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Spatial patterns of large-scale land transactions and their potential socio-environmental outcomes in Cambodia, Ethiopia, Liberia, and Peru

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Abstract

Recent large-scale land transactions, often framed as 'land grabbing,' are historically unprecedented. Millions of hectares of land have changed hands for agriculture-driven development over the past decade, and their implementation generates substantial risk of land degradation. This paper investigates land transaction patterns and evaluate their potential socio-environmental impacts in Cambodia, Ethiopia, Liberia, and Peru. We undertake a novel spatially explicit approach to quantify land transactions and conduct scenario-based analyses to explore their implementation consequences on people, land, and carbon emission. Our results demonstrate that existing global datasets on land transactions substantially underestimate their incidence but can either exaggerate or underreport transacted areas. Although confirming that land transactions are more likely to occur in sparsely populated, poorer, and more forested areas, our scenario-based analyses reveal that if fully implemented for agricultural development, land transactions in the four countries will affect more than one million people, yield over 2 Gt of carbon emissions, and disrupt vast swathes of forests. Our findings refute the 'empty land' discourse in government policy and highlight the consequences of land degradation that can occur at an unexpected scale in the 'global land rush.' Future policymaking needs to anticipate the risk of land degradation in terms of deforestation and carbon emission while pursuing agriculture-driven development through land transactions.

KEYWORDS

carbon emission, deforestation, degradation, development, land transactions, spatial patterns

1 | INTRODUCTION

The convergence of global crises in food, energy, and water has driven a dramatic increase in the demand for land (D'Odorico, Rulli, Dell'Angelo, & Davis, 2017; Kugelman & Levenstein, 2012; Rulli, Saviori, & D'Odorico, 2013). Existing global estimates of transactions, based on data collected from government documents, research articles, and media reports, suggest that between 45 and 227 million ha of land have changed hands since the early 2000s (Anseeuw, Lay, Messerli, Giger, & Taylor, 2013; Deininger & Byerlee, 2011; Zagema, 2011). Despite the positive expectations of their proponents, changes in both land tenure and land use incurred by large-scale land transactions can accelerate land degradation (Bustamante et al., 2014) and exacerbate food insecurity (Barrett, 2013). Emerging evidence indicates that land transactions do not always result in intended level of agricultural production (Ali, Deininger, & Harris, 2019), and reasons include but are not limited to poor infrastructure, underestimation of risks, speculative or rent-seeking behavior, and displacement of smallholders resulting from land transactions (Adnan, 2013; Feldman & Geisler, 2012; Julia, & White, 2012). Critics argue that land transactions can lead to declines in household income (Wendimu, Henningsen, & Gibbon, 2016), loss of household assets (Shete &

Rutten, 2015), local dissatisfaction and social tension (Gingembre, 2015), compromised food security (Rulli & D'Odorico, 2014), deforestation (Davis, Yu, Rulli, Pichdara, & D'Odorico, 2015), and soil degradation (Shete, Rutten, Schoneveld, & Zewude, 2016).

Hundreds of publications have been generated regarding the extent, cause, implementation, and impact of land transactions over the past decade (Ali et al., 2019; Borras & Franco, 2012; Nolte, Chamberlain, & Giger, 2016). These research outputs, however, did not provide comparative investigations across countries based on a large number of land transaction cases and their spatial boundaries. The existing empirical research, although valuable in documenting and interpreting the 'global land rush,' has often involved cases selected according to observed outcomes related to social inequality, displacement, and conflict (Burnod, Gingembre, & Andrianirina Ratsialonana, 2013; McAllister, 2015), rather than a reasonably comprehensive sample of land transactions with accurate location information released by government or nongovernmental organizations.

Due to the above shortcomings, there is a risk that the literature has been self-reinforcing on certain fundamental assumptions and understanding about land transactions. For example, in terms of data sources, Land Matrix (Anseeuw et al., 2013) and GRAIN (GRAIN, 2013) have been commonly used because they are global in coverage and include transaction covariates such as location, size, year, investor, and intended purposes of production. However, to what extent they represent land transactions in each country is still unknown. Regarding size, the majority of land transaction literature assumes that the transactions are large, typically over 1,000 ha (Cotula, 2011). Land transactions are also understood as primarily taking place in regions of host countries that are sparsely populated (White, Borras, Hall, Scoones, & Wolford, 2012), relatively poor (Lavers, 2012), and more forested (Gill, 2016; Messerli, Giger, Dwyer, Breu, & Eckert, 2014), because host country governments seek to ameliorate local resistance and strengthen state control in these remote frontiers. The lack of data on the spatial extent of land transaction also results in knowledge gaps on outcome assessment. Other than some emerging estimates on water use (Rulli et al., 2013), deforestation (Rulli et al., 2019), and affected population (Davis, D'Odorico, & Rulli, 2014), quantification of potential land degradation outcomes at the national level is still at its infancy, leaving government agencies, investors, local communities, and other stakeholders poorly prepared for unexpected socio-environmental consequences.

The objective of this study is to investigate key characteristics of land transactions across countries and evaluate their socio-environmental outcomes under different scenarios of implementation for agricultural production. Our analysis focuses on Cambodia, Ethiopia, Liberia, and Peru, which have among the highest numbers of land transactions according to Land Matrix. Specifically, we aim to answer the following research questions:

1. How do the land transaction data of the four countries compare with Land Matrix data in terms of the number, area, and size distribution of transactions?
2. Are land transactions located in areas that are more sparsely populated, poorer, and more forested?
3. What are the potential socio-environmental consequences of land transactions in terms of the amount of affected population, forest area, and carbon emissions given varying degrees of implementation?

2 | MATERIALS AND METHODS

2.1 | Countries of study

We chose Cambodia, Ethiopia, Liberia, and Peru as the countries of study in this research. While data availability is a key determinant in our choice of countries, these four countries provide a valuable sample for our analysis because: 1) they are among the countries globally with the greatest numbers of transactions; 2) they represent three different continents on which land transactions are occurring; and 3) they represent areas with both agricultural and forestry concessions in both drier and more mesic environments. While not selected to be globally representative, this sample of countries is sufficiently variable to draw initial conclusions that can be further tested as more spatial data on transactions becomes available.

As developing countries, government decision makers in Cambodia, Ethiopia, Liberia, and Peru have pursued both domestic and international investments in rural areas in an effort to boost economic development through agricultural intensification (Crewett & Korf, 2008; Lavers, 2012). The scale of land transactions is large in all four countries. According to Land Matrix, Ethiopia is only second to Mozambique in Africa in the number of land transactions. Cambodia ranks second in Asia, after Indonesia. Peru also ranks second in Latin America, after Brazil. Liberia has a smaller number of land transactions, with 18 cases reported by Land Matrix so far. However, due to its relatively small country size, the transacted lands cover nearly 30% of the national territory (Geary, 2012).

There are substantial variations in how land transactions have been pursued in these four countries owing to their distinct environmental settings, socioeconomic variations, institutional arrangements, and national objectives. Transacted lands in Cambodia are put to diverse uses, including logging, crop cultivation, and rubber tree plantations (Davis et al., 2015). From 2005 to 2013, Cambodia experienced the largest expansion in sugarcane cultivation worldwide, with a 376% increase (McKay, Sauer, Richardson, & Herre, 2016). The Land Law of 2001 introduced new property right categories, such as state public land (mostly forested areas) and state private land (land that can be converted into various forms of concessions). Yet, there is to date no clear differentiation in how state public and state private lands are treated. Large parcels of lands in both categories have been allocated to domestic and foreign investors in the form of economic land concessions (Oldenburg & Neef, 2014).

