New actors and scales of agriculture

Debonne, Niels

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A land system science perspective

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Is a tractor bad? Is the power that turns the long furrows wrong? If this tractor were ours it would be good - not mine, but ours. If our tractor turned the long furrows of our land, it would be good. Not my land, but ours. We could love that tractor then as we have loved this land when it was ours. But the tractor does two things - it turns the land and turns us off the land. There is little difference between this tractor and a tank.

- John Steinbeck, 1939, The Grapes of Wrath -

Contents

Summary

The study of land systems aims to disentangle and understand the range of interactions between humans and the land they use. It takes, among others, environmental, biophysical, economic, political, technological, and social perspectives to comprehend how coupled human-environmental systems work, who decides over them, and how they could or should be transformed. Land systems take a central position in human livelihoods and environmental issues, and are a crucial parameter in many Sustainable Development Goals.

This thesis starts from the premise that land systems are increasingly changing in ways that are poorly understood from a conventional land system science perspective. Conventional land system science rests on assumptions of mostly gradual processes, driven by a somewhat narrow range of actors, such as family farmers or local land administrations. However, large-scale land acquisitions, arguably the most dramatic land system changes of the 21st century, are definitively non-gradual, operate at scales that are orders of magnitude larger than typical smallholder dynamics, and are instigated by an international group of actors with a very different set of priorities than traditional actors. Pejoratively known as land grabs, large-scale land acquisitions globally cover an area over double the size of Germany, yet as a process, they have not been introduced in land system change models.

This lacuna is significant, not only because large-scale land acquisitions cover large areas, but also because they profoundly change the relation that humans have with land as a resource. For example, the conversion of swidden landscapes to rubber monocultures in Southeast Asia causes a significant loss of agro-environmental diversity, but also a complete overhaul of livelihoods, culture, tradition, diets, and more. Furthermore, the constellation of decision-making concerning land is changed, and therefore, the possibilities for sustainable transitions are different.

Upon closer inspection, large-scale land acquisitions are merely the most visible manifestation of a more general trend of new actors, changing land systems at new scales. In Sub-Saharan Africa, a trend is being signaled of an emergence of medium-scale farms replacing smallholders, and, as a consequence, commercial agriculture replacing semi-subsistence agriculture. With limited empirical data, it is unclear whether this is an organically appearing structural transformation or an elite capture of land with similar characteristics as large-scale land acquisitions, nor is it clear what the potential consequences are for livelihoods or the environment. Even when farm

scales are not perceivably shifting, decision-making concerning land is: value chain actors usurp some of the agency concerning land management from smallholders or state actors, for example by using contract farming.

Land system science wishes to understand why land systems have the characteristics they have and change the way they change. To do so, new actors and new scales of changes can no longer be disregarded as mere aberrations. This leads to the overall objective of this thesis, which is **to develop concepts and methods to integrate new actors and scales of agriculture into land system science.** In pursuing this objective, four research questions are posed.

RQ1: What are the land system characteristics related to new agricultural actors?

RQ2: How can new agricultural actors, and associated scales of land system change, be integrated in land system models?

RQ3: What are the objectives of new actors in agriculture and how do these objectives align or misalign with environmental or rural development objectives?

RQ4: How do new actors and arrangements in agriculture provide opportunities for environmental management and rural development?

Chapter 2 gives a broad overview of the new actors and scales in global land system changes, introduced above. The geography and characteristics of large-scale land acquisitions, medium-scale farming and related processes, and value chain coordination, are presented, and they are conceptually linked as processes that bestow more agency to value chain actors, at the expense of land managers and state actors. The importance of this agency shift for land system science is demonstrated by assessing its role as an enabler of land degradation processes. The chapter shows that the ambitious goal of achieving land degradation neutrality could face significant challenges because of the power of new actors to break institutional and ecological barriers against agricultural expansion, while creating incentives for often unsustainable forms of land management. However, value chain actors also have tools and business cases to be a positive force in the push towards land degradation neutrality, and their position enables them to catalyze such action across value chains. Governments and other brokers can unlock this potential by triggering the motivators for value chain measures against degradation, while also (re-) instituting constraints for value chain actors.

Chapter 3 focuses on the data-scarce topic of medium-scale farms, a process which is claimed by some to be of similar or larger significance as large-scale land acquisitions. The few empirical field studies on medium-scale farms have mostly used overly targeted sampling frames and did not allow for a comparison with small farms because of this. Still, such studies are used to make claims about medium-scale farms, presenting them as innovative, commercial farms led by urban entrepreneurs, or, alternatively, as an elite capture of land originally controlled by people with an insecure land tenure status. Chapter 3 shows the results of a systematically sampled study in the Kenyan Rift Valley, and compares small-, medium-, and large-scale farms in terms of land tenure, farm characteristics, crop mixes and yields, labor, and market outlets. While the findings partly corroborate some of the claims made around medium-scale farms (e.g. they are, on average, more cash crop-oriented and have a higher labor productivity), the survey finds a large diversity within classes. The high amount of entrepreneurial small-scale farms, and the high amount of very traditional medium-scale farms, puts into question the usefulness of farm size brackets to make broad claims on agricultural development.

Chapter 4 aims to enhance land system models so that they can incorporate large-scale land acquisitions simultaneously with ongoing small-scale land system dynamics. This represents a technical challenge to allow for changes to take place at multiple scales in the model. It also requires a reconsideration of the drivers of land system changes. Using the Lao PDR as a case study, a modified version of the CLUMondo model is deployed to parameterize large-scale land acquisitions and assess future land system distributions for three different policy scenarios. By doing this, the implications of large-scale land acquisition policies for smallholders is demonstrated. Model outcomes show that a scenario with an intensive push for more large-scale land acquisitions results in smallholders reverting back to subsistence farming, while a ban on new large-scale land acquisitions finds smallholders transitioning to cash crops. This model shows that including large-scale land acquisitions in land system scenarios is possible and relevant, and it carries the message that large-scale land acquisitions are a policy choice with consequences that are likely not fully considered today.

Chapter 5 builds on chapter 4, representing a use case of the improved model for Cambodia. Cambodia aims to harbor a new population of tigers in the near future, and has the habitat to do so. However, at the same time, the large-scale land acquisition policies of Cambodia threaten to fragment this habitat. The chapter highlights how large-scale land policies (i.e. for large-scale land acquisitions and for conservation) are often misaligned and risk undermining each other. Additionally, the model is further enhanced by including a new layer of decision-making in the model procedure: The model simulates how large-scale land acquisition managers make decisions on the extent to which they convert their concession area to plantations, and how governmental actors regulate this dynamic, in an interactive feedback. Results suggest that, if new large-scale land acquisitions are opted for, they can only coexist with tigers under very strict nature protection schemes, and non-conversion of concession areas, which leads to inefficient land use distributions, has to be discouraged. If such strict land governance is not feasible, the reintroduction of tigers in the Eastern Plains (the preferred habitat) is jeopardized. The Cardamom and Virachey forest are less suitable as tiger habitat, but because their poor agricultural suitability and accessibility makes them unattractive for large-scale land acquisitions, they are a safer tiger habitat in the absence of strong land governance.

Taken together, these chapters represent progress in characterizing new actors and scales in agriculture as land systems and land system changes. The chapters additionally engage with questions on the decision-making and the distribution of benefits and harms related to novel land system changes. Lastly, they offer entry points towards alternative pathways, thereby identifying how transformation can be leveraged. This thesis invites us to reckon with the diversification of land-related societal demands and actors, and to envision the future land systems we want.

