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DISCUSSION PAPER

Financial dimensions of global zoonotic disease risks

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Financial dimensions of global zoonotic disease risks

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Abstract

Emerging and re-emerging infectious diseases with pandemic potential (EID) such as COVID-19 and avian influenza, pose serious threats to human health and wellbeing all over the world. The emergence and re-emergence of zoonotic diseases are affected by a number of interacting social, environmental and ecological changes. The financial sector plays an important, yet often ignored role as owners and investors in industries linked to anthropogenic changes in ecosystems associated with increased zoonotic disease risks. This discussion paper explores the connections between financial institutions, their investments through equity, and increased zoonotic disease risks in nine selected regional case studies in the world. Our analysis includes 54 companies operating in sectors associated with EID risks in the selected regions, with over 3,290 associated Global Universal Owners. Our results shows that U.S. based asset managers (Vanguard, State Street, BlackRock and T. Rowe Price) are the largest owners in terms of total equity size with ownership volumes ranging from $0,5 to $2 billion USD. The specific patterns of cross-national ownership however, depend on the case study region of interest, thus making not only global but also regional investors central. Our network analysis of company and investor headquarters show that the governments of Norway and France are particularly influential. North America, and European countries together with China, Australia, Argentina and Brazil form the largest community in the global investor and corporate network.

1. Introduction

Zoonotic diseases are on top of global agendas due to the COVID-19 pandemic. The impacts of emerging and re-emerging infectious diseases (EID) such as Ebola, SARS, MERS, H1N1, and COVID-19 on human health and societies can be devastating as these propagate through trade connections, travel networks, and fragile health systems and communities. There is an increased recognition that various forms of environmental and ecological changes – including deforestation, the expansion of agricultural land, and increased hunting and trading of wildlife – can be linked to their emergence and re-emergence (Alimi et al., 2021; UNEP and ILRI 2020; Di Marco et al., 2020; Allen et al., 2017). Zoonotic disease risks are also likely to increase substantially in the near future due to climate and land-use change (Carlson et al., 2022).

The causal links between social-ecological change and increased EID-risks is highly complex and the result of both evolutionary pressures and anthropogenic changes (Jørgensen et al., 2020). Many of the anthropogenic environmental and ecological changes that affect EID risks, can however be connected to specific economic activities that drive or contribute to such changes. For example, the production of certain types of commodities associated with high deforestation risks, may result to increased zoonotic spill-over through the loss of biodiversity, land fragmentation and habitat loss (e.g. Morand and Lajaunie, 2021). Economic activities that influence such EID risks are not only part of global commodity markets for consumption, but also dependent on financial investments (such as loans, bonds and equity) for their operations. The financial and economic impacts of the latest COVID-19 pandemic can to some extent be seen as one example of the many possible secondary or domino-effects as financial investments and their impacts on ecosystems, feedback on the economy (Sanchez et al., 2022).

To what extent changing EID risks can be understood and mitigated by analyzing the influence financial institutions (such as asset managers, banks and pension funds) have through their investments, has yet to be explored in detail however. As we elaborate here, such financial influence could be viewed as an important contribution to the broader planetary health agenda (Whitmee et al., 2015) as it offers insights into the indirect drivers of EID risks, as well as some possible leverage points for change. Here we ask:

a) How is the financial sector causally linked to changing EID risks globally?
b) Which financial institutions could be said to have influence over changes in such risks?
c) In what ways could this influence be leveraged to help reduce EID risks?

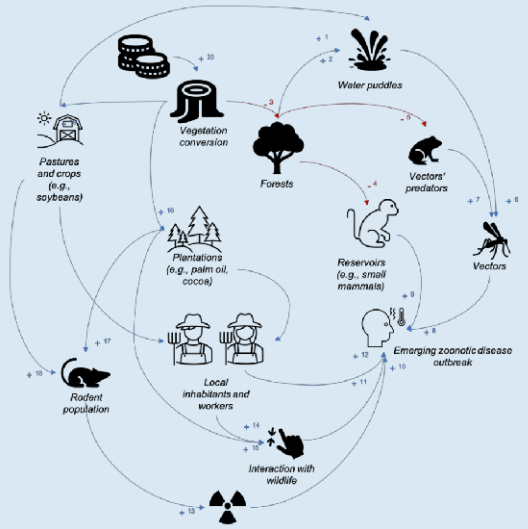
2. Exploring the connection between the financial sector and global zoonotic disease risks

The expansion of international commodity trade contributes to anthropogenic land use change, such as deforestation and habitat fragmentation, all over the world, (Meyfroidt et al., 2022; Hoang and Kanemoto, 2021; Green et al., 2019). Today's globalized economy and the companies that are central to this trade, relies heavily on both public and private to fund their operations often with notable environmental, ecological and social impacts (Dempsey et al., 2021; Crona et al., 2021; Galaz et al., 2018a; Galaz et al., 2018b). Financial institutions such as banks, pension

funds and asset managers act as owners through their ownership of stocks (equity), and can also provide additional investments needed by companies that operate in sectors associated with agricultural intensification, deforestation, habitat loss, land fragmentation and other forms of land use change (Yang et al., 2021; Galaz et al., 2018b). As a result, financial investments and institutions hence also indirectly affect EID risks by funding and benefitting from activities that create new patterns of interactions between pathogens, non-human animals, and humans (e.g. Morand and Lajaunie, 2021). Box 1 illustrates the connection between financial investments, extractive economic activities, and modified zoonotic disease risks in more detail (references can be found in the Supporting Information).

Box 1. Outbreak mechanism of emergent and re-emergent infectious zoonotic diseases (EIZD)

Financial institutions fund economic activities that alter the climate system and the biosphere (Jouffray et al. 2019), driving land-use conversion of key biomes such as the Boreal and Amazon forests (Galaz et al. 2018). Landscape conversion to plantations and pastures generally leads to the loss of the regulating service water retention. As more still water ponds and puddles are generated, they become mosquito breeding sites, increasing vector abundance, and increasing the risk of vector-borne diseases like malaria and Leishmaniasis (Austin et al., 2017; Patz et al., 2000; Sileshi et al., 2007). Agriculture has also been shown to increase the availability of for example ponds or irrigation systems, which function as breeding sites for vectors (Austin et al., 2017; Phillipo et al., 2018). On the other hand, less forest coverage will lead to the increase of mosquito breeding sites and less natural enemies that keep mosquitos' populations under control, thus increasing the risk of vector-borne disease outbreaks (Austin et al., 2017; Montira J. Pongsiri et al., 2009; Mull et al., 2020; Patz et al., 2000). Similarly, higher degrees of land transformation increase human population by settling of local inhabitants, and migration of workers. A growing population in frontier areas increases the chances of people interacting with wildlife (Mull et al., 2020; Riccò et al., 2021). This, together with a decreasing number of natural reservoirs (e.g., small mammals), due to forest conversion into productive landscapes, increases the risk of emergence and re-emergence of zoonotic diseases such as Lyme disease, Babesiosis and tick-borne encephalitis virus in plantations, crops, and pastures (Brito et al., 2020; Ferreira et al., 2016; Rulli et al., 2017). Conversion of natural landscapes to areas of pastures and cultivation such as maize, rice, sugar cane and soybeans propitiate maintenance of rodent populations and rodents' breeding sites (Brito et al., 2020; Mull et al., 2020), which in turn increases the rodent zoonotic disease spread through inhalation of infected aerosols particles stemming from the rodents' urine, feces, or saliva (e.g., hantaviruses) (Mull et al., 2020; Riccò et al., 2021).



1. (Austin et al. 2017, Phillipo et al, 2018)
2. (Austin et al. 2017, Patz et al. 2000, Sileshi et al. 2007)
3. (Ordway et al. 2017)
4. (Austin et al. 2017, Brito et al. 2020, Ferreira et al. 2021., Mohd et al. 2016, Rulli et al. 2017)
5. (Montira et al. 2009)
6. (Austin et al. 2017, Patz et al, 2000, Phillipo et al, 2018)
7. (Montira et al. 2009)
8. (Morand and Lajaunie 2021)
9. (Ferreira et al. 2021, Brito et al. 2020, Rulli et al. 2017)
10. (Ricco et al. 2015, Morand and Lajaunie 2021, Mull et al. 2020)
11. (Ricco et al. 2015, Mull et al. 2020)
12. (Joergenson and Burns 2007, WHO 2015)
13. (Morand and Lajaunie 2021)
14. (Ricco et al. 2015, Mull et al. 2020)
15. (Falco et al. 2008, Kanhima et al. 2020, Yang et al. 2021, Gritsun et al. 2013, Mrazljak et al. 2021)
16. (Curtis et al. 2018, Harris et al. 2015, Global Forest Watch 2020)
17. (Ricco et al. 2015, Mull et al. 2020)
18. (Mull et al. 2020, Brito et al. 2020)
19. (Graesser et al. 2015, Sy et al. 2015, Armenteras et al. 2017)
20. (Jouffray et al. 2019, Galaz et al. 2018)

2. Understanding financial influence

Investments through equity, loans and bonds also provide pathways for investors to influence the policies and actions of companies. Financial institutions such as pension funds for example, engage in direct dialogues with corporate management, use their voting influence at corporate annual general meetings, and sometimes even threaten to divest as a way to influence issues that are in their interests as investors and owners (Golland et al., 2022). Such active engagements have become increasingly common in the last years on climate issues and sustainability in general (Galaz and Collste, 2022; Azar et al., 2021) and can have considerable "down-stream" effects in cases where large companies choose to use their dominating market position and globally spanning supply chains to advance a suite of sustainability ambitions (Folke et al., 2019; Österblom et al., 2022).

Financial influence through active investor engagements with centrally placed companies, could thus potentially offer a complement to attempts by national governments and international organizations to implement strategies that help reduce zoonotic pandemic risks (e.g. Bernstein et al., 2022; Dobson et al., 2020). Leveraging such financial influence however, requires empirical assessments of where in the world and which with companies such influence is at all possible. The next sections present such an assessment.

3. Mapping global financial influence

Our methodological approach builds on four steps (c.f. Galaz et al., 2018b). In the first step, we select a number of case study regions in the world with documented EID risks, and where there is clear evidence of connections between anthropogenic land use change and the emergence of EID risks (n=9 case study regions). In the second step, we identify the economic sectors associated with these anthropogenic changes, as well as the companies operating in these identified sectors. In the third step, we analyze the ownership structure of all publicly listed companies. Lastly, we analyze to what extent this ownership can be translated into financial influence. We make such an assessment at both the global, and the regional level. Methodological details can be found in the next sections, and in the Supporting Information.

Anthropogenic land-use change, corporations and zoonotic disease risks

The analysis of the geographical distribution of EID risks and their connections to anthropogenic changes and especially land use change, has become increasingly sophisticated in the last decade (e.g., Jones et al., 2008; Jones et al., 2013; Allen et al., 2017; Carlson et al., 2022). Allen and colleagues (2017) identified a series of regions in the world where EID risks are prominent. Anthropogenic land-use changes in these geographical areas are linked to specific economic sectors, often through the production of commodities such as pulp and wood products, soy, cocoa and cattle (Supporting Information, Table 2).

Based on existing data and literature, we identify a total of 227 companies (of which n=101 are publicly listed) operating in these sectors and regions. However, only 54 of these companies were assessed as relevant for the analysis for the chosen case study regions (see Supporting Information SI Table 4-6, details about methodology can be also be found in Supporting Information). Figure 1 summarizes our results and shows zoonotic disease risk regions, commodity production practices associated with such risks, and the number of identified public and private companies. Note that these economic sectors are one of many interacting anthropogenic forces in the specific case study regions.