Land transactions in Liberia are also diverse, and transacted lands are used for food and energy crop cultivation, as well as logging (Global Forest Watch, 2016) (Jung et al., 2019). Liberia holds some of the last remaining intact forests in West Africa, and the climate conditions are suitable for many tropical crops such as oil palm and rubber. In 2009, Sime Darby, the world's largest oil palm company, announced plans to invest US$800 m in oil palm and rubber plantations in Liberia, covering about 200,000 ha (Wilcove & Koh, 2010). Because Liberia is relatively small in size, land transactions accounted for a large proportion of its national territory, often with negative consequences for local people's livelihoods (Geary, 2012).

In contrast to Cambodia and Liberia, land transactions in Ethiopia are more recent, mostly emerging after the global food crisis in the late 2000s (Oakland Institute, 2011). The Ethiopian government has a unique capacity to initiate large-scale land transactions and relocate existing residents because the state has controlled land rights for much of Ethiopia's modern history. Most land transactions are taking place in three regions of the country: Benishangul-Gumuz (Moreda, 2015), Gambela (Baumgartner, von Braun, Abebaw, & Müller, 2015; Gill, 2016), and Oromia (Shete & Rutten, 2015) (Hajjar et al., 2019), where multiple cases of land transactions have been reported in the literature.

Land transactions in Peru are mostly implemented as logging concessions (Finer, Jenkins, Sky, & Pine, 2014). The Peruvian Amazon is an important region in global efforts to promote sustainable logging in the tropics, and previous land-use zoning and its remoteness have served to protect the Peruvian Amazon's dense forest cover (Oliveira et al., 2007). Despite so, logging activities have been implemented illegally in this region, making it imperative to understand the implications for potential deforestation and carbon emission.

2.2 | Data

We acquired both first- and secondhand land transaction boundary data in those four countries. In Ethiopia, we first collected a list of land transactions from the Ministry of Agriculture and then delineated land transaction boundaries by referring to Google Earth images and conducting fieldwork in Benishangul-Gumuz, Gambela, and Oromia in the summer of 2015 and 2016. The Cambodia data were digitized from the land concession map publicly available by Open Development Cambodia in 2014. We georeferenced the 2016 land concession data from The Common Good Institute in Peru. The data for land transactions in Liberia were acquired from Global Forest Watch, which was updated in 2015 (Figure S1). It is important to note that the boundary data do not include transaction attributes such as capital source, investor information, crop type, and year of transaction. The georeferenced transaction boundaries, however, allow us to analyze the spatial patterns and quantify potential socio-environmental outcomes.

We compared the land transaction boundary data with the records from the Land Matrix, which is the most commonly cited data source for global- and regional-level analyses. Cases of land transactions were collected according to standard protocols and cross-validated by different data sources and included information such as capital source, investor information, crop type, and year of transaction. The cases were crowdsourced from media reports and academic articles, and location accuracy is low for most cases (Nolte et al., 2016). Because the Land Matrix data show that all deals were made in or after 2000 in these four countries, we assumed that the socio-environmental context in 2000 represents the condition before the transacted lands were transferred to investors for agricultural development. Therefore, we used the socio-environmental covariates in 2000 to estimate the consequences of land transactions. To do so, we acquired raster images of population density, night light index, forest cover, and carbon stock (Figure S2–S5). Specifically, we obtained population data in 2000 at a resolution of 1 km^2 at the equator from WorldPop Data Portal. Population data in 2015 were also acquired to determine the most recent number of people affected by land transactions. Because the night light index has been shown to correlate reasonably well with poverty level in the developing world (Chen & Nordhaus, 2011; Keola, Andersson, & Hall, 2015), we downloaded the global night light image in 2000 from the NASA Earth Observatory. The spatial resolution is 1,000 m, and the nightlight index ranges from 0 to 64. We used the global forest cover dataset (Hansen et al., 2013) to represent the percentage of tree cover. We obtained the forest cover raster file in 2000 from Earth Engine Partners. The spatial resolution is 30 m, and the raster value reveals the percentage of tree cover in each grid. We resampled the image to 1,000 m to make its spatial resolution consistent with other variables. We used the global biomass carbon stored in above and belowground living vegetation in 2000 (Ruesch & Gibbs, 2008) to determine the potential amount of carbon emissions from land transactions. The spatial resolution is 1,000 m, and the value in each 1 km^2 grid, namely, carbon stock density, represents the amount of carbon with the unit of 0.01 ton/ha.

2.3 | Analytical approaches

We first estimated the number of land transactions and their sizes based on the boundary data in Cambodia, Ethiopia, Liberia, and Peru. Then, to differentiate the land locations relative to transactions, we categorized lands into four mutually exclusive classes: (a) areas within the land transaction boundaries; (b) immediate buffer zone that is within 1 km from transaction boundaries; (c) secondary buffer zone that is between 1 and 5 km from transaction boundaries; and (d) other areas within the national boundaries but excluding transacted lands and their buffer zones. We extracted the value of each pixel in the raster images of population density, night light index, forest cover, and carbon stock density within the spatial extent of each land category in the four countries. In cases where a transaction polygon partially overlaps with a pixel, we estimated its population density, night light index, forest cover, and carbon stock density according to the area in each pixel. For example, if 60% of a polygon falls in one pixel and 40% in another one, then its covariate value is 60% of the first pixel value plus 40% of the second one.

We compared differences in population density, night light index, and forest cover in 2000 across land categories by conducting *t*-tests and analysis of variance. Because the sample size is too large, we took a random sample of 10,000 for each land category. The F-statistic from analysis of variance provides an indicator of how different these four land categories are in terms of their socio-environmental contexts prior to land tenure change.

We adopted a scenario-based approach to evaluate the potential socio-environmental consequences of land transactions. In order to estimate an upper bound in which all transacted lands are cleared for agricultural production according to transaction boundaries, we proposed the scenario of full implementation. However, because not all transacted lands will be implemented for production purposes due to logistic constraints, local resistance, or speculation (Liao, Jung, Brown, & Agrawal, 2016), we proposed another three scenarios in which transacted lands are implemented at low (25%), moderate (50%), and high (75%) levels. We referred to the Land Matrix data to determine the implementation levels in the four countries. Specifically, we estimated the proportion of land that is implemented for agricultural production in each case of transaction and then determined the 25, 50, and 75% implementation ratios according to all cases in each country (Figure S6). We randomized the choice of pixels being converted in these three partial implementation scenarios. In addition, because of the likely spillover effects of land transactions beyond their boundaries (Deininger & Xia, 2016; Finer et al., 2014), we proposed two more scenarios in which an immediate buffer zone (0–1 km) and a secondary buffer zone (1–5 km) are affected by land transactions.

According to the level of implementation under the above six scenarios, we estimated the total amount of population, affected forested areas, and carbon emissions. Specifically, we multiplied the population density, forest cover, and carbon stock density of each pixel in 2000 by the area of each land transaction polygon in each pixel and added them together to determine the amount of population, forest area, and carbon emission of each land transaction. In addition, due to rapid population growth in the global south (Kc & Lutz, 2017), land transactions may affect more people than initially anticipated by the government. In order to capture such dynamics, we also estimated the affected population under different scenarios in 2015.