Nederlandstalige samenvatting

Onderzoek naar landsystemen heeft als doel om de vele interacties tussen mensen en het land dat ze gebruiken te begrijpen. De discipline gebruikt milieu-, biofysische, economische, politieke, technologische en sociale perspectieven om te begrijpen hoe gekoppelde mens-milieu-systemen opgebouwd zijn, wie erover kan beslissen, en hoe ze kunnen of zouden moeten getransformeerd worden. Landsystemen zijn van groot belang voor het levensonderhoud van mensen en voor milieuproblematieken, en zijn een cruciale parameter in veel Duurzame Ontwikkelingsdoelen.

Deze thesis start vanuit de premisse dat landsystemen steeds meer veranderen op manieren die, vanuit een conventioneel landsysteem-wetenschapsperspectief, niet goed begrepen worden. conventionele landsysteemwetenschap gaat uit van doorgaans graduele processen, aangedreven door een weinig diverse groep actoren, zoals landbouwfamilies of lokale landadministraties. Echter, grootschalige landacquisities, wellicht de meest dramatische landsysteemverandering van de 21ste eeuw, zijn absoluut niet gradueel, werken op schalen die ordegroottes groter zijn dan typische kleinschalige landbouwdynamieken, en worden aangedreven door een internationale groep actoren die een sterk afwijkende prioriteitenlijst hebben. Beter gekend onder de pejoratieve term “landroof” nemen grootschalige landacquisities op globale schaal een oppervlakte in die meer dan dubbel zo groot is als Duitsland, maar als proces zijn ze nog niet geïntroduceerd in landsysteem-veranderingsmodellen.

Deze lacune is significant, niet enkel omdat grootschalige landacquisities grote oppervlaktes innemen, maar ook omdat ze de relatie tussen mens en land fundamenteel veranderen. De conversie van rotationele brandlandbouw naar rubbermonoculturen in Zuidoost Azië houdt bijvoorbeeld een groot verlies aan landbouwlandschappelijke diversiteit in, maar leidt ook tot een her-configuratie van het levensonderhoud van mensen, hun cultuur, tradities, diëten, en meer. Verder verandert ook de constellatie van verhoudingen omtrent beslissingen over land, waarmee ook de opties voor duurzame transities veranderen.

Bij nadere inspectie zijn grootschalige landacquisities slechts de meest zichtbare manifestatie van een meer algemene trend van nieuwe actoren, die land veranderen op nieuwe schalen. In zuidelijk Afrika wordt de opkomst van mediumschalige boerderijen gesignaleerd, die kleinschalige landbouwers vervangen en daarmee ook quasi-zelfvoorzieningslandbouw vervangen door commerciële landbouw. Door een gebrek aan empirische data blijft het onduidelijk of dit een organisch opkomende structurele transformatie is, of een elite-overname van land met gelijkaardige kenmerken als grootschalige landacquisities, noch is het duidelijk wat de mogelijke consequenties kunnen zijn voor het levensonderhoud van geaffecteerde mensen of het milieu. Zelfs wanneer de schaal van boerderijen niet zichtbaar verandert kan het beslissingsproces omtrent landbouwland wel veranderen: Actoren in bevoorradingsketens usurperen gezag over landbeheer van kleinschalige landbouwers of overheidsinstanties, bijvoorbeeld door middel van contractuele landbouw.

De landsysteemwetenschap wil begrijpen waarom landsystemen de kenmerken hebben die ze hebben, en waarom ze veranderen op bepaalde manieren. Daartoe kunnen nieuwe actoren en nieuwe schalen van verandering niet langer opzij geschoven worden als deviaties. Dit leidt tot de algemene doelstelling van dit proefschrift: **Het ontwikkelen van concepten en methoden om nieuwe actoren en schalen van landbouw te integreren in de landsysteemwetenschap.** Hiertoe worden vier onderzoeksvragen gesteld:

OV1: Wat zijn de landsysteemkarakteristieken gerelateerd aan nieuwe landbouw-actoren?

OV2: Hoe kunnen nieuwe landbouwactoren, en hun geassocieerde schalen van landsysteemverandering, geïntegreerd worden in landsysteemmodellen?

OV3: Wat zijn de doelstellingen van nieuwe landbouw-actoren, en hoe verhouden die zich tot milieudoelstellingen of rurale ontwikkelingsdoelstellingen?

OV4: Hoe bieden nieuwe actoren en constellaties in de landbouwsector mogelijkheden voor milieubeleid en rurale ontwikkeling?

Hoofdstuk 2 geeft een breed overzicht van de nieuwe actoren en schalen in globale landsysteemveranderingen, hierboven geïntroduceerd. De geografie en kenmerken van grootschalige landacquisities, mediumschalige boerderijen en gerelateerde processen, en bevoorradingsketen-coördinatie worden gepresenteerd en conceptueel gerelateerd als processen die gezag afstaan aan actoren in bevoorradingsketens, ten koste van landbeheerders en overheids-actoren. Het belang van deze gezags-shift voor landsysteemwetenschap wordt aangetoond door de vaststelling van de rol die dit speelt in het mogelijk maken van landdegradatie. Het hoofdstuk toont dat de ambitieuze doelstelling om landdegradatieneutraliteit te bereiken in het gedrang kan komen door de macht van nieuwe actoren om institutionele en ecologische barrières, die landbouwexpansie tegenhouden, te doorbreken, terwijl ook nieuwe stimulansen tot niet-duurzaam landbeheer gecreëerd worden. Actoren in bevoorradingsketens hebben echter ook instrumenten en business cases om een positieve bijdrage te leveren voor landdegradatieneutraliteit, en hun positie stelt hen in staat om actie te katalyseren over hele bevoorradingsketens. Overheden en andere belanghebbenden kunnen dit potentieel ontgrendelen door in te spelen op de motivatoren voor bevoorradingsketen-management tegen degradatie, en door de actoren van die ketens in te perken.

Hoofdstuk 3 focust op het data-schaarse onderwerp van mediumschalige boerderijen, een proces waarvan door sommigen wordt geclaimd dat het van gelijkaardig of zelfs groter belang is als grootschalige landacquisities. De weinige empirische veldstudies over mediumschalige boerderijen gebruiken doorgaans een te doelgerichte steekproefmethode en laten dus niet toe om een vergelijking te maken met kleinschalige boerderijen. Toch worden er op basis van deze studies stellige beweringen gemaakt, en worden mediumschalige boerderijen gepresenteerd als innovatieve, commerciële boerderijen geleid door stedelijke ondernemers. Alternatief worden ze gepresenteerd als een elite-geleide overname van land dat toebehoord aan mensen met een precaire grondbezit-status. Hoofdstuk 3 toont de resultaten van een systematisch genomen steekproef in de Keniaanse Riftvallei, en vergelijkt klein-, medium-, en grootschalige boerderijen op vlak van grondbezitsrechten, boerderijkenmerken, gewassen, productiviteit, landbouwarbeid, en landbouwmarkten. Hoewel de bevindingen deels in lijn liggen met de beweringen omtrent mediumschalige boerderijen (bijvoorbeeld zijn deze gemiddeld inderdaad meer gericht op opbrengstgewassen en bereiken zij een hogere arbeidsproductiviteit), toont het onderzoek ook dat er een grote diversiteit bestaat binnen categorieën. Het hoge aantal ondernemingsgezinde kleinschalige boerderijen, en het hoge aantal traditionele mediumschalige boerderijen, stellen de bruikbaarheid van afgelijnde categorisaties om grote beweringen te maken over landbouwontwikkeling in vraag.

