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Large scale land acquisitions and REDD+: a synthesis of conflicts and opportunities

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Abstract

Large scale land acquisitions (LSLA), and Reducing Emissions from Deforestation and forest Degradation (REDD+) are both land based phenomena which when occurring in the same area, can compete with each other for land. A quantitative analysis of country characteristics revealed that land available for agriculture, accessibility, and political stability are key explanatory factors for a country being targeted for LSLA. Surprisingly LSLA occur in countries with lower accessibility. Countries with good land availability, poor accessibility and political stability may become future targets if they do not already have LSLA. Countries which high levels of agriculture-driven deforestation and LSLA, should develop interventions which reduce forest loss driven either directly or indirectly by LSLA as part of their REDD+ strategies. Both host country and investor-side policies have been identified which could be used more widely to reduce conflicts between LSLA and REDD+. Findings from this research highlight the need for and can inform the development of national and international policies on land acquisitions including green acquisitions such as REDD+. Land management must be considered with all its objectives—including food security, biodiversity conservation, and climate change mitigation—in a coherent strategy which engages relevant stakeholders. This is not currently occurring and might be a key ingredient to achieve the targets under the Sustainable Development Goals 2 and 15 and 16 (related to food security and sustainable agriculture and the protection of forests) among others.

1. Introduction

Land use and land use changes are influenced by global processes including two, which have received recent attention: Large Scale Land Acquisitions (LSLA) and Reducing Emissions from Deforestation and forest Degradation (REDD+). LSLA can be defined as large-scale (≥ 200 ha) land investments which result in the transfer of rights, control or ownership of land (Nolte *et al* 2016), although there is ongoing discussion about the definition of LSLA (Edelman *et al* 2013). LSLA can provide benefits to local communities (Smalley *et al* 2014, Deininger and Byerlee 2011) and income to host

governments who in some cases actively seek investments (Friis and Reenberg 2010). However, there is a general consensus that LSLA occurring in low-income countries results in negative impacts on food and tenure security, and the livelihoods of local communities (Cotula 2012). REDD+ is a mechanism designed to reduce global greenhouse gasses (GHGs) in the atmosphere, while promoting forest conservation, sustainable management of forests and enhancing carbon stocks (UNFCCC 2014). REDD+ features prominently in the Paris Climate Agreement (UNFCCC 2015) due to the impact of land use change on GHG emissions, with forest loss being

major source of GHG emissions in tropical countries (Houghton *et al* 2012).

Being a globally limited resource (Foley *et al* 2011, Seppelt *et al* 2014) competition for land for different land uses occurs and thus links LSLA and REDD+. LSLA has also been identified as a driver of forest loss potentially causing conflicts with REDD+ efforts (Scholes 2012). Yet, most research on LSLA has focussed on the social and political aspects of the phenomena (e.g. De Schutter 2011, Messerli *et al* 2013, Scoones *et al* 2013a, Borras *et al* 2012, Edelman 2013, Edelman *et al* 2013), and the impacts on forests and on forest protection efforts including REDD+ have not been widely researched to the authors' knowledge.

Most LSLA deals (80%) are for agriculture (Nolte *et al* 2016), with agricultural LSLA being the focus of much research (e.g. De Schutter 2011, Cotula *et al* 2011, Mbow 2010). There is an existing body of research on the factors related to agricultural LSLA, with underlying or ultimate drivers on the global scale being world population increases, dietary changes, financial crises (which promote land as an alternative investment source), and public policies such as European Union biofuel consumption targets and food price increases among others (Friis and Reenberg 2010, Cotula *et al* 2009, Messerli *et al* 2013, Edelman *et al* 2013, Cotula 2012). Research also exists on the characteristics of areas or countries which are hosts of LSLA and the factors making them attractive to investors. Expanding economic relations between host and investor countries (or economic liberalization of host countries) and support to the private sector through informational, technical and bureaucratic assistance are cited as important. There is no analysis yet however, which identifies the drivers of LSLA for agriculture in a statistically robust and consistent way. This study aims to fill this gap, by providing a comprehensive analysis of country characteristics which may be favourable for LSLA. We use the results to link LSLA with REDD+.

REDD+ has been compared to LSLA and has been labelled one type of 'green grabbing' (Fairhead *et al* 2012). LSLA and REDD+ can have similar impacts on land tenure, biodiversity and sustainable development (Fairhead *et al* 2012, Larson *et al* 2013), but REDD+ has been developed with the aim of avoiding some of the negative effects which are typically linked with land acquisitions (Larson *et al* 2013), partially through the Cancun safeguards (UNFCCC 2010).

Understanding where LSLA occur is the first objective of this study, and a hypothesis about the predisposing factors characterizing countries which experience LSLA was tested using a data-driven approach. The aims of the study are thus (i) determining the predisposing factors which characterize countries which are objects of LSLA, (ii) identifying countries where forest loss may be driven by LSLA and (iii) exploring the potential to reduce forest loss and conflicts between REDD+ and LSLA.

2. Conceptual framework characterizing countries which are objects of LSLA

A deductive approach based on a literature review was used to build the hypothesis that countries that are objects of LSLA will have the following four characteristics:

Potential for returns from investments: LSLA is hypothesized to be more frequent in countries which have land with high potential agricultural productivity and can produce returns on investments of agricultural inputs. Agricultural LSLA are likely to occur in areas with favourable conditions for agriculture which has been demonstrated by growing pressure on the best lands such as those with good soil fertility or irrigation potential (Cotula 2012, Breu *et al* 2016). Land value may also influence buyers, with higher valued land (probably due to their favourable conditions for agriculture) attracting investors, although cheap lands where returns can be generated also attract investors (Cotula *et al* 2009, Cotula 2012). The increase in availability of fertilizers has been cited as a driver of agricultural LSLA (Cotula *et al* 2009), since higher yields will result from the investment in fertilizer.

Suitable land: It is assumed that investors focus on countries with large areas of land suitable for agriculture. A wide range of land cover and uses are appropriate for investments, including existing agricultural land (Deininger and Byerlee 2011, De Schutter 2011, Cotula *et al* 2011); both commercial (Cotula 2012) and smallholder (Anseeuw *et al* 2012, Fairhead *et al* 2012, Edelman *et al* 2013, Cotula 2012), and forests (Scholes 2012). Since it is also suggested that most land suitable for LSLA for agriculture is under use or claim already (Cotula *et al* 2009) this implies that frontier areas will be sought in future. There is also evidence that marginal lands play a role for new agricultural developments, but that the potential is not fully realized (Nalepa and Bauer 2012). Proximity to markets is cited as important for investors (Cotula 2012).