3 | RESULTS

3.1 | Numbers, areas, and size distributions of transactions

Comparison between Land Matrix dataset and our data in the four countries suggests substantial gaps in the numbers and areas of reported transactions (Figure 1). The global dataset substantially

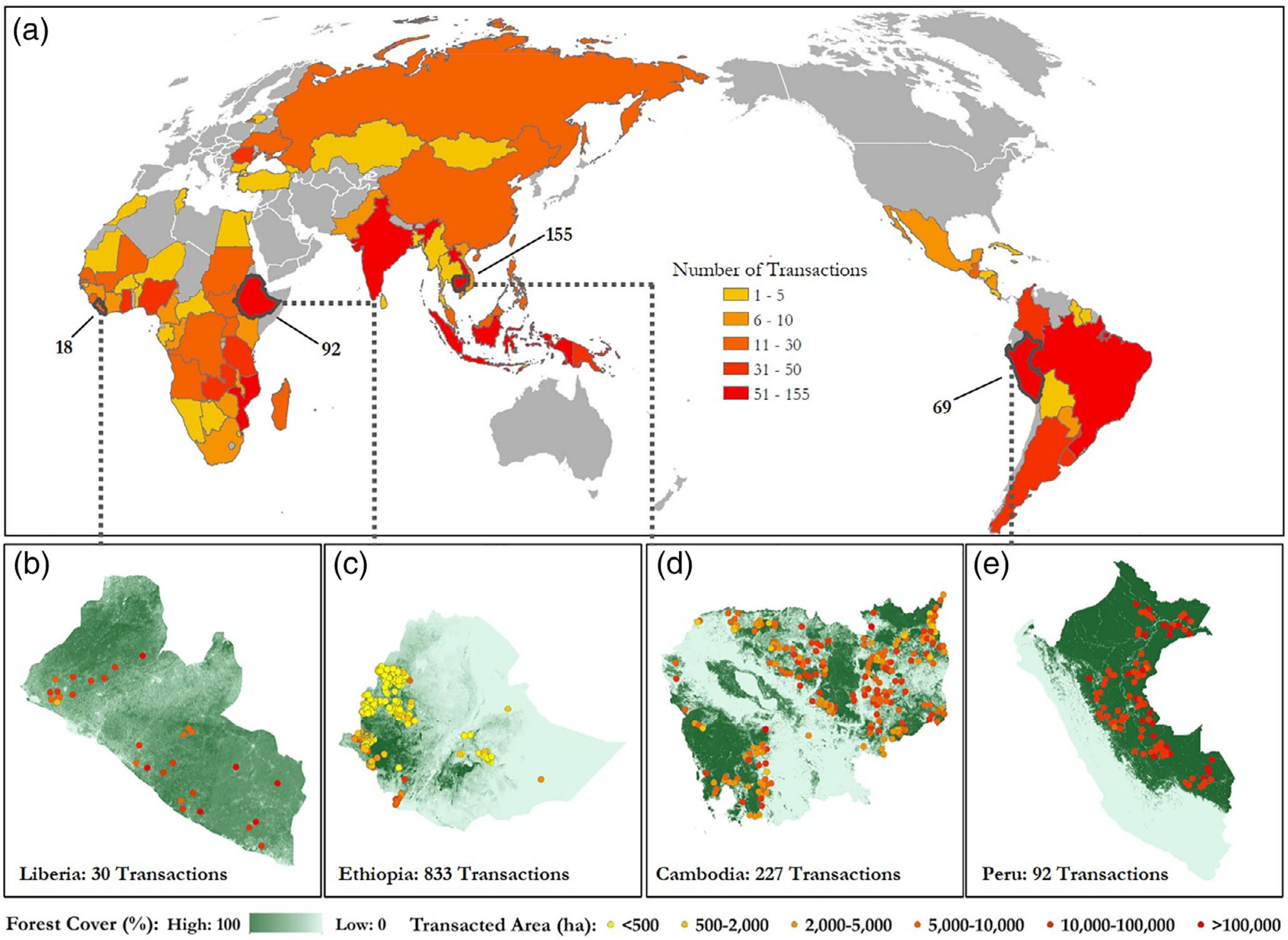

FIGURE 1 Land transactions at the global level according to Land Matrix (a) and at the country level in Liberia (b), Ethiopia (c), Cambodia (d), and Peru (e) on top of forest cover according to government and non-government sources [Colour figure can be viewed at wileyonlinelibrary.com]

underestimates the number of transactions but can either exaggerate or underreport the area of transactions. According to Land Matrix, the number of land transactions in Ethiopia is 92 by 2015, with a total area of 1.27 million ha. However, data from the Land Commission Office in Ethiopia document a total of 833 transactions accounting for 0.84 million ha, which is 805% more in terms of number but 53% less in terms of size than reported by Land Matrix. In Cambodia, Liberia, and Peru, the country-level data show that the numbers of transactions in these three countries are 46, 67, and 33% more than reported in Land Matrix, respectively, but for total transacted area, it is overestimated for Liberia by 11% and underestimated for Cambodia and Peru by 29 and 96%, respectively.

The mean size of the 1,182 individual land transactions in the national-level datasets is 11,057 ha, confirming the dominance of large transactions. However, the median value is 766 ha, which is substantially smaller than the mean. In fact, the size of land transaction varies substantially, from the smallest case of 9.5 ha in Ethiopia to the largest case of 786,461 ha in Peru. The sizes also vary by orders of magnitude across these four countries (Figure 2a). The average land transaction size is 999 ha in Ethiopia, with 659 of 833 transactions less than 1,000 ha. In contrast, land transactions are much larger in the other three countries. Average transaction size in Cambodia (9,308 ha) is almost 10 times as large as that in Ethiopia. The cases in Liberia are even larger, with a mean size at 50,250 ha. Land transactions in Peru are the largest, which average at 93,664 ha.

In all four countries, a small number of large transactions account for the vast majority of total transacted areas (Figure 2b). Ethiopia, with a median transaction size of 464 ha, represents the most extreme case, where the 62 largest ones (7.5% of all cases) account for half of total transacted area. Despite having the largest number of transactions, total transacted area is the smallest in Ethiopia, at 0.8 million ha. The other three countries had fewer transactions, but the total transacted areas were much larger than Ethiopia. In Liberia, where median transaction size is 20,637 ha, 30 transactions make up 1.5 million ha, with the 17% largest ones accounting for half of the transacted area. In Cambodia, where median is 6,911 ha, 227 transactions account for 2.1 million ha, and 18.9% make up half the area. In Peru, where median is 51,578 ha, although the number of transactions is about a 10th of Ethiopia, the total area (8.6 million ha) is over 10 times higher, and 13.7% of transactions make up half of the total transacted area.

3.2 | Location of transactions relative to population density, night lights, and forest cover

In the four countries of study, we observe a consistent trend of higher average population densities in 2000 from transaction areas, to immediate buffer, to secondary buffer, and to national average (Figure 3a). Thus, the general understanding that land transactions are occurring in less populated areas is supported by our results. However, the differences are greater in Cambodia and Peru than in Ethiopia and Liberia. Pairwise *t*-tests between transacted lands and the other three land categories show that population density is consistently and significantly lower than that of their buffer zones and national average across the four countries (p-value < .001; Table S1).