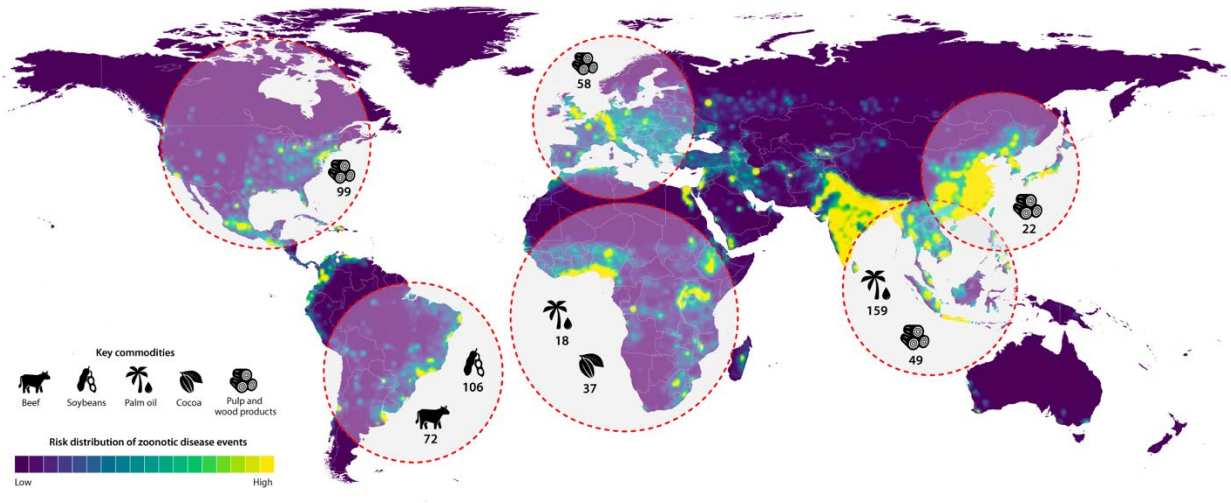


Figure 1. Zoonotic disease hotspots, commodities and companies | The figure shows the nine regional case studies associated with the production of five commodities, in six different regions of the world. Numbers indicate both public and private companies of interest for our analysis. The selection of regions only includes regions where there is documented evidence of a connection between anthropogenic land-use change, commodity production and zoonotic disease risks. Details about countries, commodities and companies can be found in the Supporting Information, Section 1-3. Map based on Allen et al., (2017).

Analyzing Financial Influence

We focus on equity (stock ownership) as a way to explore financial influence in the identified publicly listed companies. Equity data has been extracted from Orbis, and includes ownership data from April 12-15, 2021 (see Section 4 in Supporting Information). We conduct and present the analysis both at an aggregated global level, and for each of the nine individual selected case study regions.

We assess financial influence through three approaches. First, we analyze the top owners amongst financial institutions based on the number of companies where these have equity (Figure 2A), and the monetary size of their portfolio in all case study regions (Figure 2B). We also present a simple descriptive mapping of transboundary connections between investors and selected companies based on the size of their investments (Figure 3).

These values however, only offer limited insights into influence since company sizes and ownership structures can differ substantially between regions and industries, thus making cross-case comparisons challenging. We therefore also construct bipartite networks (using a community detection algorithm, Pons and Latapy, 2006) between shareholders and companies, as well as the national jurisdictions where they operate as a means to assess the potential for alliances with large influence depending on their positions in the network. We also create an exponential random graph model to study the governance features of countries hosting companies and shareholders. All methodological details can be found in the Supporting Information.

4. Results

Our results show that U.S.-based financial institutions are in a dominating position, both in terms of ownership in the total number of companies (2A) and the total economic value of that ownership (2B). Four financial institutions (Dimensional, Vanguard, BlackRock, and the Government of Norway) have ownership in at least 40 companies in total, and in three of the case study regions (North America, East Asia and Europe).

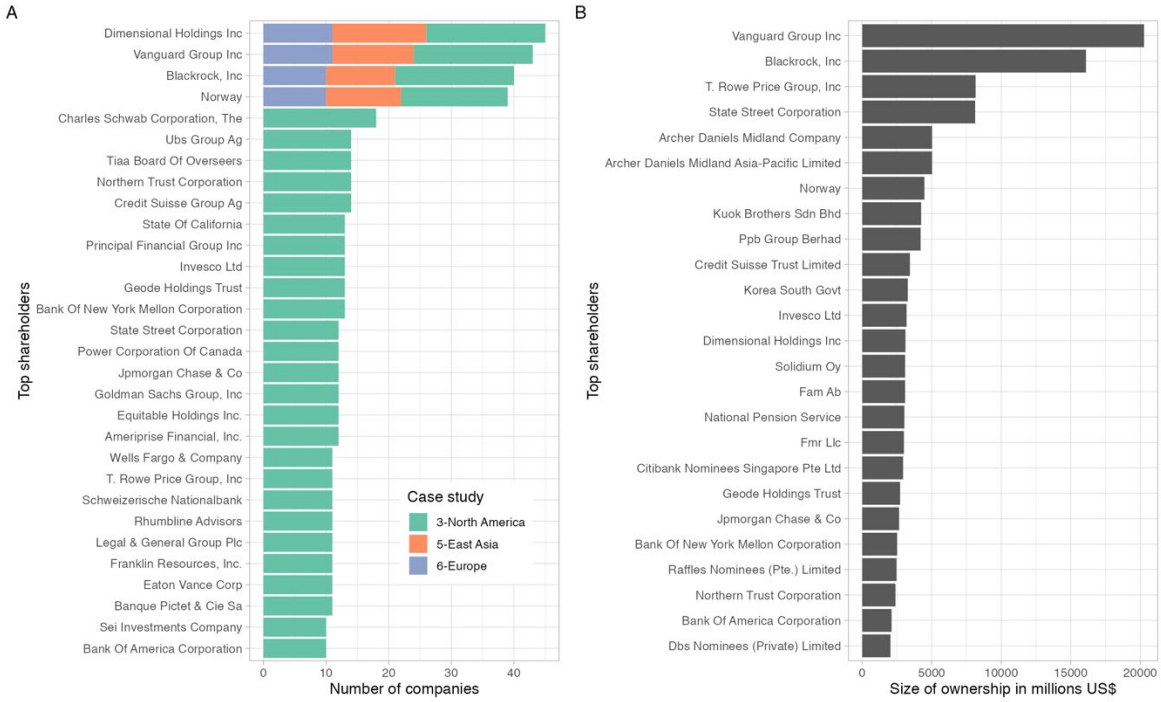


Figure 2. Top shareholders in case study regions. | **(A)** Top shareholders based on total number of ownership positions in selected companies | Data includes all financial institutions with ownership in >10 companies. This threshold result in the exclusion of six case study regions in sub-Saharan Africa, South East Asia, and South America. Color codes show regions with known connections between anthropogenic land-use change and zoonotic disease risks. **(B)** Top 25 shareholders ranked according to total equity value. See Supporting Information for methods and data.

Large U.S. based asset managers (Vanguard, State Street, BlackRock and T. Rowe Price) are the largest owners in terms of total equity size with ownership volumes ranging from $0,5 to $2 billion USD (Figure 2B). This dominant ownership is consistent with previous studies which also show the globally spanning financial influence of the so-called “Big Three” asset managers (Vanguard, State Street, BlackRock) have on fossil fuel companies and other extractive industries (Galaz and Collste, 2022; Azar et al., 2021; Galaz et al., 2018b).

The ownership structure of companies in sectors that affect zoonotic disease risks is highly globalized, but the specific patterns of cross-national ownership depend on the case study region of interest (Figure 3). For example, the importance of investors from Asia and countries like Japan is more prominent in case study regions South East Asia compared to Africa and South America. Hence, while there are a set of dominating global financial institutions, regional

investors still play a key role in each individual case study region (see also Supporting Information, Figure SI1).

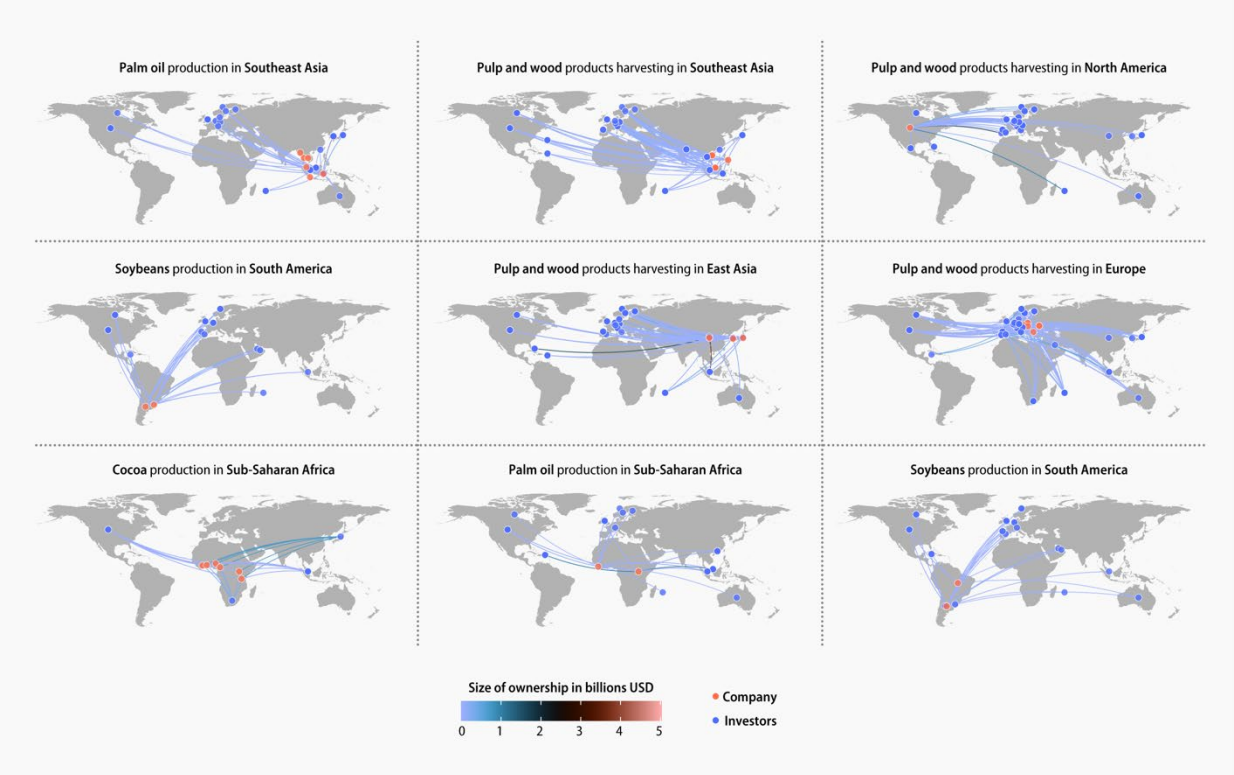


Figure 3. Global connection of investments through equity | Financial investments shape our living planet, and indirectly also zoonotic disease risks through investments in industries associated with various forms of land-use change in known zoonotic disease hot-spots. The figure shows the global characteristics of such investments in nine identified hotspots, as well as the respective investment size through equity in USD. Purple nodes are where companies and investors overlap geographically. Note that the figure is a simplified data-based illustration. See Supporting Information (Section 5 and 6) for methods and data.

Assessing financial influence - global financial networks and blockholder influence

Supply chains and the financial sector operate in a highly globalized society. The economic sectors, associated commodities and financial investments included in this study show the central role of financial institutions based in Europe and North America in sectors associated with global EID risks. While the prevention of zoonotic disease risks requires global cooperation, progress in mitigating global risks can also be made through strategic alliances between a smaller subset of countries (Victor, 2011), and through other centrally placed corporations and private sector actors (Folke et al., 2019; Österblom et al., 2022). Such "clubs" may help forge and implement policies with global effects (e.g. Aakre et al., 2017).