Hoodstuk 4 heeft als doel om landsysteemmodellen te verbeteren door grootschalige landacquisities te incorporeren, simultaan met kleinschalige dynamieken. Dit is een technische uitdaging, om processen die spelen op verschillende schalen te modelleren. Ook verreist het een heroverweging van de drijvende krachten achter landsysteemveranderingen. Gebruik makend van Laos als casestudy worden grootschalige landacquisities geparametriseerd in het CLUMondo-model, om zo toekomstige landsysteempatronen te verkennen in drie beleidsscenario's. Het model demonstreert dat beleid omtrent grootschalige landacquisities grote gevolgen heeft voor de mogelijkheden van kleinschalige landbouwers. In een scenario waar grootschalige landbouw sterk aangemoedigd wordt, worden kleinschalige landbouwers terug naar zelfonderhoudende landbouw geduwd, terwijl in een scenario met een moratorium op nieuwe grootschalige landacquisities de kleinschalige landbouwers overschakelen op opbrengstgewassen. Het model toont aan dat het inbouwen van grootschalige landacquisities in landsysteemmodellen mogelijk en relevant is, en het bouwt op het idee dat deze grootschalige landacquisities een beleidskeuze zijn met consequenties waarvan men zich wellicht niet ten volle bewust is.

Hoofdstuk 5 gaat verder op de bevindingen van hoofdstuk 4, en geeft een implementatie van het landsysteemmodel voor Cambodia. Cambodia wil een nieuwe populatie tijgers herintroduceren in de nabije toekomst, en heeft hiervoor habitat ter beschikking. Terzelfdertijd dreigen beleidskeuzes omtrent grootschalige landacquisities deze habitat te fragmenteren. Het hoofdstuk belicht hoe grootschalig landbeleid (grootschalige landacquisities en natuurbescherming) vaak in tegenstrijd is met zichzelf. Het model is verder uitgewerkt door een beslissings-parameterizatie toe te voegen: Het model simuleert hoe managers van grootschalige landacquisities beslissingen maken omtrent de mate waarin ze hun concessies benutten als plantage, en hoe overheidsinstanties dit reguleren, in een interactieve teugkoppeling. Resultaten suggereren dat, als in de toekomst gekozen wordt voor grootschalige landacquisities, deze enkel kunnen samengaan met tijgers wanneer habitat strikt wordt gereguleerd, en wanneer niet-conversie van concessies, wat tot inefficiënt landgebruik leidt, aangepakt wordt. Als dergelijk strikt beleid niet haalbaar is, dan is de herintroductie van tijgers in de Oostelijke Vlaktes (de geprefereerde habitat) in gevaar. Het Cardamom- of Viracheybos zijn minder geschikt als tijgerhabitat, maar door hun schamele agrarische bruikbaarheid en slechte bereikbaarheid zijn ze ook niet aantrekkelijk voor grootschalige landacquisities, en daardoor vormen ze een veiligere tijgerhabitat wanneer krachtdadig landbeleid ontbreekt.

De hoofdstukken representeren voortgang in het beschrijven van nieuwe actoren en schalen in de landbouw als landsystemen en landsysteemveranderingen. Verder worden vragen omtrent beleid en de verdeling van lusten en lasten gerelateerd aan nieuwe landsysteemveranderingen behandeld. Ten slotte bieden de hoofdstukken aanknooppunten naar alternatieve trajecten, waarmee hefbomen voor transformaties worden geïdentificeerd. Deze thesis nodigt ons uit om rekenschap te nemen van de toenemende veelheid aan land-gerelateerde maatschappelijke behoeften en actoren, en om een voorstelling te maken van de gewenste toekomstige landsystemen.

Key Concepts

Agency	The capacity of an actor to instigate changes in land use and land management.
Contract farming	Formal agreement between a value chain actor and a farmer.
Domestic larger-scale farm	Container term to denote a removal from family farming towards more capital-intensive, larger-scale farming controlled by domestic elites. Medium-scale farms the Sub-Saharan African manifestation of domestic larger-scale farms.
Land control	The capacity to make decisions concerning the use and management of land.
Land degradation	A reduction of biological productivity and a decrease in ecosystem complexity.
Land Degradation Neutrality	A state whereby the amount and quality of land resources, necessary to support ecosystem functions and services and enhance food security, remains stable or increases within specified temporal and spatial scales and ecosystems. Under Sustainable Development Goal Target 15.3, the aim is to, on balance, maintain or increase the amount and quality of land resources by compensating any land degradation with land restoration, within specified time- and spatial-scales.
Land governance	The processes by which decisions are made regarding the access to and use of land, the manner in which those decisions are implemented and the way that conflicting interests in land are reconciled.
Land manager	People with rights to control land.
Land system (concept)	A representation of all activities and processes pertaining to anthropogenic land use in a given geographical area, encapsulating local land use/cover with reigning socioeconomic and institutional arrangements, technology use, and the benefits and consequences of land use.

Land system (mapping device)	Typical combinations of land cover, land use, and land management.
Land tenure	The relationship, whether legally or customarily defined, among people, as individuals or groups, with respect to land (FAO, 2002).
Large-scale farm	Working definition in Chapter 3: farms larger than 50 hectares
.Large-scale land acquisition	(Broadly) Acquisition through lease, concession or sale of large (relative to the local context) tracts of land for agricultural or forestry purposes. Working definitions differ in different chapters of this thesis.
Medium-scale farm	(Broadly) Farms that are relatively larger than what is usual in their immediate context, yet smaller than large-scale land acquisitions. (Specifically in Chapter 3): Farms with sizes between 5 and 50 hectares. (In other empirical literature) See section 3.3.2 for an overview.
Smallholder	Broad term to denote farmers who generally operate relatively small farms using motly family labor.
Small-scale farm	(In Chapter 3): Farms smaller than 5 hectares.
Swidden	Rotational agriculture characterized by a long fallow period followed by a short cultivation period
Value chain actor	Actors up- and downstream of the farm in agricultural value chains.
Value chain coordination	Interactions and arrangements in value chains (e.g. contract farming) by which actors along these value chains influence each other's decision-making.

Abbreviations

COP	Conference of the Parties
DLSF	Domestic larger-scale farm
ELC	Economic Land Concession (Cambodian term)
GoL	Government of Laos
LCM	Land change model
LDN	Land Degradation Neutrality
LSF	Large-scale farm
LSLA	Large-scale land acquisition
MSF	Medium-scale farm
NGO	Non-governmental organization
RQ	Research question
SDG	Sustainable Development Goal
SLM	Sustainable land management
SPI	Science-Policy Interface
SSA	Sub-Saharan Africa
UNCCD	United Nations Convention to Combat Desertification
VCA	Value chain actor
VCC	Value chain coordination
WBCSD	World Business Council for Sustainable Development

1. Introduction

1.1. Land control dynamics and value chain coordination in the 21st century

The past two decades have seen momentous changes in actors and scales of agriculture around the world. Land control has increasingly shifted towards non-local actors, who have in many instances altered rural land systems beyond recognition (Margulis et al., 2013; Sikor et al., 2013). While globally, smallholder farming is the dominant mode of farming, especially in the Global South (Samberg et al., 2016), novel constellations of land control are on the rise in the 21st century. These land control dynamics are often characterized by large, non-gradual shifts in farm scales, with farms that may be several orders of magnitude larger than the farms that precede or neighbor them. Apart from drastic farm scale shifts, which are most readily observable, a more general shift in decision-making processes and actors in land use and land management issues is taking place, the consequences of which are not fully understood.