The night light index in 2000 is generally low in these four countries, but national average is associated with much higher index than the transacted areas and their buffer zones (Figure 3b). The difference is especially large in Cambodia and Peru, as indicated by a high F-statistic (Table S1). Given the observed inverse association between the night light index and poverty, this pattern suggests that the transacted lands and their neighboring parcels are generally associated with less economic activities than national average. The gap in the

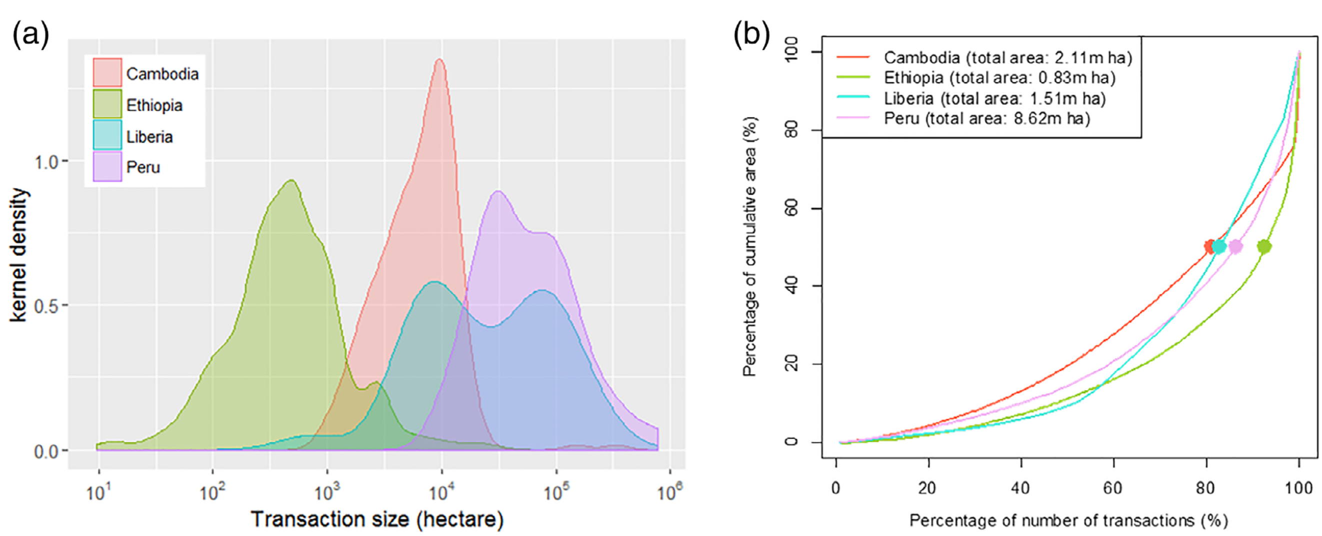

FIGURE 2 Size distribution of individual transactions in Cambodia, Ethiopia, Liberia and Peru (a), and cumulative area of land transactions in Cambodia, Ethiopia, Liberia and Peru (b). The dots on the curves indicate the percentage of smaller land transactions that make up 50% total transacted areas [Colour figure can be viewed at wileyonlinelibrary.com]

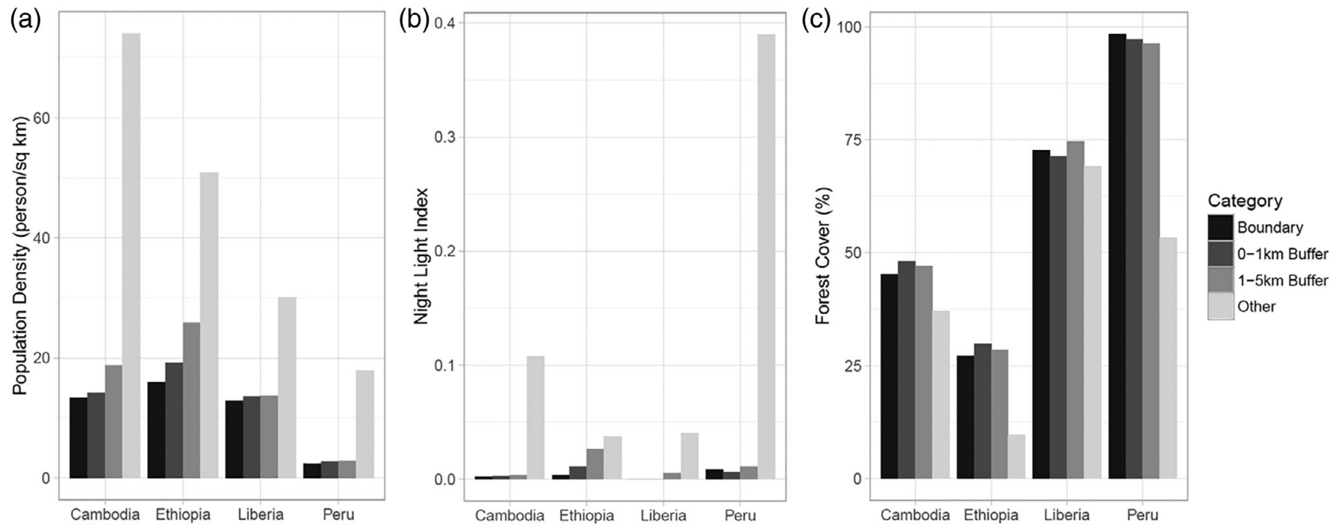

FIGURE 3 Population density, night light index, forest cover in transacted areas, their 0–1 km and 1–5-km buffer zones, and the other areas in the country in Cambodia, Ethiopia, Liberia and Peru in 2000 (see Table S2 for the total area of four land categories)

two African countries is smaller, primarily due to low overall night light index throughout these two countries.

Before land transactions (i.e., in 2000), national average forest cover was generally lower than in transacted areas and buffer zones (Figure 3c). Such intra-country spatial variations are reflected in the *t*-test results, showing the degree of difference in forest cover between transacted areas and the rest of the countries varies substantially (Table S1). In Ethiopia and Peru, land transactions take place in areas with nearly twice the forest cover of national average. In contrast, the difference in forest cover between transacted areas and national average is less than 8% in Cambodia and 4% in Liberia, suggesting a less differentiated distribution of land transaction locations along the gradient of forest cover in these two countries.

3.3 | Potential consequences on population, forest cover, and carbon emission

We estimated that a total of nearly one million people were located within the land transaction boundaries in the four countries before the lands were transferred to investors (Figure 4a), even though population densities in the transacted areas were significantly lower than the neighboring areas and national averages. Even under the low implementation scenario, 0.15 million population would be affected. Under moderate and high implementation scenarios, the numbers of affected population were 0.35 million and 0.5 million. In addition, another 1.9 million people were located within the 5-km buffer zones and subject to potential spillover effects associated with implementation of land transactions.

From 2000 to 2015, the amount of population within the transaction boundaries of these four countries increased from 0.95 million to 1.45 million, representing a 53% growth rate (Figure 4b). The population growth in the two buffer zones was even faster, with a rate over 60%. In contrast, the average population growth in these four countries was approximately 40%.