A sizable investment in a company does as a result not translate directly into influence on corporate policies and activities. The tentative influence in corporate operations is also affected by the position of economic agents (like investors) in larger networks where companies and

investors connect to each other, at times placing some of these agents in more central and influential positions through their network position (e.g. Vitali et al., 2011). Here we conduct a network analysis to assess global financial influence as it is determined by the network position of investors. Investors are connected if they invest in the same companies included in our analysis. Two standard network metrics, degree (Figure 4C) and betweenness (Figure 4D), measure the centrality of investors through their network position.

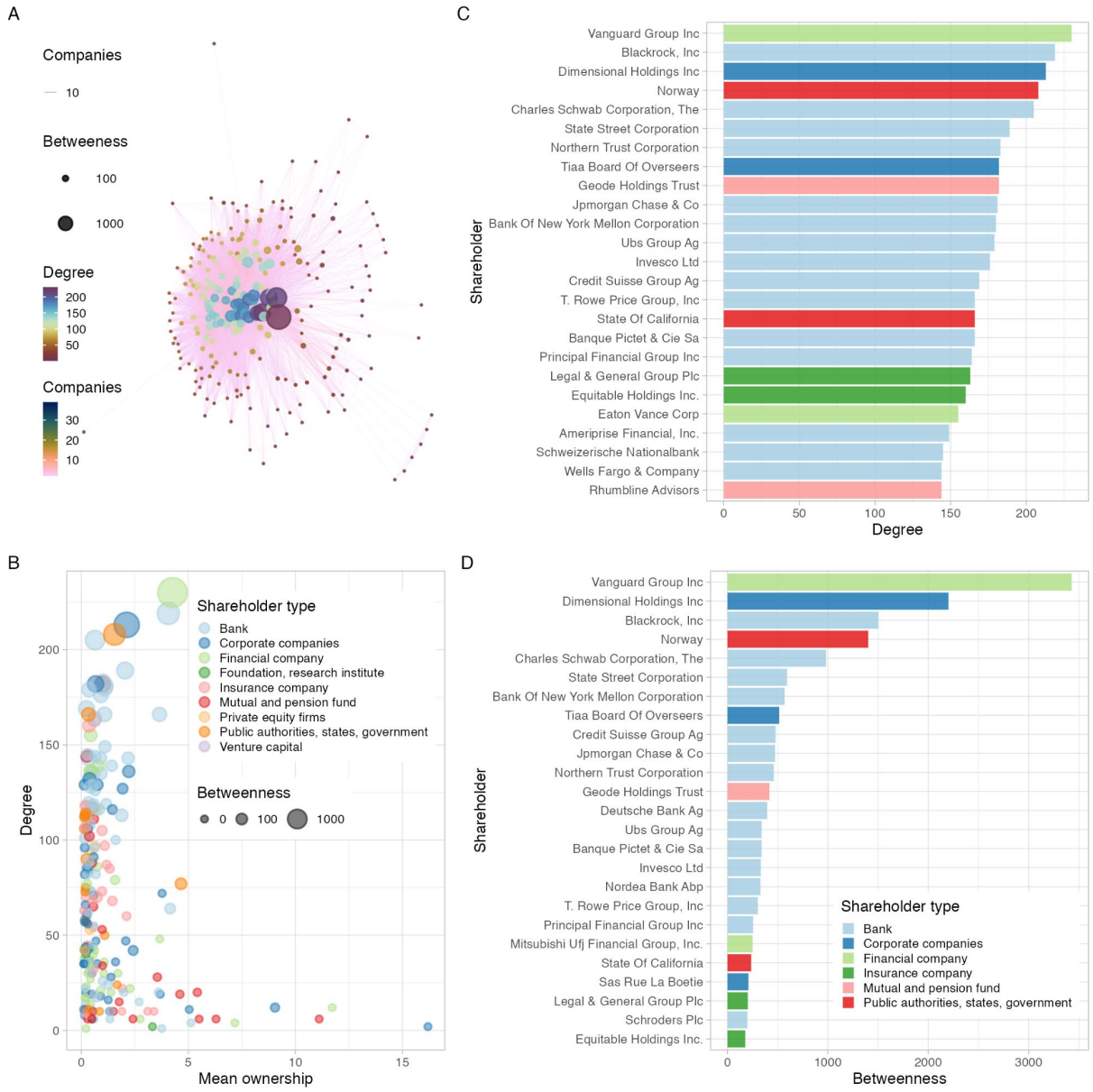


Figure 4. Global shareholder network | Investors are linked if they invest in the same companies (A). 28.4% of all possible links are realized, most links represent common investments in less than 10 companies, yet a few links between central shareholders represent common investments in over 30 companies out of the 54 analyzed in the dataset. Metrics of centrality (degree in C and betweeness in D) are not necessarily correlated with the mean ownership of companies (B), in fact most central nodes have a mean ownership of less than 5% meaning less financial influence in the companies of interest.

The most common shareholder type among the core of the network are banks, followed by financial companies and insurance companies (Figure 4C and D). Public financiers such as the State of California and Norway, are important investors in this global network as well. While most shareholders have shared investments in less than 10 companies in total, a core of 3 shareholders invest in up to 39 out of the 54 selected companies (Figure 4C and D). It should be noted that these highly connected investors (with high centrality) is not the result of high levels of mean ownership of these companies (Figure 4B). This indicates that shareholders with large ownership shares tend to invest in only a few companies (Fig 4B).

Shareholders with less than 5% ownership cannot be assumed to have strong decision power on the companies they have invested in (Edmans and Holderness, 2017). However, investors connected to many companies can however still influence companies to develop policies that mitigate EID risks. Two of the "Big Three" asset managers (Vanguard and BlackRock) and Norway are from such a network perspective, a notable group of influential investors with both high degree distribution (Figure 4C) and betweenness centrality (Figure 4D).

Identifying influential country alliances

Countries, and their respective governments, are the most central agents in international collective action, including in global health governance (Heymann, 2010). The countries where central companies, or where investors are headquartered hence also provide opportunities for the use of financial influence to help mitigate EID risks. Legislation and other forms of regulations could for example, require institutional investors like pension funds to invest or engage in ways that minimize EID risks.

Our analysis of company and investor headquarters show that the governments of Norway and France share many of the identified investors and companies operating in our cases study areas. North America, and European countries together with China, Australia, Argentina and Brazil form the largest community (Fig 5A). This means that international cooperation between these countries on issues related to investor influence and EID risks, could create additional opportunities to help reduce EID risks at the global level. A similar, but more globalized pattern is found for the network of countries connected by shared companies (Supporting Information, Fig SI2).

There is a clear Global North and South dimension in these connections. Our analysis shows that links (i.e. investments) typically occur from countries with high governance effectiveness (i.e. a known indicator of "good governance" as measured by the World Bank), to countries with lower political stability and regulatory quality. To what extent these large differences in governance capacity between countries that host investors, and those that host corporate actors will affect the possibilities to effectively leverage financial influence due to the lack of transparency and limited ability to enforce new regulations (as has been experienced for extractive industries like mining for example, see Gustafsson et al., 2022; Innis and Kunz, 2020) is worth further investigation.

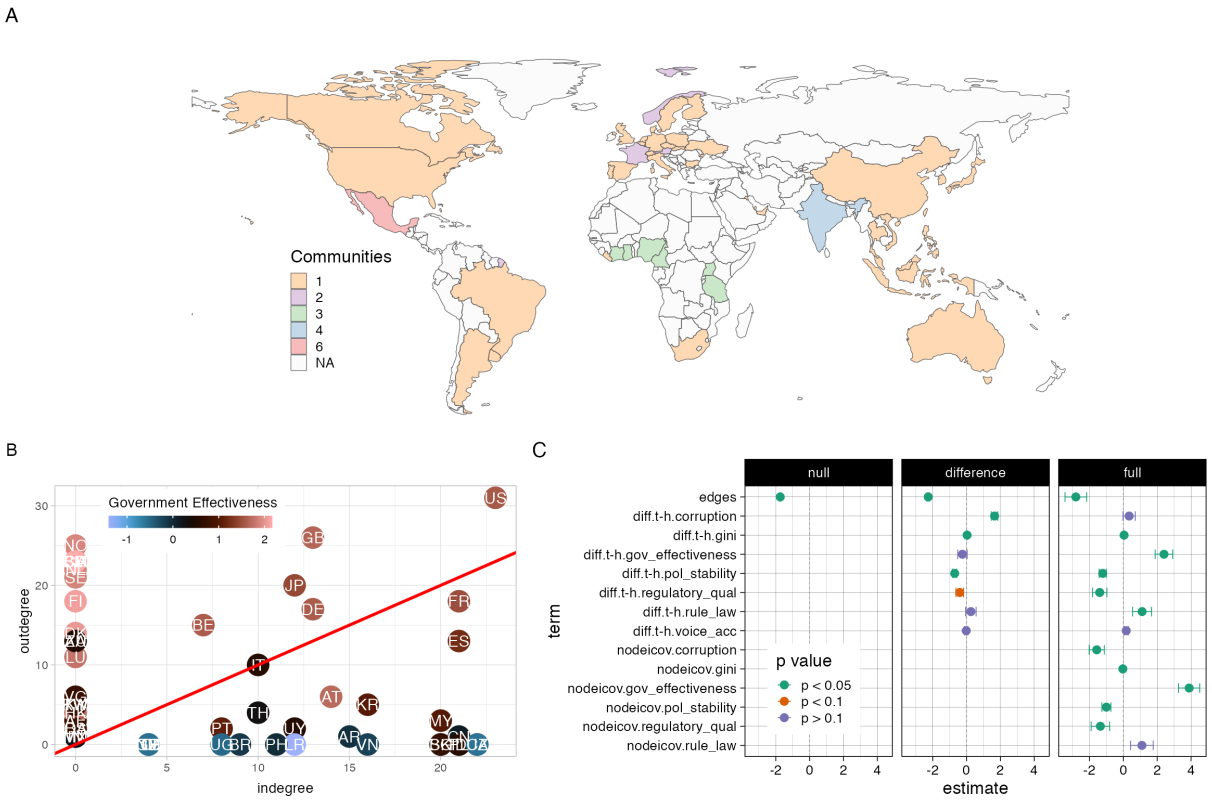


Figure 5. Communities of countries with common shareholders | The network of shareholders (Figure 4A) can be projected in terms of the countries where they operate. A community detection algorithm identifies groups of countries with common shareholders (A). A link between two countries is more likely to occur where there is a mismatch in governance effectiveness (B-C), lower political stability and regulatory quality. The same statistical trends are found on the network of countries given shared companies across cases (Supporting Information, Fig SI2).

5. Discussion

On January 20th 2022, the International Monetary Fund raised its forecast for the economic costs of COVID-19 pandemic on the global economy to $12.5 trillion through 2024 (Reuters, 2022). These numbers show the large economic impacts and material financial risks created by emerging and re-emerging diseases, and the need to address such diseases proactively. Our analysis here has focused on the way the financial sector could be viewed as contributing to such risks through their investments in sectors linked to anthropogenic land uses change in regions where EID risks have been assessed to be high by previous research.

Our results offer a number of insights. First, it shows globalized nature of investments which modify EID risks different parts of the world. The specifics differ between the selected case study regions, but show consistently the large role (and potential influence) U.S.-based asset managers have through their ownership. Such influence can in principle, be mobilized through investor engagements that support corporate action in ways that reduce EID risks.