Access for investors: It is hypothesized that LSLA are more likely to occur in countries where investors can acquire and develop the land more easily. The legal regimes and national traditions for trade, investment and property (specifically laws and policies applying to land purchasing) will impact the likelihood of LSLA occurring (Edelman *et al* 2013). Host country governments make policy reforms specifically to improve the investment climate, including tax breaks to encourage investors, and reforming land regulations (Cotula 2012, Cotula *et al* 2009, Deininger and Byerlee 2011). In contrast to supporting policies, weak tenure regulations also equate to increased acquisitions (Cotula 2012, Corbera *et al* 2011). Other governments restrict investments, for example in the forestry and agricultural sectors, several countries do not allow 100% foreign ownership (including Philippines, Mexico and Thailand which allow a 50% share, and

Armenia, India, Indonesia and Sudan which allow a 50%–80% foreign involvement) (World Bank 2014). Some countries have regulations related to specific crops, for example in Sierra Leone 5% to 20% of the shares of biofuel investments must be held by Sierra Leoneans (Cotula *et al* 2009).

Security of investments: Investors are assumed to develop LSLA in areas where there are low risks to loss of investments through for example conflicts. Political instability is considered a risk for investors in LSLA (Cotula *et al* 2009). There also needs to be a minimum regulatory requirement for investments to take place which will ensure respect for private property. The regulatory environment determines how control of resources and stakeholders allows the investor to acquire the land and use it for the desired purpose. This aspect of LSLA is referred to as 'control grabbing' (Borras *et al* 2012, Messerli *et al* 2013). Additionally economic sanctions in the form of trade embargos are often imposed on countries engaged in conflicts, which although are mainly focussed on goods related to conflicts (EC 2016) can affect agricultural activities, making investments insecure. A number of countries included in this study currently have these restrictive measures related to trade (EC 2016).

3. Data and methodology

3.1. Data on LSLA: the land matrix

Occurrences of LSLA were determined using the Land Matrix, which was designed to introduce transparency and inclusion in decision making in the land acquisition sector (Anseeuw *et al* 2012, Nolte *et al* 2016). A binary response variable (whether a country is an object of LSLA or not) was used. LSLA were therefore defined according to the definition of the Land Matrix, however only international investments for agricultural purposes (including biofuels and fibre) were included with domestic land acquisitions being excluded. Only 'concluded' or 'contract signed' deals were included. The countries included in the study were restricted to the scope of the Land Matrix, which is lower-middle income countries. In this study the World Bank (World Bank 2013) list of low to middle income countries was used to identify those countries which had no LSLA. Some inconsistencies appeared in the current list of lower-middle income countries, and those which appeared in the Land Matrix. So countries which appeared in the Land Matrix, but were middle income countries in 2010 (i.e. recently promoted to the high income category according to the World Bank definition) were included (Uruguay, Russia, Lithuania, Chile), leading to a population of 142 countries. This study therefore includes some non-annex 1 countries which were excluded for the analysis related to REDD+ and LSLA to avoid misinterpretation of results given the fact that non-annex 1 countries are not eligible for REDD+.

The Land Matrix includes land deals reported by media, official data and research outputs, so methods may be affected and results biased by the intention to produce data for advocacy purposes (Edelman *et al* 2013, Scoones *et al* 2013a). Other potential biases in the Land Matrix are that countries under autocratic rule tend to provide less information and conflict-ridden areas may receive more press attention. Biases in datasets can be dealt with statistically, however validation information on LSLA is required which is not available. Utilizing a binary response variable for LSLA occurrences largely overcomes these biases, since it is unlikely that a country with LSLA would have all LSLA occurrences from the Land Matrix database missing, and if some but not all of the occurrences were missing, the binary response would be correct. Although there is a debate as to the quality of the Land Matrix data, there is also an agreement that these data are valuable for developing the agenda on the topic (Scoones *et al* 2013b, Rulli and Odorico 2013). Indeed, several examples exist where the Land Matrix and other similar data have been successfully used to assess LSLA in a number of contexts (Deininger and Byerlee 2011, Rulli *et al* 2012, Anseeuw *et al* 2012, Giovannetti and Ticci 2016, Breu *et al* 2016).

3.2. Characterizing countries which are objects of LSLA: indicators

Indicators were identified (table 1) for each of the four components of the hypothesis regarding the characteristics of countries which are objects of LSLA (section 2). Data sources for which 33% of countries had no data were omitted (average missing data was <10% for all variables).

For the accessibility variable, we use the gridded data set provided by the EU joint research centre (JRC) to estimate the average travel time to major cities (>50 000 inhabitants) per country (Uchida and Nelson 2008). Here accessibility is the travel time to a given location of interest using available transport networks. Transport networks include land based transport; on and off roads and rail networks, and water networks; via navigable rivers and shipping lanes in lakes and oceans. Transport type, potential speeds on different road types, and environmental factors such as land cover and slope are used to calculate the travel speed of the transport network. National boundaries and border crossings are considered, as they can lead to travel delays (Uchida and Nelson 2008). Thus we characterize each country by the average travel time to major cities. As cities are defined by population, they represent potential markets.

Area of land available for agricultural use was calculated as a proportion of the country land area (Carter *et al* 2015) (table 2). Urban areas, as well as bare areas, water bodies, permanent snow and ice, and areas dominated by lichens and mosses, which are likely to have a low biophysical potential for

Table 1. Variables used to identify characteristics of countries which explain whether or not they are objects of LSLA (as defined by the Land Matrix).

Characteristic	Expected indicator for LSLA occurrence and explanation	Data source and description	Variable name
Potential for returns	Large yield gaps exist	Difference between actual yield and potential yield of major grains (t ha^{-1}) (Neumann *et al* 2010), weighted based on the area under production (Monfreda *et al* 2008)	Yield gap
	Agriculture is a successful sector, and contributes to the countries' GDP (high share)	% of GDP (gross domestic product) from agriculture (c. year 2013 or most recent) (World Bank 2013)	Agricultural GDP
	Appropriation of net primary productivity (NPP) by humans is demonstrated (high value)	Total quantity of NPP appropriated by humans as vegetables, paper, wood (including construction and fuel use), meat, soft fibre, eggs and milk (Imhoff and Bounoua 2006, Imhoff *et al* 2004) (Pg C)	HANPP
Suitable land	Area of land available for agricultural use, which is not protected is large (high percentage)	Multiple data sources (table 2) (% of country land area)	Available land
	Accessibility to markets is high (lower travel time; low value)	Accessibility, average travel time to city (minutes) (Uchida and Nelson 2008)	Accessibility
Access for investors	Favourable conditions for business (high score on business index)	Ease of doing business (World Bank 2013), ordinal data	East of doing business
	Regulatory quality (high value)	World Bank governance indicators (World Bank 2012), ordinal data	Regulatory quality
Security of investment	Control of corruption is good (high value)	Control of corruption (World Bank 2012), ordinal data	Corruption
	Country is peaceful (high value)	Global peace index (Institute for Economics and Peace 2015), ordinal data	Peace
	Country is stable (low value)	Fragile states index (Fund For Peace 2015), ordinal data	Fragile

Table 2. Land available for LSLA—data sources and availability conditions.