Large-scale land acquisitions (LSLAs) are the most visible new actors that have arisen, and have received ample academic and societal attention (Scoones et al., 2013). Their scale and the speed at which they have proliferated have led some scholars to name them "the most radical land use change in the history of humankind" (Mann and Bonanomi, 2017). LSLAs are acquisitions through lease, concession or sale of large (relative to the local context) tracts of land for agricultural or forestry purposes[1]. They started appearing in high numbers following the global food price crisis and financial crisis in 2007, although earlier instances are reported. By 2016, the global area covered by LSLAs, as reported in the Land Matrix repository, plateaued at 79 million hectares, and as of yet it is unclear to what extent this represents a true leveling-off or merely a reporting time lag (Land Matrix, 2019). LSLAs are typically located in Sub-Saharan Africa, Southeast Asia, Eastern Europe and Latin America, while the acquiring parties tend to originate from wealthier

[1] This definition is inexplicit concerning minimum size requirements or the nationality of land acquirers, in order to accommodate the many shades of grey found in large-scale land acquisitions. A commonly used minimum size used in global databases is 200 ha (Land Matrix, 2019). The different chapters of this thesis use different working definitions to best suit their conceptual and methodological frameworks.

countries, countries that lack sufficient arable land and depend on imports, and elites from within the LSLA's country (Deininger et al., 2011; Seaquist et al., 2014). They may be an investment group, an agribusiness, domestic elites, domestic government actors, or foreign states or state companies.

New actors also emerge in less eye-catching forms. The shift away from smallholder family farms does not always materialize in the form of LSLAs, and the focus on LSLAs may have unduly shifted attention away from less dramatic, but more widespread dynamics. In Sub-Saharan Africa, survey data from multiple countries and at multiple times indicates that the share of land in the hands of medium-scale farms (MSFs – defined in the referenced study as farms with sizes between 5 and 100 hectares[2]) is rising sharply. This rise of a new class of farmers combines to a process of larger spatial proportions, potentially impacting more people, compared to LSLAs (Jayne et al., 2016). Contrary the development of LSLAs, much less is known about the rise of MSFs. It is unclear to what extent MSFs are the product of an organic consolidation process, where successful smallholders expand their farms by buying land of exiting farmers, or, alternatively, an elite capture of rural land, where domestic investors find opportunities to leverage power relations to acquire land. The former option would essentially represent an agricultural transition process (Byres, 1977), while the latter option is akin to LSLAs in smaller form, risking the arising of similar negative externalities. Case studies have found corroborating evidence for both options (Anseeuw et al., 2016; Chapoto et al., 2013; Chimhowu, 2018).

Apart from the origins of MSFs, it is also unclear if and how MSFs are functionally different from small farmers and if the signal observed in national-scale censuses has implications for rural development or the environment. Farm scale is a readily available metric in agricultural censuses, yet this does not necessarily make it an informative metric to classify farmers with. Whether MSFs grow different crops, for different markets, using different amounts and sources of labor, is unclear.

The land control dynamics outlined above do not imply the end of the smallholder farmer. In all their diversity, smallholders persist and have engaged with urban and international value chains in a myriad of ways (Barrett et al., 2012). This can be captured under the umbrella term of value chain coordination (VCC), denoting the many ways in which up-and downstream actors in agricultural value chains

[2] Note that this is not a standard definition. Chapter 3 of this thesis uses 5 – 50 hectares as the range of MSFs.

coordinate with smallholders and thus influence their farm management and crop choices (Swinnen and Maertens, 2007). The most common form of VCC is contract farming, where a processor or supermarket sets out an agreement with supplying farmers. These contracts may stipulate quantities and minimum requirements of products, but can also make demands on certain prerequisite land management requirements (Bellemare and Lim, 2018; Cramb et al., 2016). In some instances, contracts may cover upfront costs of inputs, thus enabling land system changes which would otherwise be impossible. Where such contracts induce debt, or yield very high short-term profits, this may lead to boom-and-bust cycles.

1.2. A land system science approach to new actors in agriculture

The emergence of new actors has hitherto been studied from many disciplines, including political ecology (Borras et al., 2012b; Messerli et al., 2015; Meyfroidt, 2017a), rural development (Deininger et al., 2011; Hall et al., 2017; Li, 2011), land governance (Chitonge et al., 2017; Schoneveld, 2017), human rights perspectives (Mann and Bonanomi, 2017), and more. These disciplines have not necessarily worked in an integrative, interdisciplinary manner. Bridging knowledge across disciplines can increase understanding of emerging dynamics and inform the design of more sustainable pathways. Land system science can act as an integrative platform, bringing together insights of various disciplines (Verburg et al., 2015). Studying LSLAs, or agricultural value chains more generally, from a land systems perspective has the potential to increase our understanding of the causes and consequences of observed dynamics, and may enable the envisioning of alternative land futures (Messerli et al., 2013). Such contributions have, for example, highlighted the multifaceted relationship between food security and environmental concerns (Meyfroidt, 2017a), or the role of agribusinesses in environmental stewardship (Folke et al., 2019).

A land system is a representation of all activities and processes pertaining to anthropogenic land use in a given geographical area. As a conceptual boundary object, land systems bring together local land use/cover with reigning socioeconomic and institutional arrangements, technology use, and the benefits and consequences of land use (Verburg et al., 2013)[3]. The emergence of new actors in global agriculture can be framed as a land system change: to varying extents and in

[3] This definition pertains to land systems as a conceptual framework. In later chapters, land systems are deployed as a mapping device, similar to van Asselen and Verburg (2012).

varying ways, LSLAs, MSFs and VCC alter the land cover, land use, land management, and societal relationship to land. Land institutions undergo changes (e.g. from customary land tenure arrangements to private land ownership), new technologies are disseminated (e.g. new crop varieties, agrochemicals), and the mix of benefits reaped from land and negative consequences caused by its use are redistributed.

In land system science, Messerli et al. (2013) distinguish three types of knowledge that provide a framework for the understanding of land system sustainability: (1) systems knowledge, which concerns the status, dynamics, drivers and impacts of the land system (changes), (2) target knowledge, which concerns matters of agency to decide over a land system and the distribution of benefits and negative consequences, and (3) transformation knowledge, which concerns pathways of future development and leverage points to shape alternative land system futures. This thesis aims to contribute to systems, target, and transformation knowledge on new actors in global agriculture. In what follows, a state of the art is summarized and knowledge gaps are identified (Table 1.1).

1.2.1. Systems knowledge

Considerable efforts have been undertaken to gain systems knowledge on LSLAs. At the global scale, the Land Matrix serves as a crowd-sourced repository of intended, concluded and failed land deals (Anseeuw et al., 2013; Land Matrix, 2019). An increasingly rigid triangulation system aims to ensure data quality and minimizes errors of commission (Nolte et al., 2016). However, the crowd-sourced nature of the data implies that areas with, for example, low press freedom or limited NGO activities are often omitted. This, combined with spatial inaccuracies (Eckert et al., 2016), implies that the Land Matrix is currently insufficient to use as input in global-scale land system analysis (Edelman, 2013) and that any assessment of the impact of land systems made using Land Matrix data should be interpreted as a lower limit rather than a precise estimate (see comment and reply in Rulli and D'Odorico, 2013).

Still, the Land Matrix and other inventories have enabled the identification of broad-scale drivers, contexts and impacts. Concerning drivers, the timing of the proliferation of LSLAs coincides with the 2007 food price crisis (Watson, 2017) and the financial crisis. By disseminating and reinforcing a narrative of land scarcity (Lambin, 2012; Scoones et al., 2018), the food price crisis triggered a number of import-dependent countries to secure food supplies by acquiring land abroad (Cotula et al., 2009). Many host countries further drive the rise in LSLAs by welcoming such investments and facilitating for candidate-investors (Schoneveld, 2017). The financial crisis amplified this trend: amidst distressed markets, the global agricultural markets, and land markets specifically, maintained positive prospects (Cotula et al., 2011). The contexts in which LSLAs are situated are mostly either densely populated croplands or sparsely populated forests (Messerli et al., 2014). LSLAs appear to value agro-ecological productivity and are not typically found to target supposed "idle land reserves". They are furthermore overrepresented in, and likely attracted to, poor land governance and land tenure security (Arezki et al., 2011). The impacts of LSLAs on rural livelihoods (Davis et al., 2014; Oberlack et al., 2016), the global commons (Dell'Angelo et al., 2017b), water availability (Rulli et al., 2012), and socio-environmental systems in general (Agrawal et al., 2019) have been summarized and often quantified by building on inventory data.