Second, such engagements are already taking place for policies of major companies related to climate change (e.g. Azar et al., 2021), but have yet to materialize for EID risks linked to anthropogenic land uses change. Such active engagements offer a potentially fruitful way to complement other strategies and policies developed by governments and IOs (e.g. Dobson et al., 2020) by also engaging with the corporate sector through investor influence. Our analysis offers clear indications of which corporate actors and financial institutions to engage with in this endeavor.

Third, our analysis also shows some of the limitations of leveraging financial influence in some regions of the world. Financial influence is diffused in EID risk associated economic sectors in Africa, South East Asia and South America. These results indicate a wider diffusion of ownership which lessens the potential for financial influence through engagements by (and with) a few centrally placed financial institutions. A similar pattern was found by (Jouffray et al., 2019) for marine resources, where they instead propose alternative financial leverages like the development of banking principles, requirements by stock exchanges via their listing rules, and through more active engagements by insurance companies. Such pathways for financial influence could prove important in the case of EID risk as well.

There are a number of limitations to this study as well. Anthropogenic land use change is only one of the many complex interacting drivers that shape EID-risks in the selected case study regions, thus limiting the influence of corporate and financial actions. In addition, the identification of investor influence through equity in publicly listed companies (54 out of 227 identified companies) also limit the number of companies that are included in our analysis. A complementary study that includes other sources of finance, like bonds and loans, would offer a richer picture. Our analysis should thus be viewed as the first step to further explore the way the financial sector connects to new challenges to planetary health, and some ways to leverage such influence for the future.

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Supporting Information

"Financial dimensions of zoonotic disease risks"
Beijer Discussion Paper No. 277

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SECTION 2. Supporting information for identifying drivers of land-use change at a global and regional scale

In this section, we present additional information regarding the methods of the literature review conducted for identifying the drivers of land-use change at a global scale. Firstly, we selected articles published between 2015-2020 in Google scholar and Scopus studying drivers of deforestation or land-use change at a global and regional scale. Generally, we research for articles whose titles and abstract contained the words: drivers AND (deforestation OR "land-use change" OR "land use change" OR "land cover change") AND (review OR "review article" OR "annual review" OR "literature review"). This first search allowed us to capture land-use change dynamics in most regions except for: USA, China, Southeast Asia, Caribbean Islands, Central America, and Middle East Asia. Thus, we expanded our search criteria searching for articles and on-line reports that described deforestation and land-use change drivers in these regions. We found information for the USA, China, and Central America case studies only. SI Table 1 contains all search formulas used for conducting this analysis. Based on the information available in selected articles and reports, we identified drivers and commodities linked to land-use change per region. SI Table 2 summarizes the findings of this analysis.

SI Table 1. Search formulas used for identifying deforestation and land-use change drivers at a global and regional scale.

Search formulas

1	(global AND (deforestation OR "Land-use change" OR "land use change") AND (review OR "review article" OR "annual review" OR "literature review"))
2	(deforestation OR "Land-use change" OR "land use change") AND (review OR "review article" OR "annual review" OR "literature review")
3	(deforestation OR "Land-use change" OR "land use change") AND (review OR "review article" OR "annual review" OR "literature review") AND (USA OR "United States" OR "North America")
4	(deforestation OR "land-use change" OR "land use change" OR “land cover change”) AND (review OR "review article" OR "annual review" OR "literature review") AND (USA OR "United States of America" OR "United States" OR "The United States of America" OR "North America”)
5	(deforestation OR "land-use change" OR "land use change") AND (review OR "review article" OR "annual review" OR "literature review") AND (usa OR "United States of America" OR "United States" OR "The United States of America" OR "North America") AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015)) AND (LIMIT-TO (EXACTKEYWORD , "United States")) AND (LIMIT-TO (EXACTKEYWORD , "Land Use") OR LIMIT-TO (EXACTKEYWORD , "Land Use Change"))
6	(deforestation OR "land-use change" OR "land use change" OR "land cover change") AND (review OR "review article" OR "annual review" OR "literature review") AND ("Central America" OR "Middle America") AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015))
7	(deforestation OR "land-use change" OR "land use change" OR "land cover change") AND (review OR "review article" OR "annual review" OR "literature review") AND (China OR "South East China" OR "Southeastern China")
8	(deforestation OR "land-use change" OR "land use change" OR "land cover change") AND (China OR "South East China" OR "Southeastern China")

SI Table 2. Summary of land-use change drivers and commodities production per region.

Region	Drivers of LUC	Commodity	References
Sahel region	Agricultural expansion and cattle raising expansion		(Walther 2016)
Sub-Saharan Africa	Shifting and commercial agriculture expansion	Coffee, rubber, cocoa, oil palm, black pepper, sugar cane, maize	(Kassa et al. 2017, Ordway et al. 2017, Curtis et al. 2018, Global Forest Watch 2020)
North America (USA and Canada)	Forestry expansion and agricultural expansion and abandonment	Pulp and wood products, corn, maize, soybeans, wheat	(Trainor et al. 2016, Bigelow and Borchers 2017, Curtis et al. 2018, Homer et al. 2020)
Mexico, Central America, and Northern South America – Colombia, Ecuador, and Peru.	Shifting agriculture, commercial agriculture cattle raising expansion	Beef and palm oil	(Graesser et al. 2015, Portillo-Quintero et al. 2015, Sy et al. 2015, Furumo and Aide 2017, Curtis et al. 2018, Devine et al. 2020, Global Forest Watch 2020, Tellman et al. 2020, Wrathall et al. 2020)
Southern South America –Bolivia, Brazil, Argentina, Paraguay, and Uruguay	Cattle raising and commercial agriculture	Beef and soybeans	(Graesser et al. 2015, Sy et al. 2015, Armenteras et al. 2017)
Europe and eastern Russia	Urban expansion, agricultural expansion, land abandonment and forestry intensification	Pulp and wood products	(Harris et al. 2015, van Vliet et al. 2015, Plieninger et al. 2016, Curtis et al. 2018)
East Asia	Urban expansion and woodlands restoration, forestry expansion	Pulp and wood products, rubber	(Harris et al. 2015, Deng and Li 2016, Curtis et al. 2018, Hurni and Fox 2018, Li et al. 2018, Ning et al. 2018)
India	Shifting agriculture and forestry expansion	Pulp and wood products	(Harris et al. 2015, Curtis et al. 2018) (Rawat et al. 2018)
Southeast Asia	Forestry, commercial agriculture and cattle raising expansion	Pulp and wood products, coconut and fruit mix plantations, rubber, coffee, sugar cane, black pepper, palm oil, cashew nuts	(Harris et al. 2015, Yap et al. 2017, Curtis et al. 2018, Hurni and Fox 2018, Ingalls et al. 2018, Austin et al.

			2019, Khorn et al. 2020)
Oceania	Fires and cattle raising expansion	Beef and dairy production	(Global Forest Watch 2020)

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SECTION 3. Supporting information for identifying the economic sectors associated with land-use change

We searched for companies producing commodities linked to land-use change based on the findings from the literature review (e.g., soybeans and beef in South America, palm oil and cocoa in South Africa, pulp and wood products in India). Firstly, we search for companies in the Global Forest Watch and Forest 500 online data bases. We downloaded the shapefiles containing information about global concessions of wood and fiber, and palm oil production in the Global Forest Watch web page (Global Forest Watch n.d., n.d.). We stored this spatial information in an independent Excel file and included all companies in our analysis, except for companies operating in Indonesia with less than 0.1% of the total palm oil or logging concession area of the country. This companies were excluded from the analysis due to the large number of operating companies in the country, yet with this selection criteria we intended to select the biggest producers of palm oil and wood products in the country's market. SI Table 3 presents a list of the countries reported in the Global Forest Watch datasets. We also downloaded three csv files from the Forest 500 web page ranking the biggest producer companies of paper, timber, and palm oil (Forest 500 2020). Later, we search for companies producing commodities related to land-use change in online reports and web pages published by commodity trading and supply chain monitoring agencies (see Environmental Justice Atlas n.d., EIA 2015b, Forest Trends et al. n.d., SEI and Global Canopy n.d., EBB n.d., ECA n.d., EIA n.d., n.d., 2012, 2014, 2015a, Friends of the Earth Europe 2010, 2014, 2015, 2020, CAPPRO 2013, Forest Trends and Ukaid 2014, PwC 2016, Heinrich Böll Foundation et al. 2017, ABC 2020). Based on the report's information, we coded the companies, their location and main economic activity, access date and commented on data limitations when relevant. SI Table 3 provides a description of all the agencies consulted between January and March 2021. We later used Orbis to determine the companies' status (e.g., activate, dissolved, etc.), origin, and type (private or public), and consulted the companies' web pages and sustainability reports to identify the countries and regions where these companies were operating. We coded all identified locations and produced commodities for each company.

SI Table 3. Description of the consulted commodity trading and supply chain monitoring agencies.

Organizations	Descriptions
Environmental Investigation Agency (EIA)	EIA publishes investigative reports providing information about complex corporate structures and supply chains of wood and other agricultural commodities focusing on illegality and violation of human rights.
Forest Trends	The Forest Trend Supply Chain Initiative intends to increase transparency around company commitments to reducing commodity-related deforestation. The initiative includes worldwide companies involved in the production of timber, cattle, soybeans, palm oil, and most recently cocoa.
EJAtlas - Global Atlas of Environmental Justice	EJAtlas is a global inventory of cases of socio-environmental conflicts built through a collaborative process between academics and activist groups documenting data on thousands of conflictive projects.
Forest 500	The Forest 500 is the world's first rainforest rating agency. It identifies and ranks the most influential companies, investors and governments in the race towards a deforestation-free global economy. By objectively identifying and ranking the 500 power brokers that have large-scale influence over forest risk commodity supply chains, the Forest 500 holds companies, investors, and governments accountable for their actions.
Global Forest Watch	The World Resource Institute (WRI) established the Global Forest Watch in 1997 as part of the Forest Frontier Initiative. Today it provides near-real-time data and tools for monitoring forest loss. The GFW also includes information regarding commodity supply chain monitoring primarily for Cameroon, Indonesia, Canada, and Gabon.
Friends of Earth	Friends of Earth is a grassroots environmental network, uniting 73 national member groups and some 5,000 local activist groups worldwide working on today's most urgent environmental and social issues seeking to expose corporations driving environmental and social degradation.
CRA	The Corn Refiners Association (CRA) is the national trade association representing a full 100% of the corn refining industry of the United States. Corn refiners manufacture sweeteners, starch, advanced bioproducts, corn oil, and feed products from corn components such as starch, oil, protein, and fiber.

European Biodiesel Board (EBB)	EBB is a non-profit organization established in January 1997. EBB aims to promote the use of biodiesel in the European Union, at the same time, grouping the major EU biodiesel producers.
The European Starch Industry Association (Starch Europe)	Starch Europe is a trade association representing the interests of the EU starch industry both at European and international level. Its membership comprises 28 EU starch producing companies, together representing more than 95% of the EU starch industry.
The European Cocoa Association (ECA)	ECA is a trade association that groups the major companies involved in the cocoa bean trade and processing representing two-thirds of Europe's cocoa beans grinding, half of Europe's industrial chocolate production and 40% of the world production of cocoa liquor, butter and powder.
Trase	Trase project uses a combination of data to attribute trade export volumes to sub-national localities and linking these to individual exporting companies.
PricewaterhouseCoopers (PwC) Global	PwC is a global network of firms delivering world-class assurance, tax, and consulting services for your business. PwC published the Global Forest, Paper & Packaging Survey summarizing the the 100 largest forest, paper and packaging (FPP) companies in the world, ranked by sales revenue.