Availability factor	Availability condition	Data source and description
Land use/cover	Land is not bare, urban, water, permanent snow and ice or currently lichen or mosses	300 m resolution land cover map based on a global surface reflectance (SR) composite time series, 2010 (ESA 2013)
Yield potential for rainfed agriculture	Potential crop productivity >3.5 t ha^{-1}	10 arc minute climate dataset combined with soil water storage map and a dynamic water and crop model (Droogers *et al* 2001)
Suitable topography for agriculture	Slopes <15%	30 arc second aggregate based on 90 m resolution digital terrain map from the Shuttle Radar Topographic Mission (SRTM) (Fischer *et al* 2008)
Protected area status	Land does not have protected area status	Globally spatially referenced World Database of Protected Areas (WDPA) (IUCN UNEP-WCMC 2014)

agriculture were excluded. Land with steep slopes, and land with a low potential for agricultural productivity was also excluded, and forests were left in. Information about the selection of these indicators can be found in Carter *et al* (2015). Protected areas were excluded since these are typically considered to be unavailable for agriculture (Lambin *et al* 2013). Protected areas can reduce deforestation (and therefore may be off-limits for LSLA), however Soares *et al* (2010) show that deforestation rates within and outside protected areas may in specific cases not differ. Additionally, in Myanmar, forest reserves have been de-gazetted in order to allow for LSLA (Woods 2015). Another study investigating land for cropland expansion did not consider International Union for Conservation of Nature (IUCN) protected areas categories V and VI

(Protected Landscape/ Seascape and Protected area with sustainable use of natural resources) a limit for agricultural expansion as cropland can exist in these areas (Eitelberg *et al* 2015). However since details on IUCN categories in the World Database of Protected Areas are incomplete (IUCN UNEP-WCMC 2014) all IUCN protected areas were excluded. The inclusion of protected areas therefore in this case gives an indication of barriers for LSLA, but LSLA can also occur where it is not permitted according to an area's protected area status.

3.3. Characterizing countries which are objects of LSLA: classification trees

Classification trees were used to understand the relationship between the response variable (presence or absence of LSLA) and the explanatory variables

(see tables 1 and 2). Classification trees have been used in a variety of situations, and when tested against other comparable methods (clustering or regressions for example) provided useful results (Moreno-Fernández *et al* 2015, Shekoofa *et al* 2014). In our case, a number of the explanatory variables are highly correlated and show strong non-linear relationships (as would be expected with socio-economic measures at the country level), and have missing data. Classification trees are able to handle such data characteristics. Classification and Regression Trees (C&RT), involve recursive partitioning to complete a binary tree of homogenous subsets through reducing the impurity in each step. C&RT uses the Gini impurity to select variables. Trees were pruned by cross-validation to avoid overfitting, the minimum number of cases for each node (parent or child) was set to 5, and trees were produced with SPSS 22 (IBM 2013).

3.4. The impact of LSLA on REDD+ and forests

In order to assess the potential for forest loss due to LSLA, two assumptions were considered. Firstly, where agriculture driven deforestation is already high, there is existing demand for farmland so it is likely that any further acquisitions would exacerbate the need for farmland. Secondly, countries which are already objects of LSLA or which have characteristics which are particularly attractive to LSLA investors (findings of the classification tree) can potentially have LSLA driven forest loss. Where both REDD+ and LSLA appear in the same country, potential conflicts occur, so possible mechanisms to avoid this are discussed. Assessments of REDD+ drivers and interventions were made, to establish if LSLA was considered a threat to forests and if interventions were in place to address this threat.

Data on agriculture-driven deforestation were obtained from Carter *et al* (2015) who combined data on deforestation for the period 2000–2010 with data on the proportion of deforested land which is converted to agriculture. Percent loss of forest area was reported, and countries were divided by tertiles into 3 groups of 41; low, medium, and high agriculture-driven deforestation (19 had no data on agriculture-driven deforestation).

In line with Carter *et al* (2015), engagement in REDD+ was determined by including engagement in international REDD+ initiatives such as UN-REDD, World Bank Forest Carbon Partnership Facility as well as REDD+ project development and funding acquisition. Countries were classed as being engaged in REDD+ if any of these occurred.

A review of REDD+ documents was carried out to identify if LSLA-related drivers specifically are considered a threat to forests according to national REDD+ preparation documents. For this study, the most recent REDD+ Readiness Preparation Proposals (R-PPs) submitted to the World Bank Forest Carbon Partnership Facility (FCPF) (FCPF 2015) were reviewed to assess if

LSLA was specifically considered a driver. Additionally, country reported information on the main drivers of deforestation (direct and indirect) as summarized by Kissinger *et al* (2012) were divided into those related to and not related to LSLA (supplementary table 2 available at stacks.iop.org/ERL/12/035010/mmedia).

Data from Salvini *et al* (2014) were used, to identify countries whose REDD+ interventions address LSLA. An analysis of available documents (including R-PPs) was carried out by Salvini *et al* (2014) who assessed whether proposed interventions which were designed to reduce deforestation were linked to the drivers which were also identified. Both Kissinger *et al* (2012) and Salvini *et al* (2014) use official documents which are available and on which REDD+ implementation is based.

4. Results

4.1. The characteristics of countries which are objects of LSLA

There were 142 countries in the analysis, 80 (56%) of which were objects of LSLA and 62 (44%) were not. The classification tree's main split was based on available land, showing this has the most discriminating role ($p < 0.0001$) in determining whether or not a country is likely to have LSLA. Countries with relatively small areas of land available (<18.9% of the country area) are more likely not to have LSLA. If available land area is above this threshold, then an accessibility indicator (mean travel time in the country >192 minutes to a large city or market), determines that countries are likely to have LSLA. For countries with a travel time below this threshold, then fragility is the determinant, and those more fragile (>72.8—described as a 'warning' or 'alert' by the Fragile states index (Fund For Peace 2015)) are likely not to have LSLA. The classification tree has an overall accuracy of 78.9%, an omission error (not identifying a LSLA country) of 13.8% and comission error (identifying a non-LSLA country as a LSLA country) of 30.6% for LSLA.

