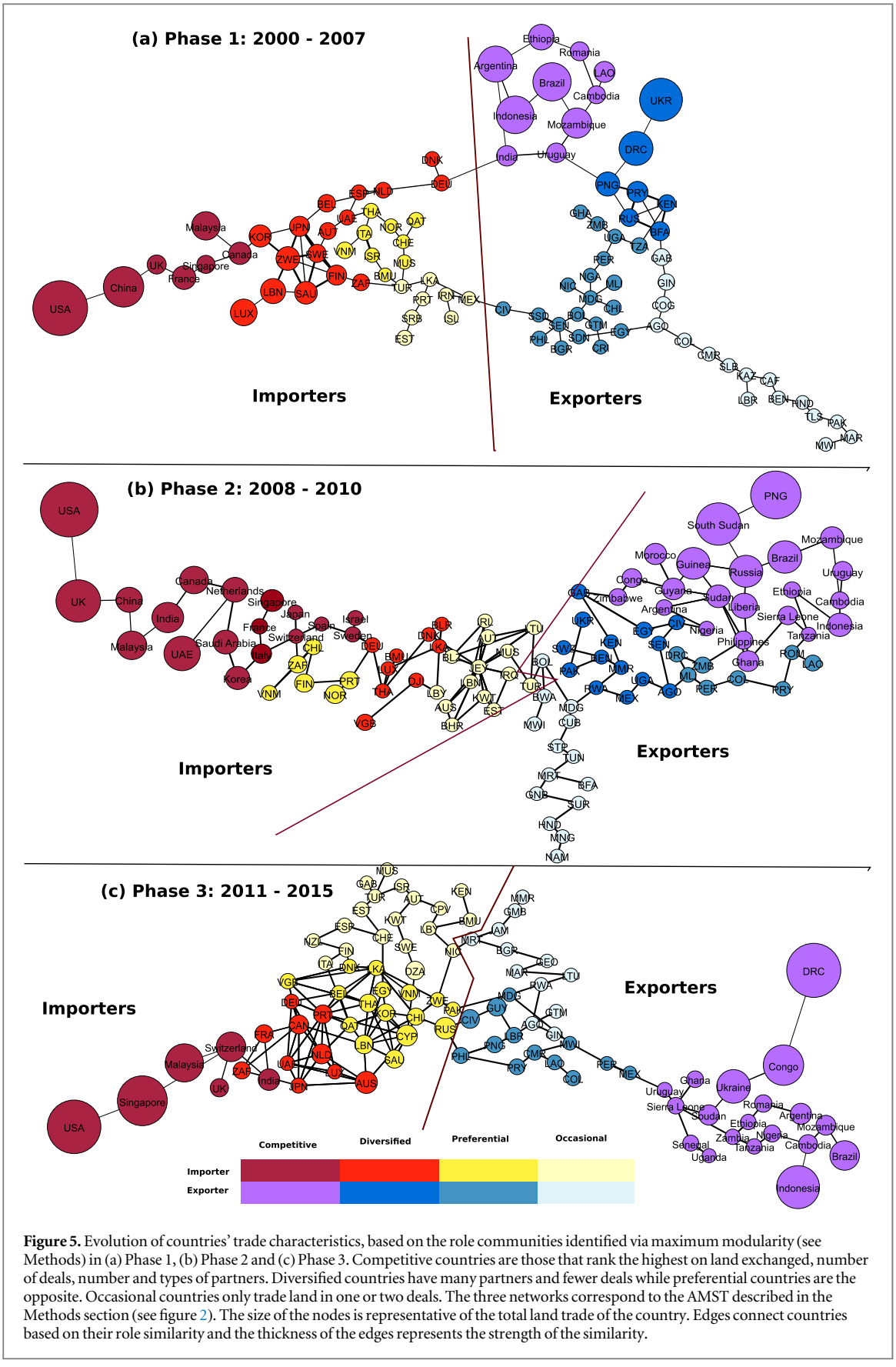

Figure 5. Evolution of countries' trade characteristics, based on the role communities identified via maximum modularity (see Methods) in (a) Phase 1, (b) Phase 2 and (c) Phase 3. Competitive countries are those that rank the highest on land exchanged, number of deals, number and types of partners. Diversified countries have many partners and fewer deals while preferential countries are the opposite. Occasional countries only trade land in one or two deals. The three networks correspond to the AMST described in the Methods section (see figure 2). The size of the nodes is representative of the total land trade of the country. Edges connect countries based on their role similarity and the thickness of the edges represents the strength of the similarity.

facilitated by already existing trade agreements, whether they be regional or preferential at the WTO (WTO 2016). However, this hypothesis deserves further investigation.