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SECTION 4: Supporting information for selecting case studies and companies

We selected case studies according to the total number and total number of public companies identified. We excluded rubber and sugar cane production in Southeast Asia because more than 70% of the companies operated in only one country, thus not being representative of regional land-use change dynamics. We also excluded coffee and sugar beet production in Southeast Asia and Europe because all companies were privately owned. Case studies for which land-use change was driven by urban development, land abandonment, fires or shifting agriculture were also

excluded from the analysis. We selected a total of the nine case studies associated with the production of five commodities in six different regions (see SI Table 4). List of all identified companies is summarized in Table 5. Based on this preliminary selection of case studies, we later search for evidence linking commodity production or economic activities to increase risk of infection of zoonotic diseases for each case study. For this, we first looked for general evidence linking the economic activity and/or commodity and emergence of zoonotic diseases using the search formulas: TITLE-ABS-KEY: (commodity AND zoonotic AND disease*).

We also looked for evidence linking forestry, agriculture, and livestock and emerging zoonotic diseases in the regions of interest using the general formulas: TITLE-ABS-KEY: (region AND forestry AND zoonotic AND disease*); TITLE-ABS-KEY: (region AND agriculture AND zoonotic AND disease*); (region AND (livestock OR cattle ranching OR cattle raising OR cattle farming) AND zoonotic AND disease*). Lastly, we search for evidence that connected EID with the relevant economic activities of our cases studies. For this, we used the list of emerging zoonotic infectious disease (EID) events reported to be connected to land-use change in Jones et al. (2008) (n=28), and search for papers describing the outbreak, emergence or re-emergence of these EID (e.g., Andes virus, California encephalitis, Borrelia bugdorferi, Rickettsia slovaca) using the formula: (TITLE-ABS-KEY: (EZID* AND (outbreak OR emergence OR re-emergence)).

All search formulas were conducted in Scopus in November 2021. SI Table 5 summarizes all commodities, regions and EZID used as searching criteria. We were able to identify evidence for linking land-use drivers and (or) commodity production for all 9 case studies. A list of all identified companies for each case study can be found in the SI Table 6.

SI Table 4 Region, commodity, countries, total number of companies, and total and public number of companies per case study.

Region	Commodity	Countries	Companies (Public companies)
Southeast Asia	Palm oil	Myanmar Indonesia Malaysia Cambodia Thailand	91 (33)
Southeast Asia	Pulp and wood products	Indonesia Malaysia Cambodia Thailand Vietnam Philippines	45 (20)
Southeast Asia	Rubber	Indonesia Malaysia Laos	22 (1)

Southeast Asia	Coffee	Indonesia Papua New Guinea Vietnam	16 (0)
Southeast Asia	Sugar cane	Indonesia Papua New Guinea Vietnam Laos Malaysia	18 (3)
North America	Pulp and wood products	USA	31 (25)
Southern South America	Soybeans	Argentina Uruguay Paraguay Brazil	25 (3)
East Asia	Pulp and Wood Products	China Japan South Korea	24 (17)
Eastern, Central, and Southern Europe	Pulp and wood products	Austria UK Belgium Italy France Portugal Spain Hungary Romania Bulgaria Germany Poland Czech Republic Slovakia Ukraine Moldova Estonia Lithuania	24 (14)
Eastern, Central, and Southern Europe	Sugar beet	UK Belgium Italy France Austria Spain Hungary	18 (0)

		Croatia Romania Bulgaria Greece Netherlands Germany Poland Czech Republic Slovakia Slovenia Switzerland Ukraine Lithuania	
Sub-Saharan Africa	Cocoa	Cameroon Uganda Nigeria Sierra Leone Ghana Ivory Coast Madagascar Tanzania	17 (3)
Sub-Saharan Africa	Palm oil	Cameroon Congo Uganda South Africa Gabon Nigeria Republic of Sao Tome Sierra Leone Ghana Liberia Ivory Coast	15 (7)
Southern South America	Beef	Argentina Uruguay Paraguay Brazil	14 (8)

SI Table 5. Evidence linking land-use change driver, economic activities and (or) commodity production, and zoonotic infectious disease risk per case study

Region	Commodity	No. EID directly linked with the sector	No. EID indirectly linked with the sector	Mechanism description
Southeast Asia	Palm oil	0	2	The conversion of forests to plantations favors mosquitos that serve as vector of infectious diseases such as Leishmaniasis. Deforestation is associated with reduced natural demographic controls of the small mammals that are main reservoirs of Leishmania species (Mohd et al. 2016). A meta-analysis of this mechanism in Southeast Asia showed that the exposure to infectious diseases in relation to oil palm and other monoculture plantations, increases the risk of infectious diseases, both zoonotic and vector-borne (ibid). Studies also indicate that palm oil workers are at higher risk of getting vector-borne and zoonotic infectious diseases such as Leptospirosis due to the constant contact with potential contaminated environments (Morand and Lajaunie 2021). Evidence indicates that oil palm workers in Malaysia and India generally have a higher seroprevalence of zoonotic infectious diseases (ibid).

North America, Europe and Asia	Pulp and wood products	0	5	Tick-borne zoonotic diseases including Lyme disease (Falco et al. 2008), Babesiosis (Karshima et al. 2020, Holdebrandt et al. 2021, Yang et al. 2021) and tick-borne encephalitis virus (Gritsun et al. 2013, Dumpi n.d.), are transmitted through changing patterns of human interaction with small wild mammals in woodlands in North America, Europe, and Asia. Meta-analysis indicates that forest workers in the USA and Europe generally have higher seroprevalence of hantaviruses, a rodent zoonotic disease spread to the environment through inhalation of infected aerosols particles stemming from the host's urine, feces, or saliva (Ricco et al. 2015, Mull et al. 2020). The Sin Nombre virus is the most important hantavirus pathogen virus in North America because of its high case-fatality ratio (Ricco et al. 2015). Studies conducted in Europe indicate that forest workers have a higher risk of HEV (hepatitis E virus) infections due to frequent contacts with HEV-infected animals, especially wild boars (Mrazljak et al. 2021).
Sub-Saharan Africa	Cocoa and palm oil	0	1	Forest conversion to produce cocoa and palm oil production in Sub-Saharan Africa has increased in recent years (Ordway et al. 2017). The links between

				deforestation and zoonotic disease outbreak and emergence, such as Ebola, has been documented in Central and West Africa. The proposed mechanism for increased EID risks is that deforestation results in the movement of wildlife to human-modified landscapes and the reduction of wildlife disease reservoirs (Ferreira et al. 2021, Ebola Virus Disease and Forest Fragmentation in Africa n.d., Rulli et al. 2017, Brito et al. 2020)
Southern South America	Soybeans and beef	2	0	Evidence indicates that Hantavirus cardiopulmonary syndrome (HCPS) in Brazil, Uruguay, Argentina, and Chile linked to conversion of natural landscapes to areas of pastures and cultivation such as maize, rice, sugar cane and soybeans, mostly likely due to these landscapes propitiate maintenance of rodent populations (Mull et al. 2020, Brito et al. 2020). Other zoonotic infectious disease linked to livestock in Brazil and Argentina is Variola virus (da Domingos et al. 2021).

SI Table 6. Corporate actors. List of identified public and private companies used for conducting the financial ownership analysis.

Company	Region	Commodity	Type
Aceitera General Deheza S.A.	South America	Beef	Private
ADECOAGRO S.A.	South America	Beef	Public
ADECOAGRO S.A.	South America	Soybeans	Public
Agro Mandiri Semesta PT	Southeast Asia	Palm oil	Private
AHLSTROM-MUNKSJO OYJ	East Asia	Pulp and wood products	Public
AHLSTROM-MUNKSJO OYJ	Europe	Pulp and wood products	Public
AHLSTROM-MUNKSJO OYJ	USA	Pulp and wood products	Public
ALEX DO BRASIL S.A.	South America	Soybeans	Private
ALEX INC.	South America	Soybeans	Private
Altri	Europe	Pulp and wood products	Public
AMAGGI LUXEMBOURG S. A R.L.	South America	Soybeans	Private
AMORIM - INVESTIMENTOS E PARTICIPAÇÕES, SGPS, S.A.	East Asia	Pulp and wood products	Private
AMORIM - INVESTIMENTOS E PARTICIPAÇÕES, SGPS, S.A.	Europe	Pulp and wood products	Private
AMORIM - INVESTIMENTOS E PARTICIPAÇÕES, SGPS, S.A.	USA	Pulp and wood products	Private
ANGLO-EASTERN PLANTATIONS PLC	Southeast Asia	Palm oil	Public
APICAL MANAGEMENT SDN. BHD.	Southeast Asia	Palm oil	Private
Appvion Inc.	USA	Pulp and wood products	Private
Archier Daniels Midland (ADM)	South America	Soybeans	Private
Archier Daniels Midland (ADM)	Southeast Asia	Palm oil	Private
ARTIC PAPER S.A.	Europe	Pulp and wood products	Private
ASIA PACIFIC RESOURCES INTERNATIONAL HOLDINGS LTD	Southeast Asia	Pulp and wood products	Private
ASIA PAPER MFG. CO.,LTD.	East Asia	Pulp and wood products	Public
ASIA PULP & PAPER COMPANY LTD	East Asia	Pulp and wood products	Private
ASIA PULP & PAPER COMPANY LTD	Southeast Asia	Palm oil	Private
ASIA PULP & PAPER COMPANY LTD	Southeast Asia	Pulp and wood products	Private
Asia Symbol	East Asia	Pulp and wood products	Private
Asia Symbol	Southeast Asia	Pulp and wood products	Private
ASIAN AGRI GROUP	Southeast Asia	Palm oil	Private

ASSOCIACAO DOS FUNCIONARIOS DO GRUPO ANDRE MAGGI	South America	Soybeans	Private
Auto Industrial Co. Ltd	Southeast Asia	Palm oil	Private
BAHIA BLANCA	South America	Soybeans	Private
BALLARPUR INDUSTRIES LIMITED	Southeast Asia	Pulp and wood products	Public
BARRY CALLEBAUT AG	South America	Soybeans	Public
BARRY CALLEBAUT AG	Southeast Asia	Palm oil	Public
BARRY CALLEBAUT AG	Sub-Saharan Africa	Cocoa	Public
BD ASSOCIATES UK LTD	Sub-Saharan Africa	Cocoa	Private
BENFORD CAPITAL PARTNERS LLC	Sub-Saharan Africa	Cocoa	Private
BEST INDUSTRY CO	Southeast Asia	Palm oil	Private
BILLERUD KORSN√ÑS AB	Europe	Pulp and wood products	Private
BILLION VENTURE SDN BHD	Southeast Asia	Pulp and wood products	Private
Bio Pappel S.A.B	USA	Pulp and wood products	Public
BNP PARIBAS	East Asia	Pulp and wood products	Public
BNP PARIBAS	Southeast Asia	Pulp and wood products	Public
BOISE CASCADE COMPANY	USA	Pulp and wood products	Public
BOUSTEAD HOLDINGS BHD	Southeast Asia	Palm oil	Public
BRF S.A	South America	Beef	Public
BUKIT DARAH PLC	Southeast Asia	Palm oil	Public
BUMI MEKAR INTI LESTARI	Southeast Asia	Palm oil	Private
Bumitama Agri Ltd.	Southeast Asia	Palm oil	Public
BUNGE LIMITED	South America	Soybeans	Public
CARGILL INC	South America	Soybeans	Private
CARGILL INC	Southeast Asia	Palm oil	Private
CARGILL INC	Sub-Saharan Africa	Cocoa	Private
CARLY MAREE SCADDAN	Southeast Asia	Palm oil	Private
CASCADES INC	Europe	Pulp and wood products	Public
CASCADES INC	USA	Pulp and wood products	Public
CLEARWATER PAPER CORP	USA	Pulp and wood products	Public
COAMO	South America	Soybeans	Private
COCOA MARKETING COMPANY (GHANA) LIMITED	Sub-Saharan Africa	Cocoa	Private
COCOANECT	Sub-Saharan Africa	Cocoa	Private
COFCO Corporation	South America	Soybeans	Private
COMPLEJO AGROINDUSTRIAL ANGOSTURA SA	South America	Soybeans	Private