4.2. LSLA, forest loss and REDD+

Figure 2 (see also supplementary table 1) groups countries according to the level of agriculture-driven deforestation (percent forest loss, divided into tertiles) and the node in which they end up in the classification tree. Node 1, in which 22.2% of the countries have LSLA, includes mainly countries with low agriculture-driven deforestation, and node 2, where most countries (81.6% of all countries) have LSLA includes countries which are more likely to have high agriculture-driven deforestation.

REDD+ and LSLA can both occur in the same country (figure 2, table 3). Only countries that are eligible for REDD+ (non-annex 1 countries) and are
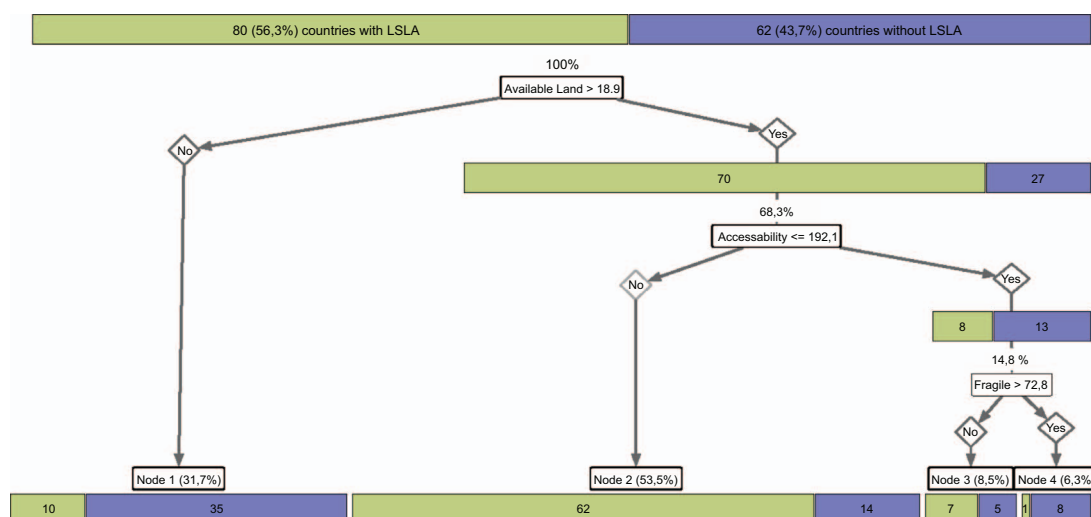
Figure 1. Classification tree characterizing countries which are and are not objects of LSLA. The percentage and number (*n*) of countries belonging to each node are shown, with the condition by which the split is made labelled above each node, and the name of the variable related to that condition is marked at each split.
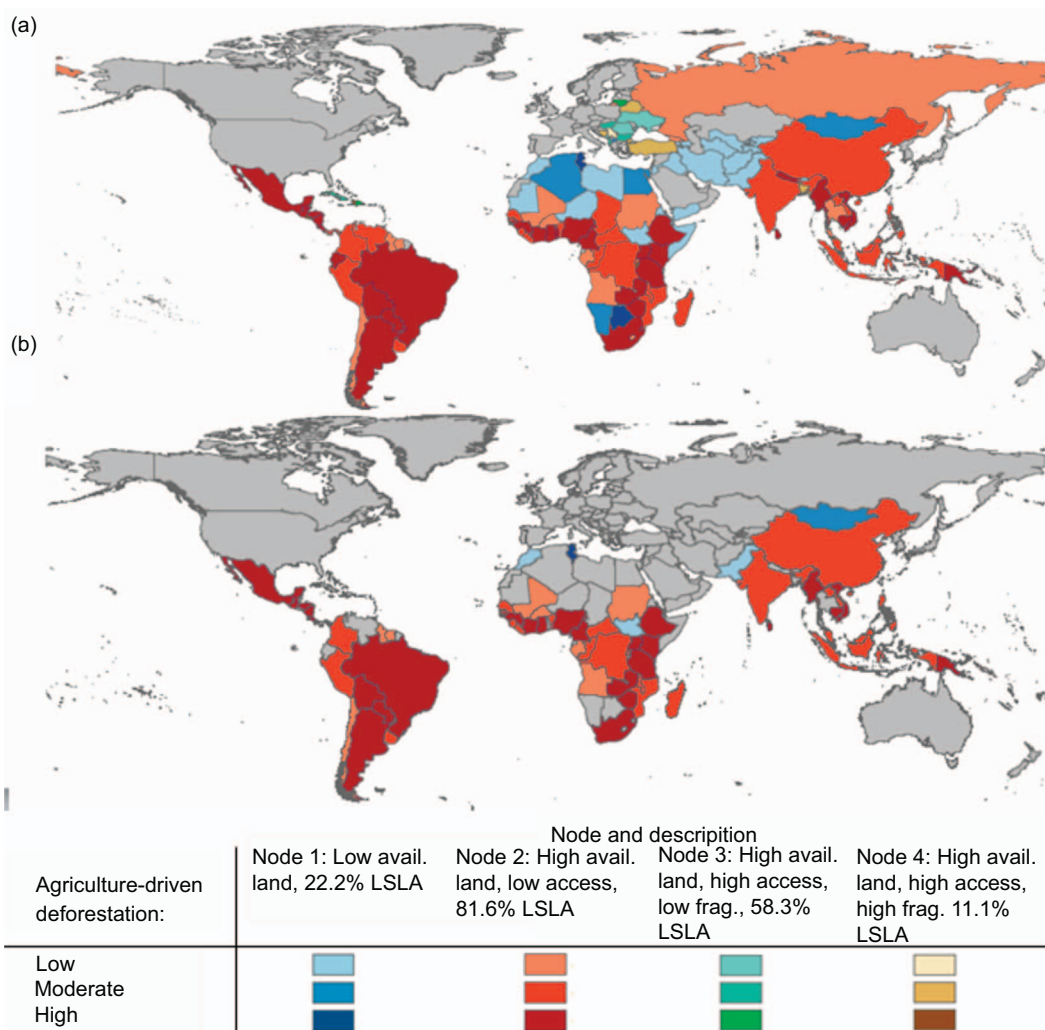
Figure 2. Agriculture-driven deforestation (percent forest loss 2000–2010 divided into tertiles) and classification of country with respect to likeliness of LSLA placement in the classification tree (figure 1) for (*a*) all countries in the study, which also colours those countries which do not report LSLA but show similar characteristics to those with LSLA. (*b*) only those countries are coloured (in accordance to the classification as described in a), for which LSLA is reported and which participate in REDD+. Nodes are defined in accordance to the results of the classification tree, 1: low available (avail.) land, 2: High available land and low access, 3: high available land, high access, low fragility (frag.), 4: high available land, high access and high fragility.