A key missing aspect of systems knowledge concerning LSLAs is how they cause land use and land cover changes. First, the assumption that the acquisition of land will always be followed by land clearing and plantation development has proven to be unfounded. A great number of LSLAs do not materialize into plantations or only succeed to develop a small fraction of the acquired area (Agrawal et al., 2019), and many operations fail (Schönweger and Messerli, 2015). Second, where LSLAs claim smallholder farmland, they may generate a displacement of land use (Lambin and Meyfroidt, 2011). Their immediate land system changes are thus followed by secondary effects. This is further complicated as smallholders and LSLAs are operating in overlapping land resources, but also in overlapping market outlets (Byerlee, 2014). The space in which smallholders farm and the markets they serve are therefore to a large extent indirectly influenced by LSLA policies. Neither the incomplete implementation of LSLAs nor their influences on smallholders have been assessed from a land system science perspective. This has also resulted in the absence of LSLA dynamics in land system change models (Rounsevell et al., 2012; Verburg et al., 2019a). Such models can be instrumental not only to formally summarize systems knowledge, but also to assess the importance of various impacts as they emerge from diverging policy scenarios.

The same level of systems knowledge found in LSLAs is not present for MSFs: with the exception of a handful of case studies, MSFs are studied by proxy through census data with insufficient qualitative detail to deduct drivers or impacts with certainty (Jayne et al., 2016). Case studies find that MSFs tend to be located in highly accessible, highly productive areas (Hall et al., 2017; Sitko and Chamberlin, 2015). The rise in MSFs, as reported in census data, is found to be synchronous with a rise in non-family farms (i.e. corporate farms) and ownership of rural land by urban people (Jayne et al., 2016; Lowder et al., 2016). However, neither the existence nor the direction of a causality is immediately evidenced from these observations. The paucity of case study evidence is aggravated by the tendency of case studies to only sample farms meeting preconceived ideas of MSFs. In this way, stereotypes of entrepreneurial, urban-owned MSFs are recycled rather than validated.

To better understand MSFs, more case study work is needed. However, such case studies should go beyond verifying that entrepreneurial, urban-owned MSFs exist. Instead, more may be learned from a mapping of the diversity in MSFs, and a comparison with other farm scales. For this, a naïve sampling strategy is crucial. Furthermore, MSFs are currently understood as a Sub-Saharan African phenomenon. It is unclear if and how similar processes may exist in other continents.

VCC similarly suffers from a poor systems knowledge base: contract farming is mostly studied from a micro-economic perspective (Otsuka et al., 2016). There is uncertainty on the importance and extent of VCC, owing to definitional and data issues (Oya, 2012). Land system science perspectives on VCC are only found where it generates dramatic land system changes. This is particularly the case for boom-and-bust cycles, where high levels of lucrativeness and/or indebtedness generate rapid expansive land system changes (Hall, 2011). Because contract farming is often argued to be a more responsible and less damaging alternative to LSLAs (Cramb et al., 2015; Hall et al., 2017), knowledge on occurrence, drivers, and impacts is urgently needed. This knowledge base is currently emerging, for example under the banner of the TRASE initiative which aims to link agricultural commodities to their environmental impacts (Paitan and Verburg, 2019), but insights into how VCC drives land management decision-making remains limited.

1.2.2. Target knowledge

Target knowledge on LSLAs is relatively rich, although significant gaps remain. Inquiries into who decides on LSLAs, who defines which land is available, and who benefits and loses are many (Keene et al., 2015). Still, the scope of host governments to set out LSLA policies and how these policies are married with other land use policies is not well-understood. Land, especially in the Global South, is increasingly under pressure to meet food demands, biodiversity targets, and other ecosystem services. Governments are trying to accommodate these demands, but often fail to acknowledge and address trade-offs. Instead, a silo mentality is found to dominate land use planning, where disparate governmental agencies and ministries set out land use policies that are, as a result, often mutually exclusive (Rudel and Meyfroidt, 2014). This way, LSLAs may for example be part of a governmental strategy to attract foreign direct investment, while at the same time undermining a government strategy to preserve biodiversity hotspots (Souter et al., 2016) or support smallholder farmers (Brent et al., 2017). While the risks related to this lack of coordination are often flagged (African Union et al., 2014; FAO, 2012), the implications of LSLAs' uneasy relationship with other land-related targets are rarely assessed beyond the case study level (Liao et al., 2016; but see Dell'Angelo et al., 2017). This highlights the need for integrative, scenario-based, spatially explicit assessment tools that can accurately represent LSLAs amidst other land claims and simulate implications of policy choices in one domain of land governance on other domains of land governance.

For MSFs, any target knowledge remains speculative and lacks sufficient empirical backing (i.e. a sufficiently large systems knowledge base is missing). The rise of MSFs is alluded to be either an elite capture of land benefiting urban-based entrepreneurs, or a rural consolidation process led by successful smallholders (Sitko and Jayne, 2014). The role of agricultural lobbies, processors and supermarkets as a driving force behind MSFs is believed to be large (Neven et al., 2009; Reardon et al., 2009), but remains hypothetical. MSFs are reported to leverage statutory land tenure to overrule customary land tenure, thus victimizing customary land users (Sitko and Chamberlin, 2016), but to what extent such findings are generalizable across SSA is uncertain. In short, we know only that MSFs are on the rise as a category, yet we do not have a clear profile of MSFs (if such a typical profile exists), nor do we know who benefits and loses from their emergence or which policies and power relations are behind it.

VCC is better understood in terms of target knowledge. There are multiple lines of inquiry into how contract farming may be beneficial to participants (Ton et al., 2018) and how it leads to overall gains in value chain efficiency (Wang et al., 2014), leading some to proclaim contract farming as being a prerequisite for "modern farming" (Bellemare and Lim, 2018). However, VCC is also criticized for being exclusionary to already disadvantaged farmers, either intentionally or as a side-effect of contract prerequisites that are difficult to attain for underprivileged farmers (Colen et al., 2012). Furthermore, while contract farming can be an equal partnership, it often takes the form of an exploitative relation (Luo et al., 2017; Ochieng, 2010). Thus, target knowledge on VCC is relatively well-developed, yet what is still unclear is to what extent the goals and priorities of contracting businesses translate to environmental change. Contracts could be hypothesized to induce degradation where they spread damaging land management techniques. However, they may also enable participants to adopt more sustainable practices, for example by providing security and thereby allowing longer-term planning (Minten et al., 2009). This depends in large part on the goals and priorities of the contracting business as well as the participants, yet knowledge on this subject is largely missing.

1.2.3. Transformation knowledge

While transformation knowledge concerning LSLAs is quite abundant, it tends to be unidirectional. LSLAs are virtually always found to represent a radical shift to an unsustainable, hyper-intensive land system with negative consequences for local livelihoods (Dell'Angelo et al., 2017a; Friis et al., 2016). Proponents of LSLAs proclaim their potential to bring rural development and modernize agriculture (Collier and Dercon, 2009). However, even if LSLAs would bring benefits, that does not mean that an LSLA pathway is therefore optimal to tackle issues of rural poverty and rural development vis-à-vis a smallholder-support pathway (De Schutter, 2011). Any benefits remain largely in the hypothetical, and whether LSLAs have the potential to be leveraged towards sustainability and livelihood improvements, and if so, in which contexts, is much less studied. LSLAs have been found to generate technological spillovers to neighboring smallholders in Mozambique (Deininger and Xia, 2016), but whether these results are generalizable to other contexts remains unclear. Potential sustainability leverages related to LSLAs have rarely been studied, although such leverages can be hypothesized (Cotula et al., 2011). For example, if LSLAs would be a part of a national or international integrated land use planning effort, they could be used to channel agricultural expansion requirements to produce sufficient food. In this way, environmental damages of agricultural expansion could be minimized. While such planning infrastructure may seem unattainable, it is precisely this reasoning that underpins the narratives of "available, idle land" that are used to justify LSLAs (Deininger et al., 2011). Surprisingly little research has been devoted to formalizing such narratives and to sincerely questioning the land governance needed to direct LSLAs to least-damage pathways (but see Dwyer et al. 2015).