Across the four countries, land transactions in Cambodia can directly affect the largest amount of population. About 0.33 million people are located in the 2.1 million ha of transacted land in 2000. In the following 15 years, the directly affected population grew 73%, making the total at 0.57 million in 2015. During this period, national average growth rate is only 23%. In Ethiopia, from 2000 to 2015, the amount of population within transaction boundary increased from 0.15 million to 0.26 million, with a growth rate at 67%, whereas national average population growth rate is 49%. The population growth rates within the transaction boundaries in Liberia and Peru between 2000 and 2015 were lower, at 45 and 22%, respectively.

Land transactions can also generate unintended environmental consequences. Within the total area of 13 million ha of transacted lands in the four countries, over 10 million ha is covered with forests (Figure 5a). In addition, another 8.9 million ha of forest are located within 5 km from the transaction boundaries. The total transacted lands, if all cleared for agricultural and forestry production, can emit a total over 2 Gt of carbon emission (Figure 5b). In addition, potential spillover effects of land transactions can lead to another 1.5 Gt of carbon emission within the 5-km buffer zones.

Among these four countries, Peru has a total 8.5 million ha of forest area within transaction boundaries, accounting for nearly 80% of the total transacted area in Peru. Meanwhile, because land transactions are mostly located in the Peruvian Amazon, potential carbon emission from the land clearing process can be as high as 1.6 Gt, which is nearly four times as much as the three other countries combined. Even under low implementation scenario, 4.3 million ha of forest would be lost, generating 0.8 Gt of carbon emission. Although the total transaction area in Liberia is smaller than Cambodia, the greenhouse gas consequences in Liberia is greater, with 1.1 million ha of forest in the transacted area that can potentially emit 0.23 Gt from

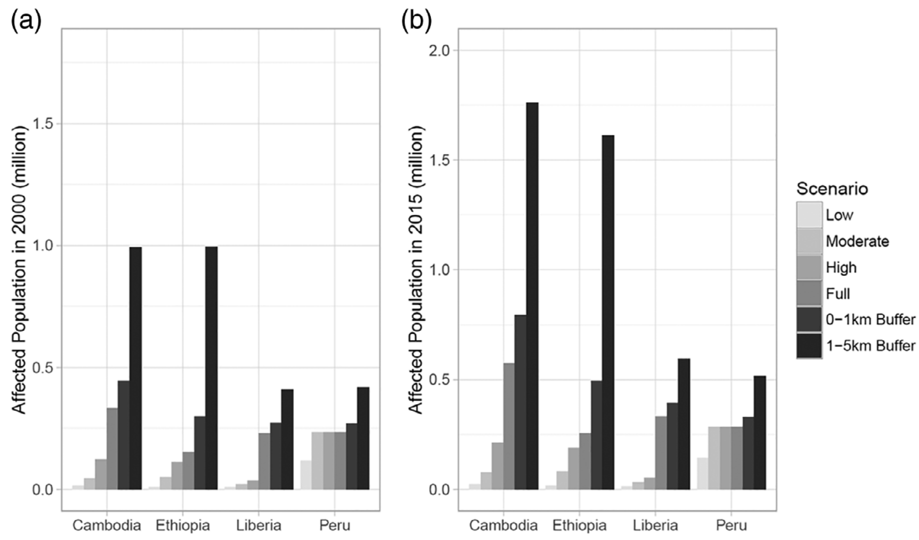

FIGURE 4 Potentially affected population in 2000 (a) and 2015 (b) under six land transaction implementation scenarios

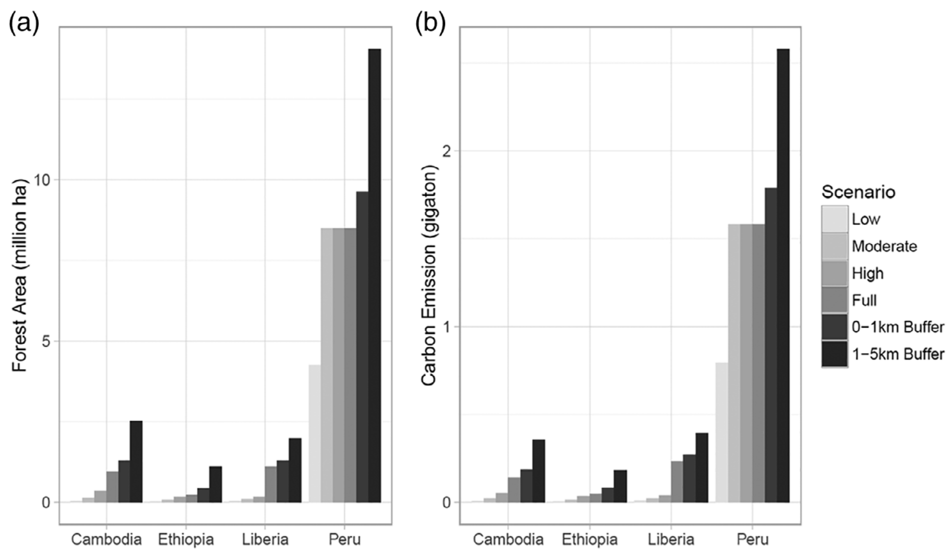

FIGURE 5 Forest areas (a) and carbon biomass (b) to be affected by land transactions with different implementation scenarios

full implementation. In Cambodia, within the 2.1 million ha of transacted land, there is a total of 0.95 million ha of forest under threat, which can generate 0.14 Gt of carbon emission. Because of the dominance of savanna landscape in Ethiopia, there is only a total of 0.23 million ha of forest on the 0.83 million ha of transacted lands, which hosts a total of 0.04 Gt of carbon stock.

4 | DISCUSSION

This paper investigates land transaction patterns and their potential socio-environmental impacts in Cambodia, Ethiopia, Liberia, and Peru. Based on the extensive spatial data of land transactions in the four countries, and through comparison with Land Matrix data, our research indicates that the information in the global dataset provides a distorted picture of the 'global land rush.' On-the-one-hand, it underrepresents the numbers of land transactions. On-the-one-hand, total transaction area can be either overestimated or underestimated. This finding highlights the need for government agencies, local communities, and researchers to work together to promote transparency and accuracy in recording the incidence of land transactions and thereby make more authoritative data publicly available (Edelman, 2013). Such data will not only contribute to better information and analyses regarding land transactions but also help improve the monitoring and assessment of land transactions.

Most literature typically associates land transactions with large-scale tenure change involving thousands of hectares of land (Cotula, 2011). Our data suggest that although large transactions are common, not all of them are large in size. In fact, data from the Ethiopian Land Commission indicate that there are hundreds of small land transactions. Evidence from other countries suggests that positive economic outcomes are more likely to be associated with small-scale land transactions, where smallholder farmers were fully engaged in the economic opportunities from the agricultural investment (Sikor, 2012).

Therefore, it is important to consider the role of small-scale land transactions in producing social, economic, and environmental outcomes, in addition to the larger transactions that have been the focus in much of the literature.

Our analysis of socioeconomic contexts of transactions and nearby areas across the four countries is consistent with some findings in earlier work (White et al., 2012). For example, the transacted areas and their buffer zones are much more sparsely populated than the countries in which they occur. Compared with densely populated areas, host country government can better justify land transaction by using the "empty land" discourse (Tura, 2018; White et al., 2012). On the one hand, because there are fewer economic activities on these lands, the national and regional governments can justify land transactions by claiming promotion of economic growth and development through collaboration with international and domestic investors, while strengthening the administrative control of these frontiers (Lavers, 2012). On the other hand, people in poor regions are more politically marginalized and lack the resources to make their voices heard when land appropriation occurs and their land rights are threatened (Oberlack, Tejada, Messerli, Rist, & Giger, 2016).