Table 3. Instances of LSLA recorded in Land Matrix and engagement in REDD+.

Number of countries[a]	LSLA	No-LSLA
REDD+	62	17
No-REDD+	12	41

[a] 10 countries included in the Land Matrix were not eligible for REDD+ (i.e. they were UNFCCC Annex 1 countries) so they were not included in this analysis.

within the scope of the Land Matrix (low and middle income countries) were analysed. Targets of LSLA were 12 times (95% confidence interval 5–32) more likely to be engaged in REDD+ than those who do not have LSLA (P-value of Fisher exact test of association between 132 targets of LSLA and REDD+ <0.001).

Of the countries which are eligible for REDD+, countries in node 2 (around 80% of which have LSLA) are more likely to be engaged in REDD+ than those in the other nodes in the decision tree (which less have LSLA). Countries in node 2 with high agriculture-driven deforestation tend to be engaged in REDD+ (31 out of 34 countries, all of which are eligible for REDD+), and are spread across Africa, South and Central America and Asia.

In the 30 countries for which REDD+ documents were assessed, agriculture expansion was noted as a major driver of deforestation, with commercial monocultures typical of LSLA being cited as major causes in many countries (supplementary table 2). In a number of countries, agricultural LSLA are occurring but the country does not cite commercial agricultural expansion as a driver (Democratic Republic of the Congo, Kenya, Republic of Congo, Zambia) (Kissinger *et al* 2012). In these cases it could be that LSLA occur in non-forested land, or more likely that the driver is not recognized. In some countries, LSLA was specifically identified as a direct driver of deforestation (Burkina Faso, Cambodia, Central African Republic, Guatemala) (Kissinger *et al* 2012). Indirect drivers also pointed towards LSLA being a threat, with weak governance, poor enforcement of laws, and tenure being cited commonly as drivers (Kissinger *et al* 2012). Two of the countries in the study by Kissinger *et al* (2012) which did not have LSLA (El Salvador, Panama) cited agriculture expansion, and in particular commercial/mechanized agriculture as a main driver of deforestation. In these cases, it could be that domestic LSLA were occurring (which were excluded from the analysis). Of the 27 REDD+ countries investigated which have LSLA, only nine have interventions aiming to reduce deforestation which address the driver. For the four countries that specifically cite LSLA as a driver of deforestation (including Cambodia, Burkina Faso and Central African Republic), only Guatemala has planned interventions which specifically address this and other drivers identified[a] there.

5. Discussion

5.1. The characteristics of countries which are objects of LSLA

The review of literature revealed four important requirements for LSLA: potential for returns, available land, access for investment and security of investment. The results from this analysis confirm several of these requirements. Available land was found to be the main determinant of whether a country will have LSLA. Countries with >19% land suitable for agriculture were more likely to have LSLA than countries with less than 19% available land (21 countries). These countries with less than 19% available land included those covered by large arid areas which is not suitable for agriculture (for example those with land area within the Sahara desert: Algeria, Eritrea, Egypt, Libya, Niger). For countries with large areas of available land, access to land is also relevant to whether or not they have LSLA. Literature on LSLA suggests that areas with access to markets are more favourable for LSLA, and this may be the case for individual instances of LSLA. Our study found that countries with low access are more likely to have LSLA, which is likely to be partly because our research focuses on deals, which are often large (on average >330 km^2 (The Land Matrix Global Observatory 2013)), and it is likely that large tracts of land cannot be found in countries which have more urban areas for example (where access is high). Countries which have a large areas of suitable land but access of <192 minutes travel time to markets on average in the country, are not interesting to investors if countries fragility is high. This confirms the hypothesis that security of investments is likely to be a consideration for investors. Indicators which identified the 'access for investors' criteria (favourable conditions for business, and regulatory quality), were not found to be related to LSLA according to this methodology. However, an indicator not being recognized in the decision tree does not confirm the absence of a link with LSLA. Other indicators for this criteria 'access for investors' could be tested to confirm the hypothesis posed in this study.

Countries which exhibit the characteristics which are attractive to investors: land availability, poor accessibility and political stability may be future targets if they do not already have of LSLA (for example Belize, Ecuador, Nepal and Togo).

There are other characteristics which literature suggested would be linked with LSLA but which were excluded from the analysis because they were not relevant for investors, or data were not available or suitable. For example land prices were found to influence LSLA, with cheap land being preferred by investors as there is potential for capital accumulation, which can mitigate risks in agricultural production (Cotula 2012). However, there is a lack of data on land prices thus it was not included in the analysis.

Populated areas can also be attractive to LSLA investors (Messerli *et al* 2013), however population density was not included since it is likely to vary widely across countries, with the national average not describing situation for local LSLA investments well (Eckert *et al* 2016). Despite these limitations, the deductive approach used to identify factors which attracted investors, allowed the identification of key characteristics of countries which were objects of LSLA. More research carried out at different scales, would allow the identification of more characteristics linked to LSLA (Eckert *et al* 2016).

5.2. Impact of LSLA on forests
This study did not include domestic LSLA, since the aim of the C&RT analysis was to investigate what characteristics attract foreign LSLA investors to countries. However, domestic LSLA can still threaten forests, so Bangladesh, Niger and Thailand which have only domestic deals should be considered when analysing the impact of LSLA on forests (see supplementary table 1).

Countries with LSLA or that have characteristics found in countries with LSLA, often have high agriculture-driven deforestation (figure 2). Although this study cannot confirm a causal relationship (neither direct nor indirect) between LSLA and deforestation, LSLA are often very large, and have been reported to occur in forested areas, and therefore can impact forest cover. According to the Land Matrix, the average size of concluded transnational deals (for any intention) is 364 km^2, which is more than the area of annual deforestation in 83 of 125 countries included in this study for which data were available (17 had no data). Many countries also have multiple deals, and considering that the largest agriculture-related reported deal is 14 000 km^2 (Republic of Congo), there is potential for large areas of forest loss if forested areas are targeted. On average there are 15 concluded deals in each country, and the countries with the largest number of LSLA are Indonesia (125), Cambodia (104) and Mozambique (79). In these countries increased attention to forest loss associated with LSLA would be beneficial, as a larger area of LSLA may result in a larger chance of forests being targeted. The relative size of forest compared to agricultural land is also likely to be important for estimating impacts of LSLA on forests, for example Democratic Republic of the Congo has vast forest areas, and the total area of land deals in this country (according to the Land Matrix database) account for an area of only 1% of the total forest area. In contrast, in Cambodia, land deals account for an area equivalent of 16% forest area, 28% agricultural area, or 41% of its arable land area (NGOs estimate a higher proportion: between 56 and 63% of the arable land area (Edelman 2013)). Even if non-forested land in Cambodia is targeted for LSLA, deforestation could occur indirectly where existing activities on the land are displaced into forests.