MSFs are championed to be a transformative power that may bring dynamism to an otherwise stagnant African smallholder agriculture (Jayne et al., 2016). Such claims are stated hypothetically. Apart from the underlying, questionable assumption that smallholders are not dynamic, it is at this point not possible to portray MSFs as such because there is insufficient knowledge on their profiles (i.e. target knowledge) and multi-temporal assessments have not been performed. Here, again, the more important question to ask is not whether MSFs bring beneficial sustainability and livelihood outcomes, but whether they are the most efficient pathway towards such outcomes. However, to make such an assessment, more systems and target knowledge is needed first: the farm-level performance, crop mixes, market orientation and labor requirements of MSFs must be mapped and compared to smallholders.

VCC can be transformative through a range of pathways of change (Sikor et al., 2013; Zimmerer et al., 2018). For example, where it acts as a provider of agricultural inputs such as artificial fertilizer or improved seeds, it may enable land system intensification (Otsuka et al., 2016), which may have sustainability implications. Alternatively, by providing a more direct link between consumers and producers, sustainability concerns of consumers can be transferred through the value chain and result in on-the-ground changes in land management (Rueda and Lambin, 2013). This pathway is being formalized through eco-certification, which is found to be an effective tool towards reaching sustainability targets (Defries et al., 2017). The extent to which VCC contributes to environmental issues or the solution thereof is context-dependent. Much depends on the priorities of the businesses that engage in such schemes (Mårtensson and Westerberg, 2016), as well as the consumers' willingness to pay for sustainability. While this field has progressed significantly, questions remain on the effectiveness of various tools of private land governance (which may range in stringency from issuing strict production demands to voluntary farmer trainings), and how these interact with public land governance tools (Lambin et al., 2014). If such tools are effective, their use in the attainment of sustainable development goals should be assessed.

Table 1.1: State of land system science knowledge and knowledge gaps concerning new actors in agriculture. More explanation is given in text.

		Systems knowledge *Status, dynamics, drivers and impacts of the land system (changes)*	**Target knowledge** *Agency, decision-making, goal-definition, distribution of benefits and negative consequences*	**Transformation knowledge** *Pathways of future developments, leverage points towards alternative pathways*
Large-scale land acquisitions	**State**	Globally coordinated efforts to build knowledge repositories have led to a good understanding of the geography, contexts, drivers and impacts.	Rich knowledge on the decision-making, power dynamics, and roles of various actors.	Evidence of LSLAs as unsustainable rural development pathways. Implementation of LSLAs are rarely in line with narratives of "bringing idle land into productive use".
	Gaps	- Land use/cover changes post-acquisition - Indirect land changes via impacts on smallholders - Representation of land use/cover changes in land change models	- Trade-offs between LSLA policies and other land-based goals - Representation of LSLA actor decision-making in land change models	- Least-damage LSLA pathways - Scenarios of future LSLA development - LSLAs as a leverage for sustainable development
Medium-scale farms	**State**	A strong signal emerging from census data in a limited number of countries, combined with sporadic case study evidence.	The role of agricultural lobbies, processors, and supermarkets as drivers of a rise in MSF is debated. Land tenure issues are sometimes found to enable a rise in MSF, and vice versa.	Theories of change present MSFs as either a new land rush with detrimental impacts on local priorities, or as sources of dynamism that may bring innovation to rural areas.
	Gaps	- Profiles, characteristics, and impacts of MSFs - Connection with similar dynamics outside of Africa	- MSF decision-making - Who wins and loses? - Land tenure issues related to MSF	- MSF as a transformative power - MSFs as part of a sustainable development pathway
Value chain coordination	**State**	Intensifying efforts to assess value chain architectures and sustainability (e.g. TRASE), and specific land system research into boom-and-bust crops	VCC is often found to benefit participants, but risks of exploitation can arise. VCC can be exclusionary to already disadvantaged farmers.	Depending on the context, VCC is found to either encourage unsustainable practices or enable transitions to sustainability.
	Gaps	- Geography of VCC - Drivers of VCC - Impacts of VCC on land management	- Motivation towards Sustainability of value chain actors - Choice of value chain interventions	- Effectiveness and suitability of private land governance for sustainable transformations

1.3. Objective and research questions

Because the changes in actors and scales of agriculture as described above can have considerable socio-economic as well as biophysical consequences, it is important to better understand the underlying land system change processes and contribute to filling the identified knowledge gaps. Understanding the drivers, impacts, threats, and opportunities they may represent requires a multi-scaled, interdisciplinary approach, which land system science may be able to deliver. **Therefore, the overall objective of the thesis is to develop concepts and methods to integrate new actors and scales of agriculture into land system science.**

From the land system science knowledge gaps identified in Table 1.1, four research questions can be distilled that can be seen as logical next steps towards this objective.

RQ1: What are the land system characteristics related to new agricultural actors?

RQ2: How can new agricultural actors, and associated scales of land system change, be integrated in land system models?

RQ3: What are the objectives of new actors in agriculture and how do these objectives align or misalign with environmental or rural development objectives?

RQ4: How do new actors and arrangements in agriculture provide opportunities for environmental management and rural development?

1.4. Thesis outline

This thesis starts with a broad overview of the new actors and scales of agriculture, questioning what conceptually links them and how they are geographically manifested (Chapter 2). The chapter discusses how new actors and new constellations of land control may present a threat or opportunity to the attainment of Land Degradation Neutrality, and presents a number of policy responses for governments, international organizations, and private actors. Land Degradation Neutrality is one of the Sustainable Development Goals targets under the 'Life on Land' overarching goal and is adopted under the auspices of the United Nations Convention to Combat Desertification (UNCCD). Chapter 3 zooms in on MSF, and aims to broaden the systems knowledge base on this relatively poorly described dynamic. The chapter specifically questions to what extent MSFs are functionally different from small-scale farms, and creates a unique dataset for the Kenyan Rift Valley to do so. Chapter 4 summarizes empirical understanding of LSLAs in Laos in a land system change model. This model is developed specifically to simulate non-gradual, large-scale dynamics alongside gradual, small-scale dynamics, and can make the competition between LSLAs and smallholders for land and market shares tangible. The aim here is to fill the knowledge gap of the lacking representation of LSLA in land use models. Chapter 5 further expands the work in chapter 4 to be able to represent the land use decision-making of LSLA managers and governmental decision-makers. This model is deployed to confront LSLA policies with biological conservation targets for Cambodia, a country that has seen rapid LSLA proliferation while also aiming to reintroduce tigers. Chapter 6 synthesizes the findings from the various chapters and reflects on the research questions.

While the thesis chapters have chapter-specific objectives and questions and have been published as standalone, peer-reviewed research papers, they all contribute to the general objective of this thesis. Figure 1.1 visualizes the connections between the knowledge domains, research questions, and chapters.