CONTINENTAL GRAIN COMPANY CORP.	South America	Soybeans	Private
COPAGRA S.A	South America	Soybeans	Private
CRESUD SOCIEDAD ANONIMA COMERCIAL, INMOBILIARIA, FINANCIERA Y AGROPECUARIA	South America	Beef	Public
DAIKEN CORPORATION	East Asia	Pulp and wood products	Public
DAIKEN CORPORATION	Southeast Asia	Pulp and wood products	Public
DAIKEN CORPORATION	USA	Pulp and wood products	Public
DAIO PAPER CORPORATION	East Asia	Pulp and wood products	Public
DANZER	East Asia	Pulp and wood products	Private
DANZER	Europe	Pulp and wood products	Private
DANZER	USA	Pulp and wood products	Private
Darmex Agro	Southeast Asia	Palm oil	Private
DEKELOIL PUBLIC LIMITED	Sub-Saharan Africa	Palm oil	Public
DOMTAR CORPORATION	USA	Pulp and wood products	Public
DS SMITH PLC	USA	Pulp and wood products	Public
ECOM AGROINDUSTRIAL CORP. LIMITED	Sub-Saharan Africa	Cocoa	Private
ECOM COCOA HOLDINGS B.V.	Sub-Saharan Africa	Cocoa	Private
EL TEJAR LIMITED	South America	Soybeans	Private
ENCE ENERGIA Y CELULOSA S.A.	Europe	Pulp and wood products	Public
EXACOMPTA CLAIREFONTAINE	Europe	Pulp and wood products	Public
FERONIA	Sub-Saharan Africa	Palm oil	Private
FGV HOLDINGS BERHAD	Southeast Asia	Palm oil	Public
FIRST PACIFIC COMPANY LIMITED	Southeast Asia	Palm oil	Public
FIRST RESOURCES LIMITED	Southeast Asia	Palm oil	Public
FORESTAL ARAUCO S.A.	USA	Pulp and wood products	Private
FRIGOL	South America	Beef	Private
Fuga Couros S	South America	Beef	Private
FUJI OIL HOLDINGS INC	Southeast Asia	Palm oil	Public
FUJI OIL HOLDINGS INC	Sub-Saharan Africa	Cocoa	Public
GAVILON	South America	Soybeans	Private
GAWI MAKMUR	Southeast Asia	Palm oil	Private
GENTING BERHAD	Southeast Asia	Palm oil	Public
GLATFELTER CORPORATION	Europe	Pulp and wood products	Public
GLATFELTER CORPORATION	Southeast Asia	Pulp and wood products	Public
GLATFELTER CORPORATION	USA	Pulp and wood products	Public

GOLDEN AGRI-RESOURCES LTD	Southeast Asia	Palm oil	Public
GOLDEN ENERGY AND RESOURCES LIMITED	Southeast Asia	Pulp and wood products	Public
GOLDEN VEROLEUM (LIBERIA) INC.	Sub-Saharan Africa	Palm oil	Private
GRAPHIC PACKAGING HOLDING COMPANY	USA	Pulp and wood products	Public
GROUPE LACTALIS	South America	Beef	Private
HAINAN JINHAI PULP & PAPER CO., LTD.	East Asia	Pulp and wood products	Private
HANKUK PAPER MFG. CO.,LTD	East Asia	Pulp and wood products	Private
HANSOL PAPER CO.,LTD.	East Asia	Pulp and wood products	Public
HAYEL SAEED ANAM	Southeast Asia	Palm oil	Private
HEINZEL HOLDING GMBH	Europe	Pulp and wood products	Private
HENGAN INTERNATIONAL GROUP COMPANY LIMITED	East Asia	Pulp and wood products	Public
HOLZINDUSTRIE SCHWEIGHOFER, S.R.O.	Europe	Pulp and wood products	Private
IBERDROLA SA	Europe	Pulp and wood products	Public
IBERDROLA SA	USA	Pulp and wood products	Public
INHUTANI III	Southeast Asia	Pulp and wood products	Private
Interfor	USA	Pulp and wood products	Public
INTERNATIONAL PAPER CO	Europe	Pulp and wood products	Public
INTERNATIONAL PAPER CO	USA	Pulp and wood products	Public
IOI PROPERTIES GROUP BERHAD	Southeast Asia	Palm oil	Public
IRMAOS GONCALVES COMERCIO E INDUSTRIA	South America	Beef	Private
JBS S.A.	South America	Beef	Public
JEROKING ENTERPRISES COMPANY LIMITED	Southeast Asia	Pulp and wood products	Private
KENCANA AGRI LIMITED	Southeast Asia	Palm oil	Public
KIMBERLY CLARK CORP	East Asia	Pulp and wood products	Public
Korindo Group Co., LTD	Southeast Asia	Palm oil	Private
Korindo Group Co., LTD	Southeast Asia	Pulp and wood products	Private
KTS TRADING SDN BHD	Southeast Asia	Palm oil	Private
KTS TRADING SDN BHD	Southeast Asia	Pulp and wood products	Private
KUALA LUMPUR KEPONG BERLAND	Southeast Asia	Pulp and wood products	Private
KUALA LUMPUR KEPONG BHD	Southeast Asia	Palm oil	Public
KUALA LUMPUR KEPONG BHD	Sub-Saharan Africa	Palm oil	Public

KWANTAS CORPORATION BERHAD	Southeast Asia	Palm oil	Public
LEE & MAN PAPER MANUFACTURING LIMITED	East Asia	Pulp and wood products	Public
LEE & MAN PAPER MANUFACTURING LIMITED	Southeast Asia	Pulp and wood products	Public
LEE KUOK SAWMILL SDN BHD	Southeast Asia	Palm oil	Private
LEE KUOK SAWMILL SDN BHD	Southeast Asia	Pulp and wood products	Private
Lenzing AG	Europe	Pulp and wood products	Public
Lenzing AG	USA	Pulp and wood products	Public
LG International Corp	Southeast Asia	Palm oil	Public
LOUIS DREYFUS HOLDING B.V.	South America	Soybeans	Private
LOUIS DREYFUS HOLDING B.V.	Southeast Asia	Palm oil	Private
LOUISIANA PACIFIC CORP	USA	Pulp and wood products	Public
MARFRIG GLOBAL FOODS S.A.	South America	Beef	Public
Marubeni	Southeast Asia	Pulp and wood products	Public
Minevar S.A.	South America	Beef	Public
MITSUBISHI PAPER MILLS LTD	East Asia	Pulp and wood products	Public
MONDI PLC	Europe	Pulp and wood products	Public
MOORIM PAPER CO.,LTD.	East Asia	Pulp and wood products	Public
MP EVANS GROUP PLC	Southeast Asia	Palm oil	Public
MUSIM MAS HOLDINGS PTE. LTD.	Southeast Asia	Palm oil	Private
NATRA S.A.	Sub-Saharan Africa	Cocoa	Private
NECOCHEA	South America	Soybeans	Private
NICHE COCOA INDUSTRY LIMITED	Sub-Saharan Africa	Cocoa	Private
NIPPON PAPER INDUSTRIES	East Asia	Pulp and wood products	Public
NIPPON PAPER INDUSTRIES	Southeast Asia	Pulp and wood products	Public
NIPPON PAPER INDUSTRIES	USA	Pulp and wood products	Public
Norske Skog	Europe	Pulp and wood products	Private
OJI HOLDINGS CORPORATION	East Asia	Pulp and wood products	Public
OJI HOLDINGS CORPORATION	Southeast Asia	Pulp and wood products	Public
OKADA SHIGYO CO.,LTD.	Southeast Asia	Pulp and wood products	Private
OLAM INTERNATIONAL LIMITED	South America	Beef	Public
OLAM INTERNATIONAL LIMITED	Sub-Saharan Africa	Cocoa	Public

OLAM INTERNATIONAL LIMITED	Sub-Saharan Africa	Palm oil	Public
OUTSPAN IVORE S.A	Sub-Saharan Africa	Cocoa	Private
PACKAGING CORP OF AMERICA	East Asia	Pulp and wood products	Public
PACKAGING CORP OF AMERICA	USA	Pulp and wood products	Public
PERMATA HIJAU MARKETING SDN. BHD.	Southeast Asia	Palm oil	Private
POSCO CO.,LTD.	Southeast Asia	Palm oil	Public
POTLATCHDELTIC CORPORATION	USA	Pulp and wood products	Public
PRESTIGE PLATFORM SDN. BHD.	Southeast Asia	Palm oil	Private
PT Agrinusa Persada Mulia	Southeast Asia	Palm oil	Private
PT Agriprima Cipta Persada	Southeast Asia	Palm oil	Private
PT Anugerah Rejeki Nusantra	Southeast Asia	Palm oil	Private
PT ARTHA GRAHA NETWORK	Southeast Asia	Palm oil	Private
PT Astra Agro Lestari Tbk	Southeast Asia	Palm oil	Public
PT ASTRA INTERNATIONAL TBK	Southeast Asia	Palm oil	Public
PT Bahruny	Southeast Asia	Palm oil	Private
PT BALIKPAPAN FOREST INDUSTRIES	Southeast Asia	Pulp and wood products	Private
PT BARITO PACIFIC TBK	Southeast Asia	Pulp and wood products	Public
PT Berkat Citra Abadi	Southeast Asia	Palm oil	Private
PT Cemerlang Abadi	Southeast Asia	Palm oil	Private
PT Central Cipta Murdaya	Southeast Asia	Palm oil	Private
PT DHARMA SATYA NUSANTARA	Southeast Asia	Palm oil	Public
PT DHARMA SATYA NUSANTARA	Southeast Asia	Pulp and wood products	Public
PT Dongin Prabhawa	Southeast Asia	Palm oil	Private
PT EAGLE HIGH PLANTATIONS	Southeast Asia	Palm oil	Public
PT FKS FOOD SEJAHTERA TBK	Southeast Asia	Pulp and wood products	Public
PT Kallista Alam	Southeast Asia	Palm oil	Private
PT Kertas Nusantara Tbk	Southeast Asia	Pulp and wood products	Private
PT Lestari Asri Jaya	Southeast Asia	Palm oil	Private
PT MEDCO ENERGI INTERNASIONAL TBK	Southeast Asia	Palm oil	Public
PT MODERN INTERNASIONAL TBK	Southeast Asia	Palm oil	Public
PT Nusantara Energi	Southeast Asia	Pulp and wood products	Private

PT PABRIK KERTAS INDONESIA	Southeast Asia	Pulp and wood products	Public
PT Perkebunan Nusantara I (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara II (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara III (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara IV (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara IX (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara V (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara VI (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara VII (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara VIII (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara X (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara XI (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara XII (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara XIII (PERSERO)	Southeast Asia	Palm oil	Private
PT Perkebunan Nusantara XIV (PERSERO)	Southeast Asia	Palm oil	Private
PT Rajawali Corpora	Southeast Asia	Palm oil	Private
PT Surya Panen Subur	Southeast Asia	Palm oil	Private
PT Watu Gede Utama	Southeast Asia	Palm oil	Private
PT Wirakarya Sakti (WKS)	Southeast Asia	Palm oil	Private
PT. PAPUA AGRO LESTARI	Southeast Asia	Palm oil	Private
PT. WANA HIJAU PESAGUAN	Southeast Asia	Pulp and wood products	Private
PT. WANAKERTA EKALESTARI	Southeast Asia	Pulp and wood products	Private
Pulp Mill Holdings GmbH	Europe	Pulp and wood products	Private
PZ CUSSONS PLC	Southeast Asia	Palm oil	Public
PZ CUSSONS PLC	Sub-Saharan Africa	Palm oil	Public
RENGO CO LTD	East Asia	Pulp and wood products	Public
Resolute Forest Products	USA	Pulp and wood products	Public
RIMBA RAYA MAKMUR	Southeast Asia	Pulp and wood products	Private
RIMBUNAN SAWIT BERHAD	Southeast Asia	Pulp and wood products	Public
RIMBUNAN SAWIT BERHAD	Southeast Asia	Palm oil	Public