In some cases LSLA are 'virtual' acquisitions as the conversion to another land use is postponed for long periods, is partially realized, fails to materialize (McCarthy *et al* 2012), or acquisitions are speculative and so they involve small and temporary investments (Messerli *et al* 2013). These virtual acquisitions may have less of an impact to forests than when conversion to agriculture occurs. However, even if the land is not converted for its intended use, degradation may occur as experienced in Indonesia, where licences and subsidies are given for establishing plantations, but companies instead clear the forest, sell the timber and abandon the land (Romijn *et al* 2013). In this case, if land is not subsequently converted to agriculture, it is possible that regrowth of the forest will occur.

5.3. Potential to reduce the impact of LSLA on forests
To avoid loss of forests from LSLA, the link between the two needs to be understood. Salvini *et al* (2014) describe a logical chain for developing interventions to address drivers of deforestation. For interventions to be effective, an understanding of specific drivers should be made and following this, interventions can be designed to address these drivers. REDD+ interventions should then be redesigned following an assessment (monitoring) of the success of the intervention. In in many cases, this link between drivers and interventions is not made in REDD+ plans (supplementary table 2). For the countries in which agricultural LSLA are occurring, but in which commercial agricultural expansion is not cited as a driver (Democratic Republic of the Congo, Kenya, Republic of Congo, Zambia) more work can be invested in determining if LSLA is driving deforestation (the first step in the logical chain). The second step is designing the interventions to match the drivers. In the cases of Indonesia, Cambodia and Mozambique (the countries with the highest number of LSLAs according to the Land Matrix), the impacts of commercial agriculture on forests are recognized in the REDD+ documentation, however only in Mozambique were the interventions found to match the drivers of deforestation (supplementary table 2). For countries which do not recognize commercial agriculture as a driver of deforestation but that identify LSLA as a driver, indirect drivers such as lack of planning and consultation, and lack of secure land tenure are cited. Based on this knowledge, countries can develop interventions which address these indirect drivers, however, developing interventions directly targeting LSLA is recommended to reduce the impact of LSLA on forests.

The fact that some countries do not identify drivers, or do not propose interventions which address these drivers is particularly interesting. Of the 27 countries which were assessed (supplementary table 2), all had already produced the R-PP s which forms the basis of their strategy in the FCPF (excluding Zambia which is

participating in UN-REDD), so are relatively advanced in terms of REDD+ implementation.

In general, investments in agricultural land (such as through LSLA) are thought to lead to increased returns which incentivise expansion (Angelsen 2008, Deininger and Byerlee 2011, Pirard and Belna 2012). Two potential mechanisms exist through which agricultural investments can occur without impacting forests. Firstly, existing agricultural land can be acquired and production maintained or increased to avoid the displacement of agricultural activities to other areas (Valin *et al* 2013, Ausubel *et al* 2013). The Land sparing concept (or segregation) suggests that increasing the output on agricultural land reduces the need to increase agricultural areas (Kastner *et al* 2012, Stevenson *et al* 2013). Specifically, technology-induced intensification is supposed to be land saving at the global level (Byerlee *et al* 2014) but could potentially have negative effects on productivity (Seppelt *et al* 2016). Secondly, available or degraded land can be used for LSLA, again avoiding the need to acquire forested areas (Carter *et al* 2015). Global maps of unused or low carbon land have been produced (Dinerstein *et al* 2014), but national or regional maps are needed to suggest hot spots and cold spots of LSLA and deforestation coincidence. However there is some debate on whether there is land unused, or idle (which is non-forested), and also whether current maps are useful for identifying it, as discussed by Nalepa and Bauer (2012) on the use of remote sensing tools to identify marginal land. There are several examples of initiatives which aim to restore degraded land, for example 'Initiative 20x20' which aims to restore 20 million hectares of degraded land in Latin America and the Caribbean by 2020 (World Resources Institute 2016). However, these initiatives themselves need to be implemented with care, as they could be classed as 'green grabbing' and may involve elements found in LSLA; large areas, and a change in land rights being obvious ones.

5.4. Planning for LSLA and REDD+

Since there are a number of countries which have both REDD+ and LSLA, there is an opportunity for lessons learned in REDD+ to be transferred into the policies relating to LSLA. In the case of Liberia, the R-PP aims to avoid REDD+ becoming a LSLA. Much research is focussed on the impacts of LSLA on smallholders, which mainly stem from loss of land (Anseeuw *et al* 2012, Cotula 2012, Fairhead *et al* 2012, Edelman *et al* 2013, Oberlack *et al* 2016). Community participation is one key approach to mitigate this (Oberlack *et al* 2016). The Cancun 'guidance and safeguards for policy approaches and positive incentives related to REDD+' (UNFCCC 2010) include several actions mostly relating to rights of local communities and other stakeholders, which could be modified for the context of LSLA and directly integrated into national regulations. Consultations for REDD+ require the

engagement of relevant stakeholders, and an iterative consultation process that includes a complaint management process; a structure which would also be suited to the LSLA context. This has in some cases led to better tenure security (Larson *et al* 2013), which could also be beneficial for investors in LSLA. Similar recommendations can also be found for instance in Cotula *et al* (2009).

In practice, that there is a potential for interventions in the supply chains of agricultural products (for example those produced in LSLA) which aim to reduce deforestation, to be implemented alongside REDD+ to produce low emissions rural development (Nepstad *et al* 2013). Green public procurement policies (for example the Roundtable for Sustainable Palm Oil (RSPO 2016) and Round table on Responsible Soy (RTRS 2016)) could also make agricultural production more sustainable and aligned to climate change objectives. Zero-deforestation is commonly understood as commitments from the private sector to eliminate deforestation from their supply chain (Meyer and Miller 2015), and when applied to LSLA can avoid forest loss. Since investors of LSLA in this study are international and due to the scale of investments, it is likely that some are exporting products. Concern from countries and consumers in importing countries about environmental issues could lead to uptake of green procurement policies in LSLA.

One barrier to success is policy coherence which is typically difficult to achieve, and conflicting policies (for example those favouring LSLS and those favouring REDD+) can hinder sustainable land use (Minang *et al* 2015).

LSLA and REDD+ show two distinct patterns with respect to the governance of the global land system. While the first is driven by tele-connected global agricultural markets, the latter is a legal framework introduced to mitigate climate change. This study demonstrates how these processes co-occur in different countries where competition for land can potentially lead to conflicts. As such, LSLA should be specifically discussed in platforms where interventions to reduce deforestation are being planned. Our analysis suggests that land management must be considered with all its objectives such as food security, biodiversity conservation, climate change mitigation in a coherent strategy which engages relevant stakeholders. This is not currently occurring and might be a key ingredient for the implementation of activities to achieve the targets under the Sustainable Development Goals 2, 15 and 16 (related to food security and sustainable agriculture and the protection of forests) among others.