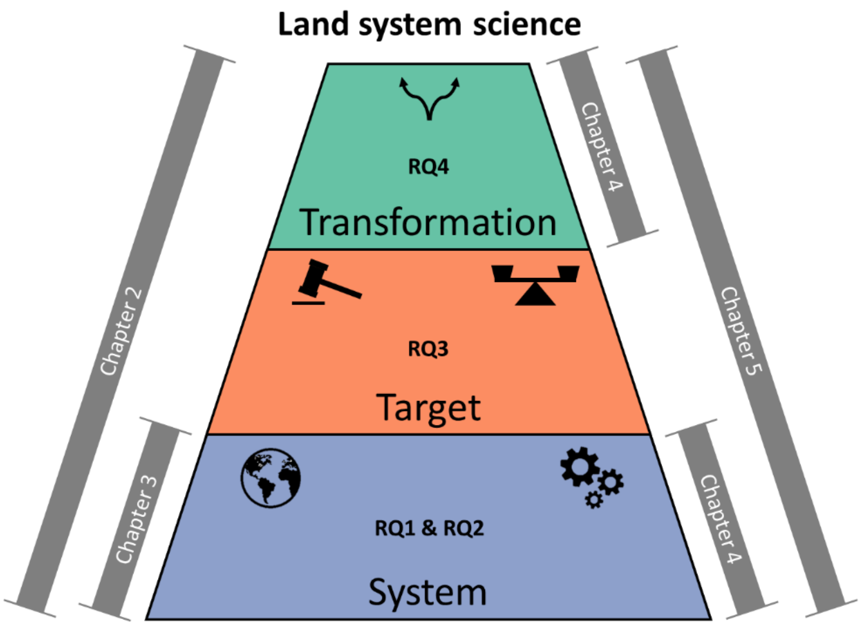

Figure 1.1: Research questions (RQs) and thesis chapters, and their relation to the systems, target, and transformation knowledge domains.

2. Agency shifts in agricultural land governance and their implications for Land Degradation Neutrality

Given current land degradation trends, Land Degradation Neutrality (LDN, SDG Target 15.3) by 2030 could be difficult to attain. Solutions to avoid, reduce, and reverse land degradation are not being implemented at sufficiently large scales, pointing to land governance as the main obstacle. In this paper, we review dynamics in agricultural land governance, and the potential this may have to enable land degradation or provide solutions towards LDN. The literature reveals agency shifts are taking place, where value chain actors are given increasing decision-making power in land governance. These agency shifts are manifested in two interrelated trends: First, through agricultural value chain coordination, such as contract farming, value chain actors increasingly influence land management decisions. Second, international large-scale land acquisitions and domestic larger-scale farms, both instances of intensified direct involvement of value chain with land management, are overtaking significant areas of land. These new arrangements are associated with agricultural expansion, and are additionally associated with unsustainable land management due to absent landowners, short-term interests, and high-intensity agriculture. However, we also find that value chain actors have both the tools and business cases to catalyze LDN solutions. We discuss how governments and other LDN brokers can motivate or push private actors to deploy private governance measures to avoid, reduce, and reverse land degradation. Successful implementation of LDN requires refocusing efforts to enable and, where necessary, constrain all actors with agency over land management, including value chain actors.

This chapter is currently in review as:
Debonne, N., van Vliet, J., Metternicht, G., and Verburg, P.H. Agency shifts in agricultural land governance and their implications for Land Degradation Neutrality.

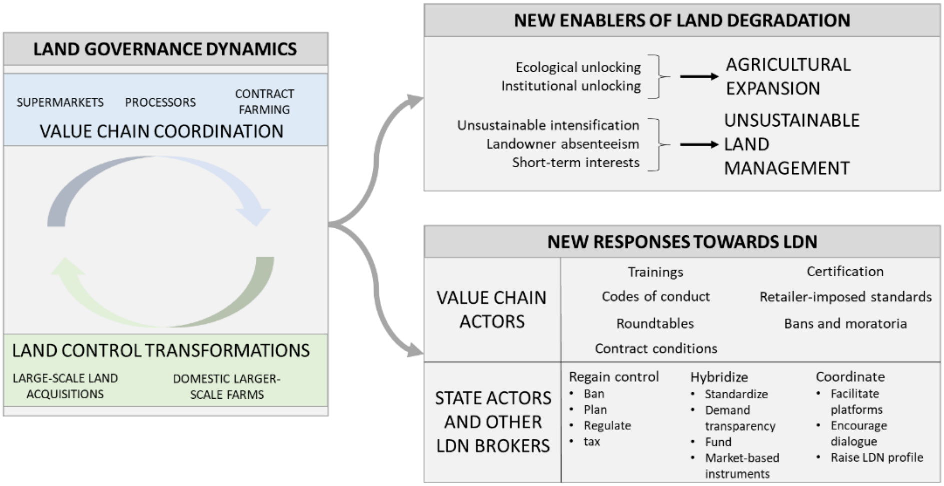

Figure 2.1: Graphical abstract for Chapter 2. Land governance arrangements are changing (left panel) as value chain coordination implies a larger role of value chain actors in land management issues, and land control is given to novel actors through LSLA and domestic larger-scale farms. This threatens progress towards LDN unlocking new areas for agricultural expansion and by disseminating unsustainable land management practices (upper right panel). However, it also enables new ways to address land degradation, with responses by value chain actors, state actors, and LDN brokers.

2.1. Introduction

Land degradation, defined broadly as a reduction of biological productivity and a decrease in ecosystem complexity, has affected over 20% of the global vegetated land area and 1.5 billion people in the last two decades (UNCCD, 2017). On agricultural land, land degradation is mostly anthropogenic, due to unsustainable agricultural practices and ill-adapted land and water management. Underlying drivers include both socio-economic and political factors (Vorovencii, 2016). On a global scale, degradation of agricultural landscapes undermines food security, reduces carbon storage in soils and biomass, and causes major economic losses, especially in already poor areas (Muchena et al., 2005; UNDP/UNCCD, 2011).

A structural answer to the land degradation issue has been proposed by the United Nations Convention to Combat Desertification (UNCCD) through the concept of Land Degradation Neutrality (LDN). LDN has been adopted as a target under the Sustainable Development Goals (SDGs) as target 15.3. A range of LDN brokers, actors aiming to drive progress towards the attainment of LDN, help countries to set targets and their implementation, including international NGOs, knowledge institutes, and funding mechanisms. Conceptually, LDN sets out the ambition to, on balance, maintain or increase the amount and quality of land resources by compensating any land degradation with land restoration, within specified time- and spatial-scales (Cowie et al., 2018). Technical implementation of LDN interventions occurs at a national scale, by compensating any ongoing land degradation within a land type by restoration and rehabilitation of the same amount of land of this type elsewhere. To this end, National Action Programmes are developed to envision pathways towards LDN, and concrete actions are outlined in Target Setting Programmes (Global Mechanism, 2019a).

LDN on agricultural land is feasible from a technical standpoint, as sustainable land management (SLM) and restoration techniques are readily available to counteract a wide range of land degradation issues. Yet, the bottleneck is the adoption of these techniques (Pacheco et al., 2018; Thomas et al., 2018). Land management decisions are made and influenced by a diverse set of actors, including for example smallholders, agribusinesses, agricultural cooperatives, and local to national land administrations. All of these need to be enabled and incentivized to avoid, reduce and reverse land degradation. Policy makers therefore face the challenge to create an enabling environment, i.e. a context that allows progress towards LDN (Akhtar-Schuster et al., 2017). This challenge is essentially an exercise of land governance (i.e. the *processes by which decisions are made regarding the access to and use of land, the manner in which those decisions are implemented and the way that conflicting interests in land are reconciled* (Borras and Franco, 2010; GLTN, 2018). Land governance encompasses elements of land use policy (the laws and regulations around land use and management) and land tenure (the bundle of rights endowed on various users and user groups). Consistently, a lack of effective and responsible land governance has been cited as a major constraint for large-scale adoption of SLM and restoration/rehabilitation projects (Nkonya et al., 2016; Verburg et al., 2019).