ROSARIO	South America	Soybeans	Private
RUMBUNAN	Southeast Asia	Pulp and wood products	Private
S&D Sucden	Sub-Saharan Africa	Cocoa	Private
S3C	Sub-Saharan Africa	Cocoa	Private
SAMBU GROUP	Southeast Asia	Palm oil	Private
Samling Global Limited	Southeast Asia	Palm oil	Public
Samling Global Limited	Southeast Asia	Pulp and wood products	Public
SAMPOERNA AGRI RESOURCES PTE. LTD.	Southeast Asia	Palm oil	Private
SAN LORENZO	South America	Soybeans	Private
SATERI (FUJIAN) FIBRE CO., LTD.	East Asia	Pulp and wood products	Private
SATERI (FUJIAN) FIBRE CO., LTD.	Southeast Asia	Pulp and wood products	Private
SATERI (FUJIAN) FIBRE CO., LTD.	USA	Pulp and wood products	Private
SGSCO	Sub-Saharan Africa	Palm oil	Private
SHIN YANG HOLDING SDN BHD	Southeast Asia	Pulp and wood products	Private
SIFCA Group	Sub-Saharan Africa	Palm oil	Private
Sime Darby Berhad	Southeast Asia	Palm oil	Public
Sime Darby Berhad	Sub-Saharan Africa	Palm oil	Public
SIME DARBY PLANTATION LIBERIA INC	Sub-Saharan Africa	Palm oil	Private
Sinar Mas	Southeast Asia	Palm oil	Public
Sinar Mas	Southeast Asia	Pulp and wood products	Public
Smurfit Kappa Group	Europe	Pulp and wood products	Public
SOCFIN	Sub-Saharan Africa	Palm oil	Public
SOCIEDADE FRANCISCO MANUEL DOS SANTOS, SGPS, S.E.	Europe	Pulp and wood products	Private
SOCIEDADE FRANCISCO MANUEL DOS SANTOS, SGPS, S.E.	South America	Beef	Private
SOCIEDADE FRANCISCO MANUEL DOS SANTOS, SGPS, S.E.	South America	Soybeans	Private
SOCIEDADE FRANCISCO MANUEL DOS SANTOS, SGPS, S.E.	Southeast Asia	Palm oil	Private
SOCIEDADE FRANCISCO MANUEL DOS SANTOS, SGPS, S.E.	Sub-Saharan Africa	Palm oil	Private

SOCIEDADE FRANCISCO MANUEL DOS SANTOS, SGPS, S.E.	USA	Pulp and wood products	Private
SOCIETE INTERNATIONALE DE PLANTATIONS ET DE FINANCE SA	Southeast Asia	Palm oil	Public
STORA ENSO OYJ	East Asia	Pulp and wood products	Public
SUMITOMO FORESTRY CO LTD	East Asia	Pulp and wood products	Public
SUMITOMO FORESTRY CO LTD	Southeast Asia	Pulp and wood products	Public
SURYA DUMAI INDUSTRI	Southeast Asia	Palm oil	Private
Sustainable Oils Cameroon	Sub-Saharan Africa	Palm oil	Private
TA ANN HOLDINGS BERHAD	Southeast Asia	Palm oil	Public
TA ANN HOLDINGS BERHAD	Southeast Asia	Pulp and wood products	Public
TERRA SANTA AGRO S.A	South America	Soybeans	Public
TEXMACO	Southeast Asia	Pulp and wood products	Public
TH PLANTATIONS BERHAD	Southeast Asia	Palm oil	Public
THE LYMAN GROUP INC	Southeast Asia	Palm oil	Private
THE NAVIGATOR COMPANY S.A.	Europe	Pulp and wood products	Public
THE NAVIGATOR COMPANY S.A.	USA	Pulp and wood products	Public
THE SIAM CEMENT PCL	Southeast Asia	Pulp and wood products	Public
Think Biotech Co. Ltd	Southeast Asia	Pulp and wood products	Private
TOUTON SA	Sub-Saharan Africa	Cocoa	Private
TRADEWINDS PLANTATION BERHAD	Southeast Asia	Palm oil	Private
TYSON FOODS INC.	South America	Beef	Public
UPM-KYMMENE OYJ	USA	Pulp and wood products	Public
VAN DRIE HOLDING B.V.	South America	Soybeans	Private
VAN DRIE HOLDING B.V.	Southeast Asia	Palm oil	Private
VERSO CORPORATION	USA	Pulp and wood products	Public
VITERRA B.V.	South America	Soybeans	Private
WEST FRASER TIMBER CO LTD	Europe	Pulp and wood products	Public
WEST FRASER TIMBER CO LTD	USA	Pulp and wood products	Public
WESTROCK COMPANY	USA	Pulp and wood products	Public
WEYERHAEUSER CO	USA	Pulp and wood products	Public
WILMAR INTERNATIONAL LIMITED	Southeast Asia	Palm oil	Public
WILMAR INTERNATIONAL LIMITED	Sub-Saharan Africa	Palm oil	Public

WTK HOLDINGS BERHAD	Southeast Asia	Palm oil	Public
WTK HOLDINGS BERHAD	Southeast Asia	Pulp and wood products	Public
ZAMACOM S.A.	Sub-Saharan Africa	Cocoa	Private
HAESUNG INDUSTRIAL CO.,LTD.	Southeast Asia	Pulp and wood products	Public
Mayr-Melnhof Karton	Europe	Pulp and wood products	Public
PT TIGA PILAR SEJAHTERA FOOD TBK	Southeast Asia	Pulp and wood products	Public
Norske Skog	Europe	Pulp and wood products	Public
Asia Pacific Resources International Holdings Ltd	Southeast Asia	Pulp and wood products	Private
Think Biotech Co. Ltd	Southeast Asia	Pulp and wood products	Private

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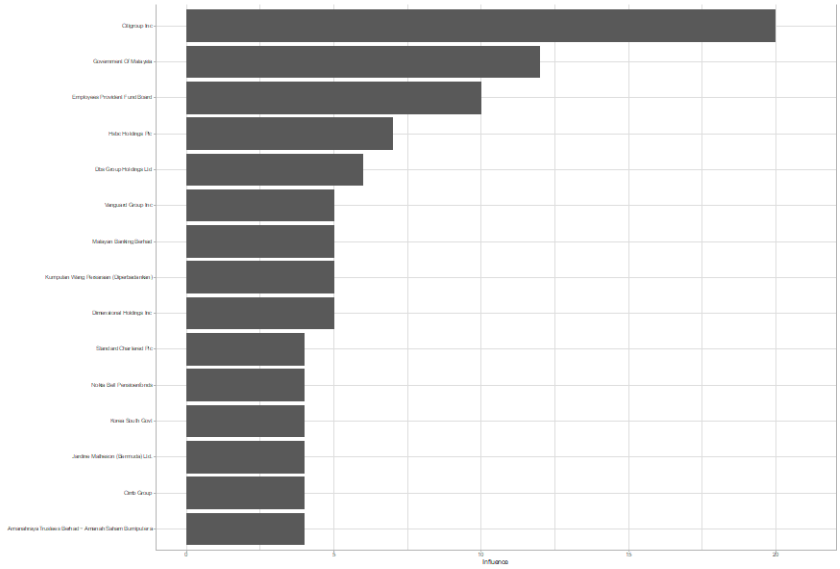
SECTION 5. Supporting information for identification of investors

A total of 101 public companies were identified for all case studies. The list of stockholders and their total and direct percentage of ownership was downloaded from Orbis database between April 12-15, 2021. We identified the unique shareholders of all the corporate actors and consulted their GUO in Orbis. In case Orbis reported two companies as independent but we suspected they belong to the same corporate group, we consulted the Financial Statements in the companies' latest Annual Reports to determine the GUO of both companies. From the 3,784 preliminary stockholders, we identified 3,295 GUO. For some cases Orbis reported non-numeric values for the percentage of ownership, we replace these numeric values based on Orbis' documentation – "FME" was reported as a missing value, and "NG" and "MO" as a 0.01 and 50.00% ownership, respectively. To make sure analysis of ownership per company was conducted only with the stockholders' GUO, we aggregate shares by the same parent shareholder within the company. For example, if Black Rock, Inc. and Black Rock Investment Fund both owned shares of one company, we aggregate their shares. When both shareholders reported a direct percentage of ownership, we took the sum as the total percentage of ownership; otherwise, we reported the maximum between the direct and/or total percentages for the shareholder. To understand the size of ownership of each stockholder, we calculated the total percentage of ownership, number of holdings – i.e., how many 5 percent blockholdings does the shareholder owns – and the size of ownership in million USD dollars – i.e., the market capitalization of the company times the percentage of the ownership of the shareholder. We reported the sum of holdings and market capitalization for each case study and the global.

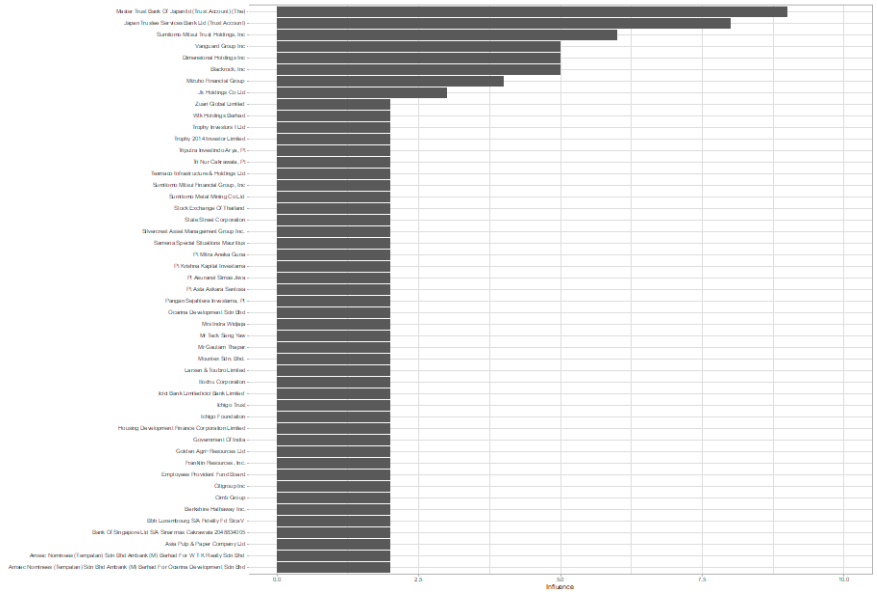
SECTION 6. Regional case study ranking of financial influence

Figure SI1. Regional case study ranking of financial influence | The figure shows a ranking of influence based on each individual investors' block holding influence (granting such investor 1 point), and top-5 ownership position in each individual selected company (also granting such investor 1 point), per regional case study. Data includes financial institutions with >0.01% ownership in each selected company.