References

Angelsen A 2008 *Moving Ahead with REDD Issues, Options and Implications* ed A Angelsen (Bogor, Indonesia: Center for International Forestry Research (CIFOR))

Anseeuw W, Boche M, Breu T, Giger M, Lay J, Messerli P and Nolte K 2012 *Transnational Land Deals for Agriculture in the Global South Analytical Report based on the Land Matrix Database*

Ausubel J, Wernick I and Waggoner P 2013 Peak farmland and the prospect for land sparing *Popul. Dev. Rev.* **38** 221–42

Borras S, Kay C, Gomez S and Wilkinson J 2012 Land grabbing and global capitalist accumulation: key features in Latin America *Can. J. Dev. Stud. Can. d'études du développement* **33** 402–16

Breu T, Bader C, Messerli P, Heinimann A, Rist S and Eckert S 2016 Large-scale land acquisition and its effects on the water balance in investor and host countries *PLoS One* **11** 1–18

Byerlee D, Stevenson J and Villoria N 2014 Does intensification slow crop land expansion or encourage deforestation? *Glob. Food Sec.* **3** 92–8

Carter S, Herold M, Rufino M C, Neumann K, Kooistra L and Verchot L 2015 Mitigation of agricultural emissions in the tropics: comparing forest land-sparing options at the national level *Biogeosciences* **12** 4809–25

Corbera E, Estrada M, May P, Navarro G and Pacheco P 2011 *Rights to land, forests and carbon in REDD+: Insights from Mexico, Brazil and Costa Rica* vol 2

Cotula L 2012 The international political economy of the global land rush: a critical appraisal of trends, scale, geography and drivers *J. Peasant Stud.* **39** 649–80

Cotula L, Vermeulen S, Leonard R and Keeley J 2009 *Land grab or development opportunity? international land deals in Africa Land grab or development opportunity?* vol 36

Cotula L, Vermeulen S, Mathieu P and Toulmin C 2011 Agricultural investment and international land deals: evidence from a multi-country study in Africa *Food Secur.* **3** 99–113

Deininger K and Byerlee D 2011 *Rising Global Interest in Farmland: Can it yield sustainable and Equitable Benefits?* (Washington, DC: World Bank)

Dinerstein E, Baccini A, Anderson M, Fiske G, Wikramanayake E, Mclaughlin D, Powell G, Olson D, Joshi A and Noss R 2014 Guiding agricultural expansion to spare tropical forests *Conserv. Lett.* **8** 262–71

Droogers P, Seckler D and Makin I 2001 *Estimating the Potential of Rain-fed Agriculture* (Colombo, Sri Lanka: International Water Management Institute)

De Schutter O 2011 How not to think of land-grabbing: three critiques of large-scale investments in farmland *J. Peasant Stud.* **38** 249–79

EC 2016 *European Union Restrictive measures (sanctions) in force*

Eckert S, Giger M and Messerli P 2016 Contextualizing local-scale point sample data using global-scale spatial datasets: lessons learnt from the analysis of large-scale land acquisitions *Appl. Geogr.* **68** 84–94

Edelman M 2013 Messy hectares: questions about the epistemology of land grabbing data *J. Peasant Stud.* **40** 485–501

Edelman M, Oya C and Borras S M 2013 Global land grabs: historical processes, theoretical and methodological implications and current trajectories *Third World Q.* **34** 1517

Eitelberg D A, van Vliet J and Verburg P H 2015 A review of global potentially available cropland estimates and their consequences for model-based assessments *Glob. Change Biol.* **21** 1236–48

ESA 2013 *Land Cover State 2010 (2008–2012) 300 m v1.1* (Paris, France)

Fairhead J, Leach M and Scoones I 2012 Green grabbing: a new appropriation of nature? *J. Peasant Stud.* **39** 237–61

FCPF 2015 Most Recent R-PP Submissions by Countries to the Worldbank Forest Carbon Partnership Facility (FCPF) (www.forestcarbonpartnership.org/redd-countries-1)

Fischer G, Nachtergaele F, Prieler S, van Velthuizen H T, Verelst L and Wiberg D 2008 *GAEZ v3.0*

Foley J A *et al* 2011 Solutions for a cultivated planet *Nature* **478** 337–42

Friis C and Reenberg A 2010 *Land Grab in Africa Emerging Land System Drivers* (Copenhagen, Denmark: GLP International Project Office)

Fund For Peace 2015 *Fragile States Index Fragile States Index* (http://fsi.fundforpeace.org/)

Giovannetti G and Ticci E 2016 Determinants of biofuel-oriented land acquisitions in Sub-Saharan Africa *Renew. Sustain. Energy Rev.* **54** 678–87

Houghton R A, House J I, Pongratz J, van der Werf G R, DeFries R S, Hansen M C, Le Quéré C and Ramankutty N 2012 Carbon emissions from land use and land-cover change *Biogeosciences* **9** 5125–42

IBM 2013 *IBM SPSS Decision Trees 21*

Imhoff M L and Bounoua L 2006 Exploring global patterns of net primary production carbon supply and demand using satellite observations and statistical data *J. Geophys. Res.* **111** D22S12

Imhoff M L, Bounoua L, Ricketts T, Loucks C, Harriss R and Lawrence W T 2004 HANPP Collection: Human Appropriation of Net Primary Productivity (HANPP) by Country and Product *NASA Socioecon. Data Appl. Cent.* pp 1–8

Institute for Economics and Peace 2015 *Global Peace Index 2015: Quantifying Peace and its Benefits*

IUCN UNEP-WCMC 2014 The World Database on Protected Areas (WDPA) (www.protectedplanet.net)

Kastner T, Rivas M J I, Koch W and Nonhebel S 2012 Global changes in diets and the consequences for land requirements for food *Proc. Natl Acad. Sci. USA* **109** 6868–72

Kissinger G, Herold M and De Sy V 2012 *Drivers of Deforestation and Forest Degradation: A Synthesis Report for REDD+ Policymakers* (Vancouver, Canada: Lexeme Consulting)

Lambin E F, Gibbs H K, Ferreira L, Grau R, Mayaux P, Meyfroidt P, Morton D C, Rudel T K, Gasparri I and Munger J 2013 Estimating the world's potentially available cropland using a bottom-up approach *Glob. Environ. Change* **23** 892–901

Larson A M *et al* 2013 Land tenure and REDD+: the good, the bad and the ugly *Glob. Environ. Change* **23** 678–89