However, because of the large number and/or size of land transactions, they can collectively affect a substantial amount of population, which may not be anticipated by host country governments. In our empirical analysis in Cambodia, Ethiopia, Liberia, and Peru, nearly one million people are located in the 13 million ha of transacted land in 2000, with another 2.5 million within the immediate and secondary buffer zones from transaction boundary. Moreover, rapid population growth in these four countries is likely to magnify social effects of land transactions such as displacement, dispossession, and marginalization (Hall, 2013; Julia & White, 2012; Kc & Lutz, 2017). Between 2000 and 2015, the population in the transaction boundaries grew by 53% in the four countries, a rate which is much higher than national averages. Rapid population growth is very likely to exacerbate land conflicts between local communities and external investors, which is barely anticipated in the national land-based development plans of host country governments.

Although the actual effect on affected population is debated, numerous research has suggested that land-based investments are not free of resistance, even if implemented in sparsely populated regions (Moreda, 2015). Before lands are transferred to investors, local communities have often come to rely on the transacted lands through their customary rights for hunting, gathering, grazing, and small-scale cultivation (Gill, 2016). Competing with local communities for large-scale agricultural production has resulted in various negative socioeconomic outcomes (German, Schoneveld, & Mwangi, 2013; Julia & White et al., 2012). Both violent confrontations (McAllister, 2015) and silent sabotages (Moreda, 2015) have emerged in some of these areas. Therefore, it is necessary to engage local smallholders in the design and implementation of future land-based investments, even on these relatively poor and sparsely occupied lands.

Our quantitative assessments of land degradation risk suggest that vast swathes of forests are situated within land transaction boundaries, which may be subject to clearing when transacted lands are implemented for agricultural and forestry production. Findings from existing research have shown that land transactions have clearly accelerated deforestation in Cambodia (Davis et al., 2015). In addition, deforestation is one effect for which negative spillover effects have been observed from land transactions. In Peru, it has been reported that logging permits associated with legal concessions are used to harvest trees in the neighboring unauthorized areas, which can cause even higher deforestation rate in the buffer areas of legal transaction boundaries (Finer et al., 2014). Moreover, road construction in these remote transacted areas also fragments forests and leads to additional clearing along their length (Perz et al., 2008).

As land-cover change occurs on transacted lands, and intended land uses are implemented, substantial amounts of carbon emissions can be emitted, especially in cases where transacted lands are located in high carbon value forests. We calculated that over 2 Gt of carbon emission can be generated in the land conversion process in the four countries. This amount is more than 40% of the global carbon emission from land-cover change in 2012 (Tubiello et al., 2015). If soil organic carbon loss following deforestation, which is yet to be considered in this research, is included in the estimation, the amount of carbon emission would be much greater. The estimated carbon emission scenario, if realized, will counter efforts by the host country governments to mitigate carbon emissions as declared in the Intended Nationally Determined Contributions to the 2015 United Nations Climate Change Conference.

This study advances the assessment of land transaction patterns and potential socio-environmental consequences based on spatial data on land transaction boundaries from multiple countries. However, two potential biases may affect our analysis. First, although we demonstrate that the number of transactions in Cambodia, Ethiopia, Liberia, and Peru is much higher than reported by Land Matrix, we do not claim to have obtained information about all cases of land transactions in these four countries. In fact, it is difficult to obtain a complete list given the sensitivity of land transactions in many host countries (Edelman, 2013). What adds further complexity to this issue is that, in certain countries, land commissioners at different administrative levels are authorized to make deals with investors, which makes it more difficult to keep track of all cases of land transactions (Vermeulen & Cotula, 2010). Second, the implementation of land-cover and land-use changes within the land transaction boundaries is yet to be validated with further evidence. On the one hand, it is possible that lands are transacted without any follow-up implementation for agricultural development due to underestimation of the challenges in clearing natural vegetation and mobilizing the inputs needed for intensive commercial cropping, local resistance to land tenure changes, and speculation of higher land price in the future (Cotula, 2011; Gill, 2016). Consequently, our dataset may exaggerate the scope of socio-environmental impact of land transactions. On the other hand, investors may take advantage of their land-use permits and extend their utilization beyond the transaction boundaries (Finer et al., 2014), which may mean that our results underestimate the impacts of implementations.

Our research suggests an urgent need for further assessment land transactions. Due to the recent nature of many transactions, our analysis only provides an initial investigation of their spatial patterns and outcomes. Long-term associations between land transactions, deforestation, carbon emissions, and other socio-environmental consequences remain underexplored. Additional empirical and qualitative investigation is needed to fully understand the effects of land transactions. For example, we used carbon emission and deforestation as indicators of environmental effects, but further empirical research that measures a wider range of outcomes is necessary to gain a more comprehensive understanding of land transactions. Because our dataset lacked information on the characteristics of land transactions, for example, the source of investment, date of transaction and implementation, and types of crops, we only assessed their spatial distribution patterns. A future rigorous impact assessment will rely on better information about these characteristics, which will allow us to better understand how land transactions affect agricultural development and land degradation in the vast rural areas in developing countries.

5 | CONCLUSIONS

Although earlier research has identified general features of land transactions and their association with different contextual variables and outcomes, little empirical work has been done to test the associations asserted as the general patterns for land transactions across countries. Our analysis of land transactions in four countries of three continents confirms some of the early arguments in the literature, but our results also point to the fact of substantial gaps in the number and area of land transactions reported by global-level dataset, as well as potential land degradation risks that are poorly anticipated by host country governments. We find that existing global datasets on land transactions substantially underestimate their incidence but can either exaggerate or underreport transacted areas. Our scenario-based analyses reveal that if fully implemented for agricultural development, land transactions in the four countries will affect more than one million people, yield over 2 Gt of carbon emissions, and disrupt vast swathes of forests.

By providing quantitative assessment on the affected population, forest, and carbon emission, our findings not only refute the "empty land" discourse adopted by many host country governments to justify land transactions but also suggest that far more empirical work is necessary before generalizations about the nature, distribution, scope, patterns, and outcomes of recent land transactions can be advanced with any confidence. In addition, reforms are needed to regulate land transactions and monitor their implementation for agricultural production. It is crucial for policymakers to balance multiple goals of sustainable development while pursing agricultural development driven by land transactions and carefully manage the tradeoffs between boosting agricultural productivity and minimizing the risk of land degradation in developing countries (Hasegawa et al., 2018; Seufert, 2013).

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REFERENCES

Adnan, S. (2013). Land grabs and primitive accumulation in deltaic Bangladesh: Interactions between neoliberal globalization, state interventions, power relations and peasant resistance. *The Journal of Peasant Studies*, *40*(1), 87–128. https://doi.org/10.1080/03066150.2012.753058

Ali, D., Deininger, K., & Harris, A. (2019). Does large farm establishment create benefits for neighboring smallholders? Evidence from Ethiopia. *Land Economics*, *95*(1), 71–90. https://doi.org/10.3368/le.95.1.71

Anseeuw, W., Lay, J., Messerli, P., Giger, M., & Taylor, M. (2013). Creating a public tool to assess and promote transparency in global land deals: The experience of the Land Matrix. *The Journal of Peasant Studies*, *40*(3), 521–530. https://doi.org/10.1080/03066150.2013.803071

Barrett, C. B. (2013). *Food security and sociopolitical stability*. New York: Oxford University Press: Oxford.