To identify country roles in the LTN, we went beyond ranking countries based on number of partners or total amount of land exchange to analyze how their overall trading characteristics changed between

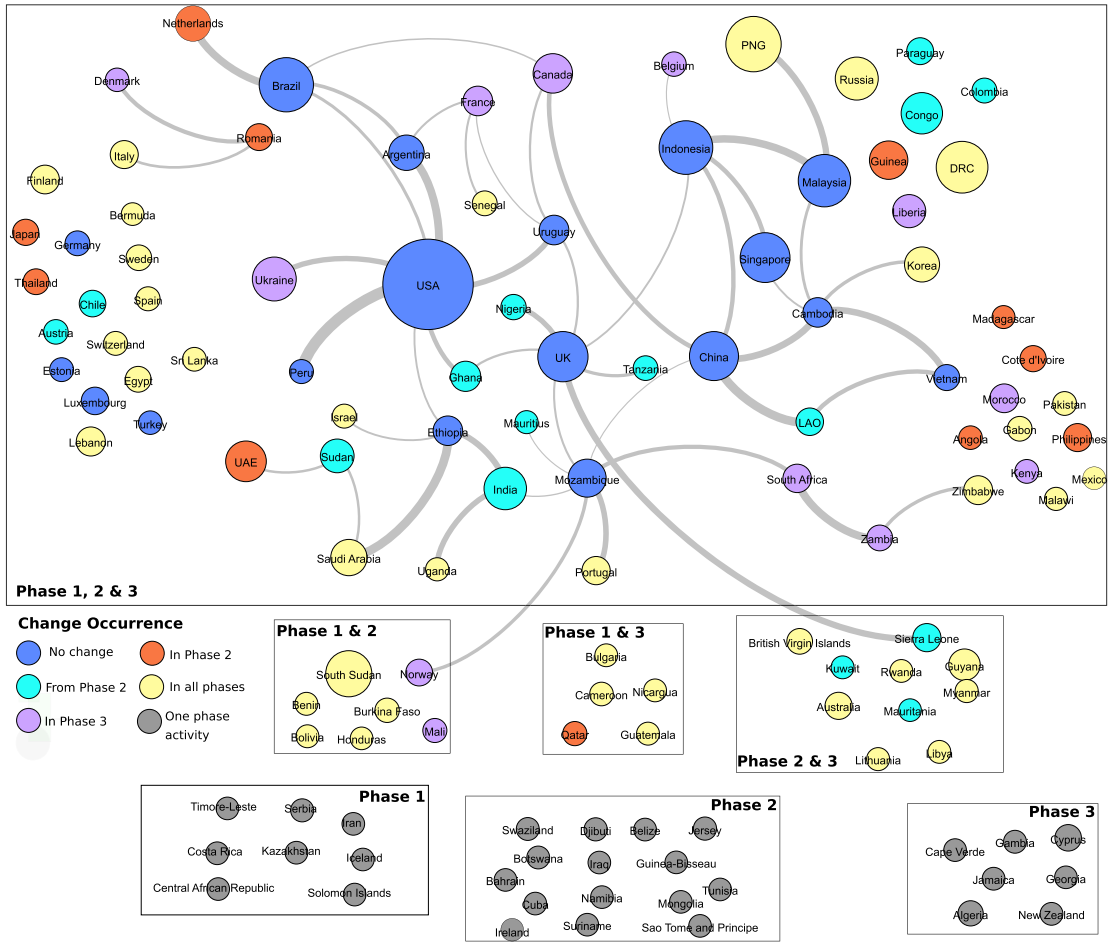

Figure 6. Summary of role changes in the land trade network. Countries are grouped by phase of activity. Node size is proportional to the total amount of land exchanged; color indicates during which phase a change in countries' role occurs (e.g. 'In Phase 2' means that a country had the same role in phases 1 and 3 but not in Phase 2 while 'From Phase 2' means that a country had one role in Phase 1 and a different one in Phase 2 which remained the same in Phase 3). Lines denote partnerships of more than 4 years between countries, and thickness represents the duration of the partnerships.

competitive, preferential, diversified and occasional importers or exporters (figure 5). We found that the USA, UK, China, Singapore and Malaysia were competitive importers across 2000–2015, while Ethiopia, Brazil, Mozambique, Argentina, Uruguay, Indonesia and Cambodia were competitive exporters (figures 5 and 6). Furthermore, previous analyses have often focused on the activity of a small group of countries while our more holistic community detection approach identified a larger core of 73 countries actively trading land during all three phases (figure 6). Other countries were more dynamic in their role, including many countries that changed roles from phase to phase (figures 5 and 6).

Finally, we have for the first time presented a global account of the different economic sectors interested in land as well as their intended use for it. We found that over time, agriculture was always the dominant intended land use but we also noted an increase in the proportion of land dedicated to biofuels, forests and conservation in Phase 2 especially, but also in Phase 3. We also highlighted the growing interest in land by new actors including industry, services and NGOs after the crisis (figure 7).