Mbow C 2010 Africa's risky gamble *Glob. Change* **June** 20–3

McCarthy J F, Vel J A C and Afiff S 2012 Trajectories of land acquisition and enclosure: development schemes, virtual land grabs, and green acquisitions in Indonesia's outer islands *J. Peasant Stud.* **39** 521–49

Messerli P, Heinimann A, Giger M, Breu T and Schönweger O 2013 From 'land grabbing' to sustainable investments in land: potential contributions by land change science *Curr. Opin. Environ. Sustain.* **5** 528–34

Meyer C and Miller D 2015 Zero deforestation zones: the case for linking deforestation-free supply chain initiatives and jurisdictional REDD+ *J. Sustain. For.* **34** 559–80

Minang P A, Van Noordwijk M, Freeman O E, Mbow C, De Leeuw J and Catacutan D 2015 *Climate-Smart Landscapes: Multifunctionality in Practice* vol 30

Monfreda C, Ramankutty N and Foley J A 2008 Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000 *Glob. Biogeochem. Cycles* **22** 1–19

Moreno-Fernández D, Cañellas I, Barbeito I, Sánchez-González M and Ledo A 2015 Alternative approaches to assessing the natural regeneration of scots pine in a mediterranean forest *Ann. For. Sci.* **72** 569–83

Nalepa R A and Bauer D M 2012 Marginal lands: the role of remote sensing in constructing landscapes for agrofuel development *J. Peasant Stud.* **39** 403–22

Nepstad D *et al* 2013 More food, more forests, fewer emissions, better livelihoods: linking REDD+, sustainable supply chains and domestic policy in Brazil, Indonesia and Colombia *Carbon Manag.* **4** 639–58

Neumann K, Verburg P H, Stehfest E and Müller C 2010 The yield gap of global grain production: a spatial analysis *Agric. Syst.* **103** 316–26

Nolte K, Chamberlain W and Giger M 2016 *International Land Deals for Agriculture Fresh insights from the Land Matrix: Analytical Report II* (Bern, Montpellier, Hamburg, Pretoria)

Oberlack C, Tejada L, Messerli P, Rist S and Giger M 2016 Sustainable livelihoods in the global land rush? Archetypes of livelihood vulnerability and sustainability potentials *Glob. Environ. Change* **41** 153–71

Pirard R and Belna K 2012 Agriculture and deforestation: is REDD+ rooted in evidence? *For. Policy Econ.* **21** 62–70

Romijn E, Ainembabazi J H, Wijaya A, Herold M, Angelsen A, Verchot L and Murdiyarso D 2013 Exploring different forest definitions and their impact on developing REDD+ reference emission levels: a case study for Indonesia *Environ. Sci. Policy* **33** 246–59

RSPO 2016 Roundtable for Sustainable Palm Oil (RSPO) (www.rspo.org/)

RTRS 2016 Round table on Responsible Soy (RTRS) (www.responsiblesoy.org/)

Rulli C M, Saviori A and Odorico P D 2012 Global land and water grabbing *PNAS* **110** 892–7

Rulli M C and Odorico P D 2013 The science of evidence: the value of global studies on land rush *J. Peasant Stud.* **40** 907–9

Salvini G, Herold M, De Sy V, Kissinger G, Brockhaus M and Skutsch M 2014 How countries link REDD+ interventions to drivers in their readiness plans: implications for monitoring systems *Environ. Res. Lett.* **9** 1–12

Scholes M 2012 After Durban: new issues on the table *Environ. Dev.* **1** 124–5

Scoones I, Hall R, Borras S M, White B and Wolford W 2013a The politics of evidence: methodologies for understanding the global land rush *J. Peasant Stud.* **40** 469–83

Scoones I, Hall R, Borras S M Jr, White B and Wolford W 2013b The politics of evidence: a response to Rulli and D'Odorico *J. Peasant Stud.* **40** 911–2

Seppelt R, Manceur A M, Liu J, Fenichel E P and Klotz S 2014 Synchronized peak-rate years of global resources use *Ecol. Soc.* **19** 50

Seppelt R *et al* 2016 Harmonizing biodiversity conservation and productivity in the context of increasing demands on landscapes *Bioscience* **66** 890–6

Shekoofa A, Emam Y, Shekoufa N, Ebrahimi M and Ebrahimie E 2014 Determining the most important physiological and agronomic traits contributing to maize grain yield through machine learning algorithms: a new avenue in intelligent agriculture *PLoS One* **9** 1–9

Smalley R, Sulle E and Malale L 2014 *The Role of the State and Foreign Capital in Agricultural Commercialisation: The Case of Sugarcane Outgrowers in Kilombero District, Tanzania* (Brighton, UK: Future Agricultures Consortium)

Soares B *et al* 2010 Role of Brazilian Amazon protected areas in climate change mitigation *Proc. Natl Acad. Sci. USA* **107** 10821–6

Stevenson J R, Villoria N, Byerlee D, Kelley T and Maredia M 2013 Green Revolution research saved an estimated 18 to 27 million hectares from being brought into agricultural production *Proc. Natl Acad. Sci. USA* **110** 8363–9368

The Land Matrix Global Observatory 2013 Land Matrix (www.landmatrix.org/)

Uchida H and Nelson A 2008 *Agglomeration Index: Towards a New Measure of Urban* (Washington, DC: World Bank)

UNFCCC 2010 *The Cancun agreements: Outcome of the work of the Ad Hoc Working Group on long-term Cooperative Action under the Convention. decision 1/CP 16, fCCC/CP/ 2010/7/add.1.* (Cancun, Mexicu)

UNFCCC 2015 *The Paris Agreement FCCC/CP/2015/L.9/Rev.1* (Paris, France)

UNFCCC 2014 UNFCCC: Full text of the convention (http://unfccc.int/land_use_and_climate_change/redd/items/7377.php)

Valin H, Havlík P, Mosnier A, Herrero M, Schmid E and Obersteiner M 2013 Agricultural productivity and greenhouse gas emissions: trade-offs or synergies between mitigation and food security? *Environ. Res. Lett.* **8** 035019

Woods K 2015 Commercial agriculture expansion in Myanmar: links to deforestation, conversion timber, and land conflicts *Forest Trends Report Series* March 2015

World Bank 2014 Investing across sectors *World Bank Data Invest. Across Bordes. Indic. foreign direct Invest. Regul.* (http://iab.worldbank.org/Data/ExploreTopics/Investing-across-sectors)

World Bank 2012 The Worldwide Governance Indicators (WGI) (www.govindicators.org)

World Bank 2013 World DataBank (http://data.worldbank.org/)

World Resources Institute 2016 Initiative 20x20 (www.wri.org/our-work/project/initiative-20x20)