Baumgartner, P., von Braun, J., Abebaw, D., & Müller, M. (2015). Impacts of large-scale land investments on income, prices, and employment: Empirical analyses in Ethiopia. *World Development*, *72*, 175–190. https://doi.org/10.1016/j.worlddev.2015.02.017

Borras, S. M., & Franco, J. C. (2012). Global land grabbing and trajectories of agrarian change: A preliminary analysis. *Journal of Agrarian Change*, *12*(1), 34–59. https://doi.org/10.1111/j.1471-0366.2011.00339.x

Burnod, P., Gingembre, M., & Andrianirina Ratsialonana, R. (2013). Competition over authority and access: International land deals in Madagascar. *Development and Change*, *44*(2), 357–379. https://doi.org/10.1111/dech.12015

Bustamante, M., Robledo-Abad, C., Harper, R., Mbow, C., Ravindranat, N. H., Sperling, F., … Smith, P. (2014). Co-benefits, trade-offs, barriers and policies for greenhouse gas mitigation in the agriculture, forestry and other land use (AFOLU) sector. *Global Change Biology*, *20*(10), 3270–3290. https://doi.org/10.1111/gcb.12591

Chen, X., & Nordhaus, W. D. (2011). Using luminosity data as a proxy for economic statistics. *Proceedings of the National Academy of Sciences*, *108*(21), 8589–8594. https://doi.org/doi.org/10.3386/w16317

Cotula, L. (2011). *Land deals in Africa: What is in the contracts?* London: IIED.

Crewett, W., & Korf, B. (2008). Ethiopia: Reforming land tenure. *Review of African Political Economy*, *35*(116), 203–220. https://doi.org/10.1080/03056240802193911

D'Odorico, P., Rulli, M. C., Dell'Angelo, J., & Davis, K. F. (2017). New frontiers of land and water commodification: Socio-environmental controversies of large-scale land acquisitions. *Land Degradation & Development*, *28*(7), 2234–2244. https://doi.org/10.1002/ldr.2750

Davis, K. F., D'Odorico, P., & Rulli, M. C. (2014). Land grabbing: A preliminary quantification of economic impacts on rural livelihoods. *Population and Environment*, *36*(2), 180–192. https://doi.org/10.1007/s11111-014-0215-2

Davis, K. F., Yu, K., Rulli, M. C., Pichdara, L., & D'Odorico, P. (2015). Accelerated deforestation driven by large-scale land acquisitions in Cambodia. *Nature Geoscience*, *8*(10), 772–775. https://doi.org/10.1038/ngeo2540

Deininger, K., & Xia, F. (2016). Quantifying spillover effects from large land-based investment: The case of Mozambique. *World Development*, *87*, 227–241. https://doi.org/10.1016/j.worlddev.2016.06.016

Deininger, K. W., & Byerlee, D. (2011). *Rising global interest in farmland: Can it yield sustainable and equitable benefits?* Washington, DC: World Bank Publications.

Edelman, M. (2013). Messy hectares: Questions about the epistemology of land grabbing data. *The Journal of Peasant Studies*, *40*(3), 485–501. https://doi.org/10.1080/03066150.2013.801340

Feldman, S., & Geisler, C. (2012). Land expropriation and displacement in Bangladesh. *The Journal of Peasant Studies*, *39*(3–4), 971–993. https://doi.org/10.1080/03066150.2012.661719

Finer, M., Jenkins, C. N., Sky, M. A. B., & Pine, J. (2014). Logging concessions enable illegal logging crisis in the Peruvian Amazon. *Scientific Reports*, *4*. https://doi.org/10.1038/srep04719

Geary, K. (2012, November 4). Our Land, Our Lives': Time out in the global land rush. Retrieved from https://books.google.com/books?hl=en&lr=&id=qDJss0Eopf8C&oi=fnd&pg=PA2&dq=%E2%80%98Our+land,+our+lives%E2%80%99:+time+out+on+the+global+land+rush&ots=-Z1zfIdHjQ&sig=40L-58oV6S066GMCyn8IpZtU4Is

German, L., Schoneveld, G., & Mwangi, E. (2013). Contemporary processes of large-scale land acquisition in sub-Saharan Africa: Legal deficiency or elite capture of the rule of law? *World Development*, *48*, 1–18. https://doi.org/10.1016/j.worlddev.2013.03.006

Gill, B. (2016). Can the river speak? Epistemological confrontation in the rise and fall of the land grab in Gambella, Ethiopia. *Environment and Planning A*, *48*(4), 699–717. https://doi.org/10.1177/0308518x15610243

Gingembre, M. (2015). Resistance or participation? Fighting against corporate land access amid political uncertainty in Madagascar. *The Journal of Peasant Studies*, *42*(3–4), 561–584. https://doi.org/10.1080/03066150.2015.1022867

Global Forest Watch. (2016, December 5). *Monitoring forests in near real time*. Retrieved April 25, 2016, from http://www.globalforestwatch.org/

GRAIN. (2013). Collating and dispersing: GRAIN's strategies and methods. *The Journal of Peasant Studies*, *40*(3), 531–536. https://doi.org/10.1080/03066150.2013.799464

Hajjar, R., Ayana, A.N., Rutt, R., Hinde, O., Liao, C., Keene, S., Bandiaky-Badji, S., & Agrawal, A. (2019). Capital, labor, and gender: the consequences of large-scale land transactions on household labor allocation. *The Journal of Peasant Studies*, *0*, 1–23. https://doi.org/10.1080/03066150.2019.1602520

Hall, D. (2013). Primitive accumulation, accumulation by dispossession and the global land grab. *Third World Quarterly*, *34*(9), 1582–1604. https://doi.org/10.1080/01436597.2013.843854

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., … Townshend, J. R. G. (2013). High-resolution global maps of 21st-century forest cover change. *Science*, *342*(6160), 850–853. https://doi.org/10.1126/science.1244693

Hasegawa, T., Fujimori, S., Havlík, P., Valin, H., Bodirsky, B. L., Doelman, J. C., … Witzke, P. (2018). Risk of increased food insecurity under stringent global climate change mitigation policy. *Nature Climate Change*, *8*(8), 699. https://doi.org/10.1038/s41558-018-0230-x

Julia, & White, B. (2012). Gendered experiences of dispossession: Oil palm expansion in a Dayak Hibun community in West Kalimantan. *The Journal of Peasant Studies*, *39*(3–4), 995–1016. https://doi.org/10.1080/03066150.2012.676544

Jung, S., Liao, C., Agrawal, A., Brown, D.G. (2019). Evidence on Wealth-Improving Effects of Forest Concessions in Liberia. *Journal of the Association of Environmental and Resource Economists*, *6*, 961–1000. https://doi.org/10.1086/704614

Kc, S., & Lutz, W. (2017). The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100. *Global Environmental Change*, *42*, 181–192. https://doi.org/10.1016/j.gloenvcha.2014.06.004

Keola, S., Andersson, M., & Hall, O. (2015). Monitoring economic development from space: Using nighttime light and land cover data to measure economic growth. *World Development*, *66*, 322–334. https://doi.org/10.1016/j.worlddev.2014.08.017

Kugelman, M., & Levenstein, S. L. (Eds.). (2012). *The global farms race: Land grabs, agricultural investment, and the scramble for food security*. Washington, D.C.: Island Press.