Overall, our analysis supports the importance of looking at the three phases we have identified when studying global or regional land acquisitions to draw more accurate conclusions. Following our approach to explore changes in trade relationships, actors involved at country and investor levels, and in investment interests over time may also help address some of the critiques to previous quantitative evaluations of LSLA at global level that are considered too simplistic and sometimes inaccurate (Oya 2013, Scoones *et al* 2013, Zoomers *et al* 2016).

What drove the three phases of large-scale land acquisitions?

Our analysis of observed patterns of land trade, and our observation of its three distinct phases from 2000–2015, cannot explain why these patterns occurred. However, here we will propose a coherent interpretation for global trends by filling the gap between our empirical analysis and more theoretical

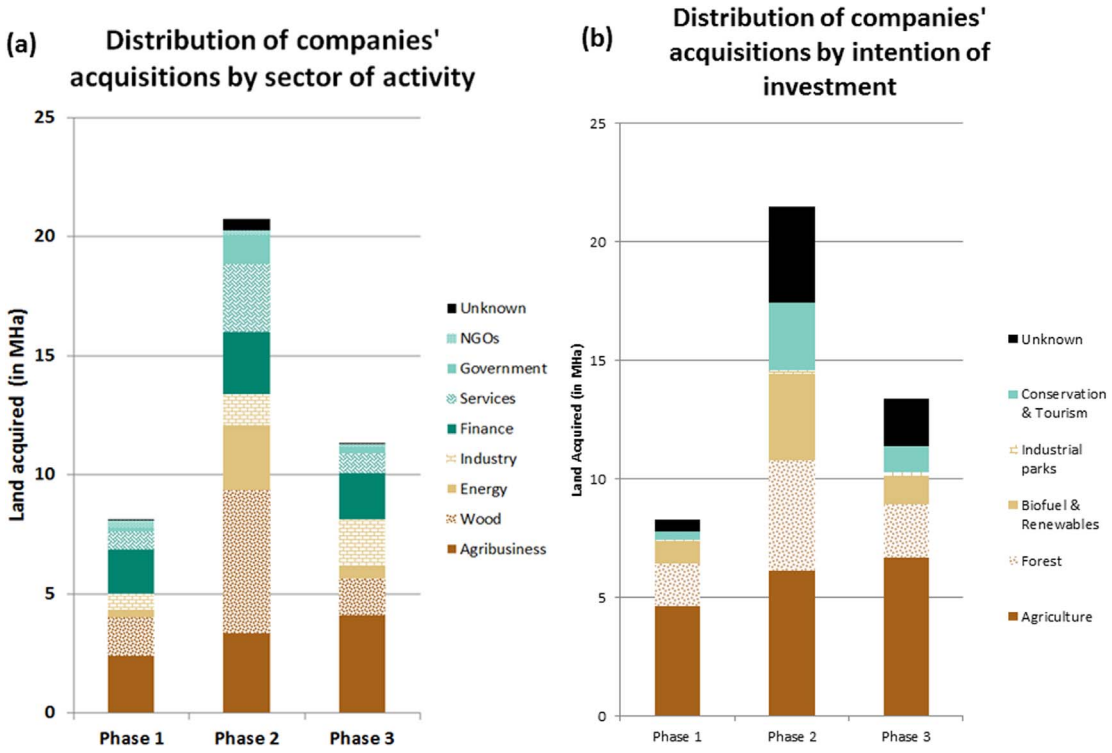

Figure 7. Distribution of companies' acquisitions (total amount of land acquired) by (a) sector of activity (classified from the internet searches) and (b) intention of investment (reported by the Land Matrix).

studies. Our interpretations still need to be more rigorously tested in future research.

We hypothesize that the interest in land in Phase 1 can be attributed to changes in corporate structures and mounting globalization and competition in the early 2000s following the global wave of privatization, free market integration and adjustment policies in different sectors during the 1980s and 1990s (Zoomers 2010, Lay and Nolte 2018). New business models such as product diversification, outsourcing schemes, and vertical integration of supply chains were adopted by increasingly larger transnational corporations especially in the agro-food industry (Friedmann 2005, Gereffi *et al* 2005, Gibbon *et al* 2008, Reardon *et al* 2009, De Schutter 2011a, Anseeuw *et al* 2017). These trends were further reinforced by the rise of financialization of natural resources. For example, food products became subject to commodity swap contracts for derivative agricultural markets (Burch and Lawrence 2009, Clapp and Helleiner 2010, Anseeuw *et al* 2017); flex crops (e.g. biofuels produced from food crops) provided new speculation havens for commodity traders (Sorda *et al* 2010, Borras *et al* 2014, Hertel 2017, Genoud 2018); and forest products were financialized through payment for ecosystem services and carbon sequestrations schemes, and used as assets in a new carbon market (Fairhead *et al* 2015, Hertel 2017, Conigliani *et al* 2018, Mehrabi *et al* 2018).