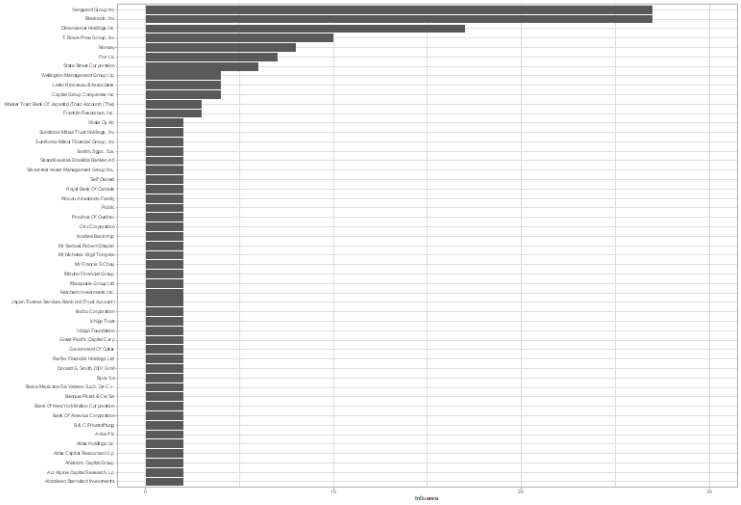
1. Palm oil production in Southeast Asia



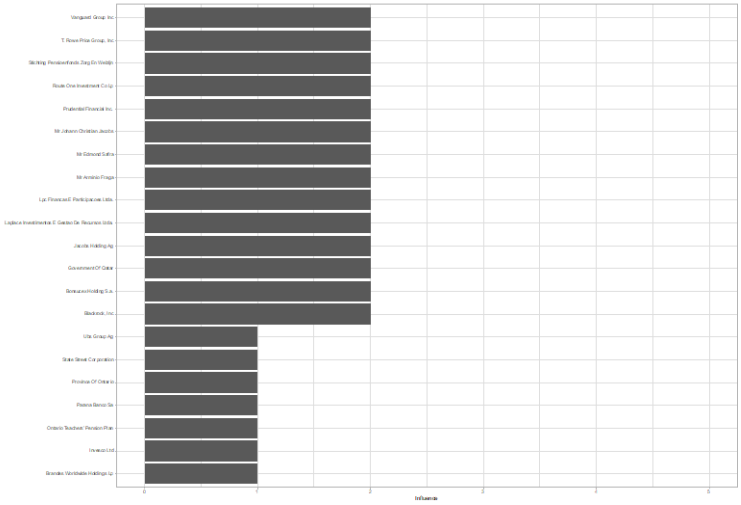
2. Pulp and wood products harvesting in Southeast Asia



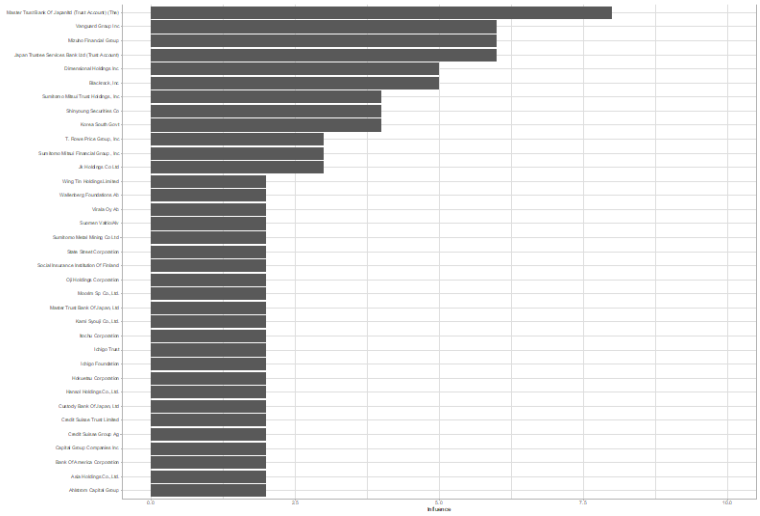
3. Pulp and wood products harvesting in North America



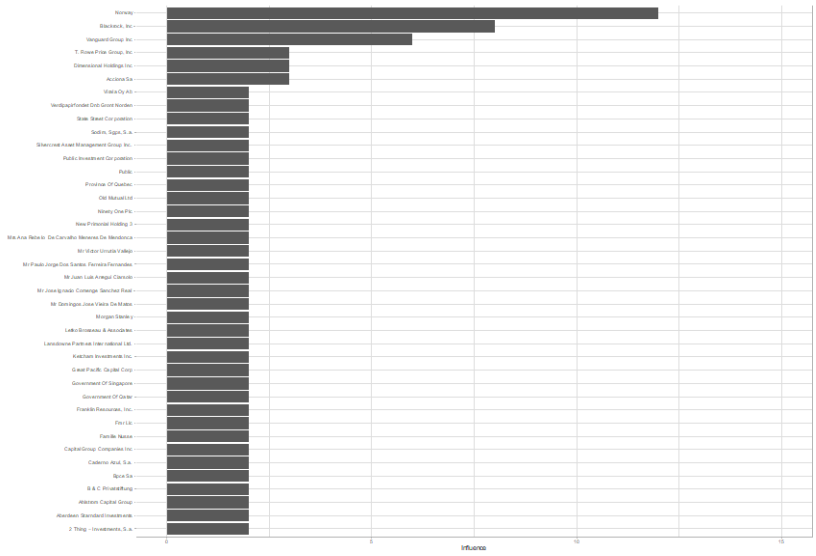
4. Soybeans production in South America



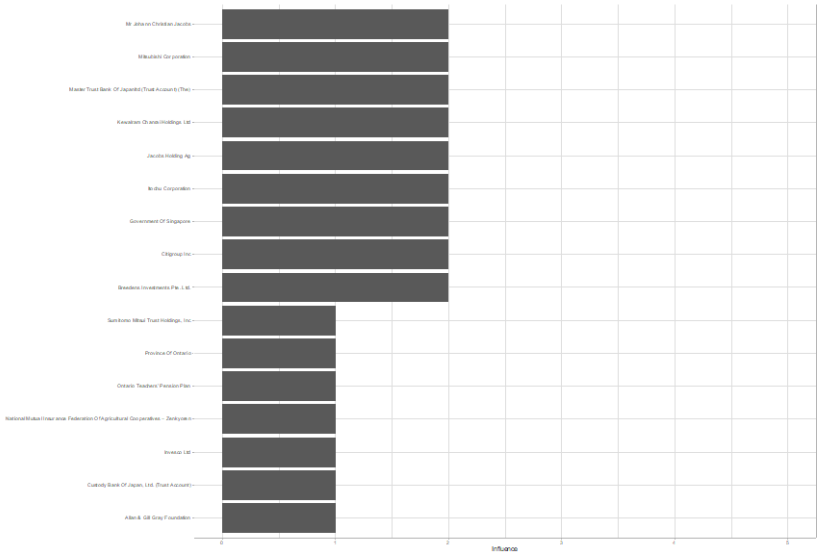
5. Pulp and wood products harvesting in East Asia



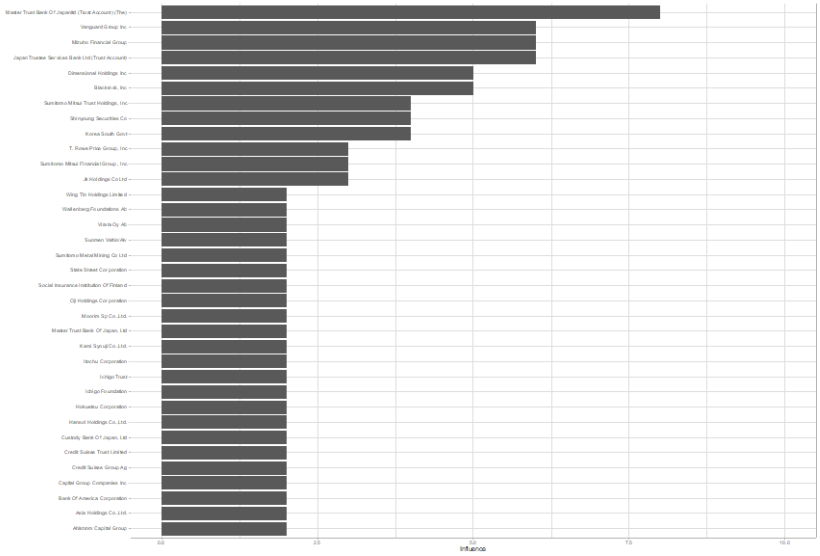
6. Pulp and wood products harvesting in Europe



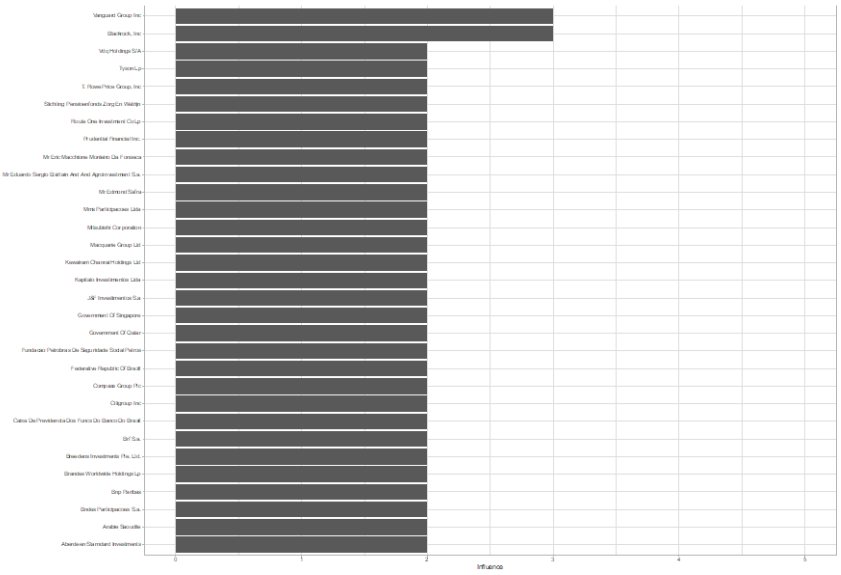
7. Cocoa production in Sub-Saharan Africa



8. Palm oil production in Sub-Saharan Africa



9. Beef production in South America


Vanguard Group Inc
Blackrock, Inc
Vtb Holdings S/A
Tycon L.p
T. Rowe Price Group, Inc
Stichting Pensioenfonds Zorg En Welzijn
Route One Investment Co Lp
Prudential Financial Inc
Mr Eric Marchione Monteiro De Fonseca
Mr Eduardo Sergio Elsztain And And Apsilon Investment S.a.
Mr Edmond Safra
Mmx Participacoes Ltda
Mitsubishi Corporation
Macquarie Group Ltd
Kesselram Chemie Holdings Ltd
Kapitalo Investimentos Ltda
Jbf Investimentos S.a
Government Of Singapore
Government Of Qatar
Fundacao Petrobras De Seguridade Social Petros
Federative Republic Of Brazil
Compass Group Plc
Citigroup Inc
Caixa De Previdencia Dos Funcs Do Banco Do Brasil
Bnf S.a
Breedens Investments Pte. Ltd.
Breedon Worldwide Holdings Lp
Bnp Paribas
Brebes Participacoes S.a.
Arabia Saoudite
Aberdeen Standard Investments
0
1
2
3
4
5
Influence

SECTION 7. Global corporate network

Figure SI2. Network of countries linked by common companies. The map in (A) shows the groups of countries that belong to the same community in the network. (B) shows the relationship between in and out degree with respect to governance effectiveness, while (C) shows an exponential random graph model that explain what governance features of the countries increase the likelihood of two countries hosting the same companies in activities related to zoonotic risk. Communities with only one country member were grouped under community #6.