Lavers, T. (2012). 'Land grab' as development strategy? The political economy of agricultural investment in Ethiopia. *The Journal of Peasant Studies*, *39*(1), 105–132. https://doi.org/10.1080/03066150.2011.652091

Liao, C., Jung, S., Brown, D. G., & Agrawal, A. (2016). Insufficient research on land grabbing. *Science*, *353*(6295), 131–131. https://doi.org/10.1126/science.aaf6565

McAllister, K. E. (2015). Rubber, rights and resistance: The evolution of local struggles against a Chinese rubber concession in northern Laos. *The Journal of Peasant Studies*, *42*(3–4), 817–837. https://doi.org/10.1080/03066150.2015.1036418

McKay, B., Sauer, S., Richardson, B., & Herre, R. (2016). The political economy of sugarcane flexing: Initial insights from Brazil, southern Africa and Cambodia. *The Journal of Peasant Studies*, *43*(1), 195–223. https://doi.org/10.1080/03066150.2014.992016

Messerli, P., Giger, M., Dwyer, M. B., Breu, T., & Eckert, S. (2014). The geography of large-scale land acquisitions: Analysing socio-ecological patterns of target contexts in the global south. *Applied Geography*, *53*, 449–459. https://doi.org/10.1016/j.apgeog.2014.07.005

Moreda, T. (2015). Listening to their silence? The political reaction of affected communities to large-scale land acquisitions: Insights from Ethiopia. *The Journal of Peasant Studies*, *42*(3–4), 517–539. https://doi.org/10.1080/03066150.2014.993621

Nolte, K., Chamberlain, W., & Giger, M. (2016). International land deals for agriculture. Fresh insights from the Land Matrix: Analytical Report II. Centre for Development and Environment, University of Bern: Bern, Switzerland.

Oakland Institute. (2011, May 4). Understanding land investment deals in Africa: Ethiopia. Retrieved from http://www.oaklandinstitute.org/understanding-land-investment-deals-africa-ethiopia

Oberlack, C., Tejada, L., Messerli, P., Rist, S., & Giger, M. (2016). Sustainable livelihoods in the global land rush? Archetypes of livelihood vulnerability and sustainability potentials. *Global Environmental Change*, *41*, 153–171. https://doi.org/10.1016/j.gloenvcha.2016.10.001

Oldenburg, C., & Neef, A. (2014). Reversing land grabs or aggravating tenure insecurity? Competing perspectives on economic land concessions and land titling in Cambodia. *Law and Development Review*, *7*(1), 49–77. https://doi.org/10.1515/ldr-2014-0014

Oliveira, P. J., Asner, G. P., Knapp, D. E., Almeyda, A., Galván-Gildemeister, R., Keene, S., … Smith, R. C. (2007). Land-use allocation protects the Peruvian Amazon. *Science*, *317*(5842), 1233–1236. https://doi.org/10.1126/science.1146324

Perz, S., Brilhante, S., Brown, F., Caldas, M., Ikeda, S., Mendoza, E., … Walker, R. (2008). Road building, land use and climate change: Prospects for environmental governance in the Amazon. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *363*(1498), 1889–1895. https://doi.org/10.1098/rstb.2007.0017

Ruesch, A., & Gibbs, H. (2008, January 30). New IPCC Tier-1 Global Biomass Carbon Map for the Year 2000. Retrieved from http://cdiac.ornl.gov/epubs/ndp/global_carbon/carbon_documentation.html

Rulli, M. C., Casirati, S., Dell'Angelo, J., Davis, K. F., Passera, C., & D'Odorico, P. (2019). Interdependencies and telecoupling of oil palm expansion at the expense of Indonesian rainforest. *Renewable and Sustainable Energy Reviews*, *105*, 499–512. https://doi.org/10.1016/j.rser.2018.12.050

Rulli, M. C., & D'Odorico, P. (2014). Food appropriation through large scale land acquisitions. *Environmental Research Letters*, *9*(6), 064030. https://doi.org/10.1088/1748-9326/9/6/064030

Rulli, M. C., Saviori, A., & D'Odorico, P. (2013). Global land and water grabbing. *Proceedings of the National Academy of Sciences*, *110*(3), 892–897. https://doi.org/10.1073/pnas.1213163110

Seufert, P. (2013). The FAO voluntary guidelines on the responsible governance of tenure of land, fisheries and forests. *Globalizations*, *10*(1), 181–186. https://doi.org/10.1080/14747731.2013.764157

Shete, M., & Rutten, M. (2015). Impacts of large-scale farming on local communities' food security and income levels—Empirical evidence from Oromia region, Ethiopia. *Land Use Policy*, *47*, 282–292. https://doi.org/10.1016/j.landusepol.2015.01.034

Shete, M., Rutten, M., Schoneveld, G. C., & Zewude, E. (2016). Land-use changes by large-scale plantations and their effects on soil organic carbon, micronutrients and bulk density: Empirical evidence from Ethiopia. *Agriculture and Human Values*, *33*(3), 689–704. https://doi.org/10.1007/s10460-015-9664-1

Sikor, T. (2012). Tree plantations, politics of possession and the absence of land grabs in Vietnam. *The Journal of Peasant Studies*, *39*(3–4), 1077–1101. https://doi.org/10.1080/03066150.2012.674943

Tubiello, F. N., Salvatore, M., Ferrara, A. F., House, J., Federici, S., Rossi, S., … Smith, P. (2015). The contribution of agriculture, forestry and other land use activities to global warming, 1990–2012. *Global Change Biology*, *21*(7), 2655–2660. https://doi.org/10.1111/gcb.12865

Tura, H. A. (2018). Land rights and land grabbing in Oromia, Ethiopia. *Land Use Policy*, *70*, 247–255. https://doi.org/10.1016/j.landusepol.2017.10.024

Vermeulen, S., & Cotula, L. (2010). Over the heads of local people: Consultation, consent, and recompense in large-scale land deals for biofuels projects in Africa. *The Journal of Peasant Studies*, *37*(4), 899–916. https://doi.org/10.1080/03066150.2010.512463

Wendimu, M. A., Henningsen, A., & Gibbon, P. (2016). Sugarcane outgrowers in Ethiopia: "Forced" to remain poor? *World Development*, *83*, 84–97. https://doi.org/10.1016/j.worlddev.2016.03.002

White, B., Borras, S. M., Hall, R., Scoones, I., & Wolford, W. (2012). The new enclosures: Critical perspectives on corporate land deals. *The Journal of Peasant Studies*, *39*(3–4), 619–647. https://doi.org/10.1080/03066150.2012.691879

Wilcove, D. S., & Koh, L. P. (2010). Addressing the threats to biodiversity from oil-palm agriculture. *Biodiversity and Conservation*, *19*(4), 999–1007. https://doi.org/10.1007/s10531-009-9760-x

Zagema, B. (2011). Land and power: The growing scandal surrounding the new wave of investments in land. *Oxfam Policy and Practice: Agriculture, Food and Land*, *11*(6), 114–164.

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