The food and financial crisis in Phase 2 may have driven increases in land investment for food production (e.g. governments concerned with their own food and energy security such as Japan, Korea and the Gulf countries), as well as encouraged new actors to enter the LTN such as the services sector and other industries (figure 7), who may perceive land as a more secure asset than financial markets (Friis and Reenberg 2010, Zoomers 2010, Arezki *et al* 2011, De Schutter 2011b). The financial crisis may have pushed many of the poorer countries into competition for attracting foreign investments, as these are perceived as a major road to development (World Bank 2007, Cotula *et al* 2009, Deininger 2011, Karlsson 2014).

We speculate that the strong decline in land trading seen in Phase 3 may be due to the decreased urgency of hedging funds in land after the financial crisis, as well as increasing concerns about the risks of large-scale land acquisitions. Since 2010, there is increasing research documenting unsustainable practices arising from LSLA, such as deforestation, land and water degradation, as well as displacement and marginalization of rural labor (Li 2011, Rulli *et al* 2012, Clements and Fernandes 2013). The heavy publicity of the land rush during Phase 2, together with increasing civil society awareness, helped lead international organizations including the UNCTAD, IFAD, FAO and World Bank to develop the Principles for Responsible Agricultural Investments in 2010 (Deininger *et al* 2010) which were formally adopted in 2014. These Principles include contributing to food security and nutrition, to economic development and poverty alleviation, and respecting land tenure (Committee on World Food Security 2014). Furthermore, due to

massive protests, that resulted for example in the government overthrow in Madagascar after the failed Daewoo Logistics deal (Ratsialonana *et al* 2011), many exporting countries have reconsidered their strategies such as the government of Papua New Guinea that finally revoked and declared special land leases illegal in early 2017 (COI SABL 2013, Orere 2017). Thus, there is both less incentive for investing countries to acquire land, and more resistance in exporting countries to participate in the LTN. This however does not mean that land is not being acquired anymore but rather that the number and size of deals shrank considerably. Moreover, Nolte *et al* (2016) attribute this decline to a potential time lag in deal reporting and further emphasize that more deals have moved to a production stage from the end of Phase 2, and more so during Phase 3.

Uncertainties and limitations

Although we used data from the LM, which represents significant effort into verifying the reliability of the information on deals reported (Anseeuw *et al* 2013, Nolte *et al* 2016), there is uncertainty related to global studies of LSLA due to limitations on the comprehensiveness of the data. To draw the strongest possible conclusions, we studied only deals that were concluded (not failed) and contracted (not intended); we may therefore have missed some deals that did go ahead but were not reported. We also only considered deals that have at least one foreign investor, so we do not capture purely domestic LSLA that are more present in Latin America for example.

Our choice to consider total rather than proportional amount of land exchanged may emphasize larger exporting countries (figures 4 and 5), but was necessary to maintain consistency between in- and out-strength. We tested this difference and found its effect to be very small on our classification, with a few exceptions (figure S7). Finally, as the maximum modularity method used to partition countries according to their role does not always detect a sharp separation among groups, there might be exceptions for each grouping of countries, i.e. the classification of some minor country in one group or another could be uncertain.

Finally, even though transnational LSLA are mostly enacted by companies rather than governments, we nevertheless aggregated the investors by country of origin. This was done in an effort to maintain symmetry between the nodes in the network. While a network analysis of companies could provide valuable insights into LSLA, it would not have yielded significant results in the community analysis as very few companies engage in more than one deal. Instead we have presented the activity of different actors (by sector of activity of investors) across the different phases and highlighted the rise of financial entities during the crisis period and the emergence of the services sector in Phase 3.

Conclusion

We have shown that LSLA preceded the food and financial crises, and that they have continued afterwards, thus contradicting the basic assumption that LSLA is a response to the crisis of 2008 and demonstrating the importance of analyzing time periods of the land trade phenomenon. We identified 73 countries actively trading land during the entire period, 11 of which remained the most competitive importers and exporters while the others changed trading strategies. We hope future research will investigate these roles in exploring the drivers and consequences of LSLA. Finally, in exploring the dynamics of the actors involved in LSLA and the intended use of the land throughout time, we contextualized the evolution of LSLA within broader changes in global economics and argued that land investments form a new way of doing business that is widespread across industries. As such, we believe that existing voluntary guidelines over the unsustainability of LSLA do not go far enough to ensure that land deals provide benefits for the local people and places where they occur. We have shown that LSLA appear to now be fully embedded across economic sectors, implying it is not only direct land transactions that need monitoring, but also financial investments in the agriculture, energy, forestry, and conservation sectors that may be targeted for acquiring land.

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