Traditional land governance assessments assume that agency over agricultural land management (i.e. the capacity to make decisions on land use and management) lies primarily with local or national actors, such as farmers or public land administrations (Sikor et al., 2013). However, land governance can be influenced by a much broader range of actors, including for example agribusinesses, retailers and other value chain actors (VCAs) (Lambin and Thorlakson, 2018), as well as consumers. As land systems globalize, agency over rural land management decisions has expanded to include urban elites and non-local actors along commodity value chains (Peluso and Lund, 2011).

Recent literature points to major dynamics in land tenure and agency over land management decisions in the agricultural sector over the past two decades.

Noteworthy are recent developments in large scale land acquisitions (LSLA), where (often foreign) investors acquire large tracts of land (Nolte et al., 2016), medium-scale farms in Sub-Saharan Africa (Jayne et al., 2016), land concentration in South America (Gómez, 2014), and contract farming (Otsuka et al., 2016). These trends point to a drastic diversification of actors relevant in contemporary land governance.

While the wider range of possible actors in land governance and environmental management is increasingly being recognized (Peluso and Lund, 2011), knowledge on their characteristics and geography is limited and scattered across disciplines. Furthermore, understanding of the implications for global environmental change issues, both in terms of threats and innovative solutions, has emerged only recently. Yet, new actors and value chain coordination are found to be associated with both severe land degradation (e.g. Liao et al., 2020), and with innovative solutions for environmental stewardship (e.g. Rueda et al., 2017). Because the heterogeneity of contexts of land degradation makes scalable LDN governance solutions highly needed (Ariti et al., 2019; Seppelt et al., 2018; Sparrow et al., 2020), it is pertinent to identify new ways to make progress towards LDN with a full consideration of the threats and opportunities that new actors present.

Most current efforts to combat land degradation and create an enabling environment for LDN are poorly reconciled with the changing land governance context. Geared towards state actors and local land managers, they remain somewhat inattentive to the role VCAs could play. For example, the National Action Programmes made by UNCCD's parties contain plans for governmental agencies, scientific institutions, and local communities (UNCCD, 2020), and rarely consider the role of VCAs as drivers of or solutions to land degradation.

The objective of this chapter is to quantify and map recent dynamics in agricultural land governance and assess the implications of these dynamics for the attainment of the LDN target, both in terms of new drivers of land degradation and innovative governance solutions towards LDN. We review evidence from recent peer-reviewed and grey literature on agency shifts in land governance and their consequences for enabling land degradation or leveraging LDN. The study focuses specifically on agricultural land and agricultural value chains. Three steps are taken towards this goal: (1) to quantify and, where possible, map current dynamics of land control and value chain coordination, and link these hitherto disparate dynamics within a framework of agency in land governance, (2) to describe the mechanisms by which they may act as an enabler of land degradation, and (3) to present ways for LDN brokers and actors along agricultural value chains to reposition themselves in this changing reality, so as to unlock novel, catalytic governance solutions for the attainment of land degradation neutrality.

2.2. Methods

2.2.1. Analytical framework and definitions

LDN requires major transitions in land use and land management, raising the question on who decides on these issues. This chapter adopts the perspective of agency to formulate answers to this question. Agency is defined as the capacity of an actor to instigate changes in land use and land management. This agency is usually not wielded by a single person or institution, but rather distributed across multiple actors. As the focus is primarily on the agricultural sector, other land-based activities (mining, forestry, etc.) that are relevant for LDN are not considered.

Conceptually, we distinguish three actor groups in land governance: individual land managers, state actors, and VCAs. First, we consider land managers, defined as people with rights to control land (Table 2.1). Control rights are an element of land tenure next to use and transfer rights (FAO, 2002). We use the term *land manager* to denote people who are entitled to change land use and management (setting them apart from *land users,* who do not enjoy such rights). Land managers can be *land owners* if they also enjoy land transfer rights, but in many situations, the land owner and land manager of a specific parcel are not the same.

Table 2.1: Distinction between land user, land manager, and land owner in terms of their respective land tenure rights. Definitions are based on *FAO (2002)*. In these definitions, rights may be formal, customary or assumed.

	Right to use	**Right to control**	**Right to transfer**
Has right to…	*use land*	*use land* *change land use* *manage land* *grant use rights*	*use land* *change land use* *manage land* *grant use rights* *grant control rights* *sell/transfer land to others*
Land user	Yes	Optional	Optional
Land manager	Yes	Yes	Optional
Land owner	Yes	Yes	Yes

A second actor group are state actors, defined as governmental institutions at any administrative level that decide on land-related issues. This is in itself a heterogeneous group, consisting of, among others, municipalities, agricultural and environmental ministries, and landscape planners.

VCAs (i.e. actors up- and downstream of the farm in agricultural value chains) compose the third group. These actors include, among others, agribusinesses, retailers, processors, and land investors, and influence land management by setting production requirements, providing agricultural technologies, and in some cases claiming full land control and/or land transfer rights.

The relative agency of these actor groups in a given land system can be visualized in an agency diagram (Figure 2.2). This diagram shows how agency is shared among the three groups, with each corner representing full agency of a single actor group. For example, the top corner represents a land system where state actors hold all authority over land-related issues, a situation that may be found in strictly protected natural reserves. In the bottom right corner, a land system of pure land manager agency is depicted, which is perhaps most closely approximated by subsistence-focused communities in remote places where state actors have no effective power. The bottom left corner represents a context where land decisions are made only by VCAs, a situation that is approximated by certain instances of plantations in countries with weak land governance institutions. In reality, however, agency is usually shared by at least two actors, and is therefore situated more centrally in the diagram. For example, most smallholder farmers act with relative autonomy but are subjected to the land laws set out by state actors insofar as these are effectively enforced, and will respond to land management requirements set by VCAs insofar as following these requirements is beneficial to them.

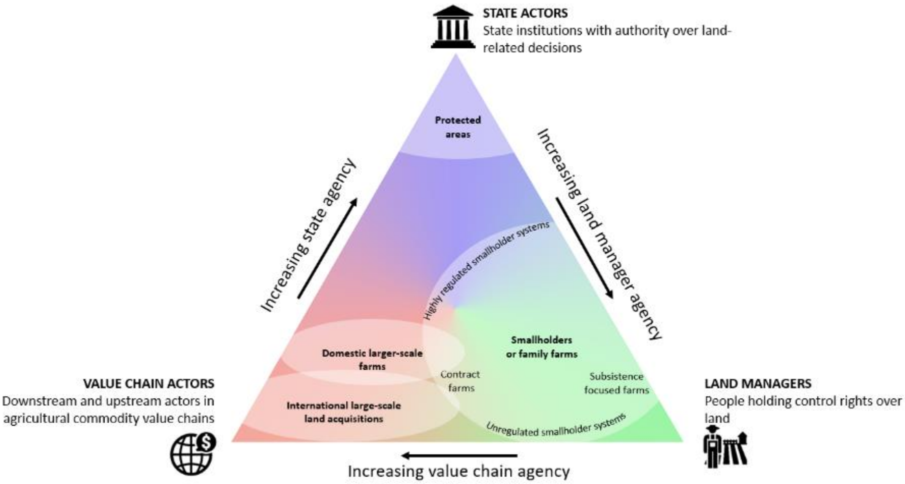

Figure 2.2: Agency diagram. Land governance in a given land system is characterized by the extent to which either of three agent groups have agency over the land management decision-making process. Smallholder or family farms are a heterogeneous group of land systems, which are dominated by individual land managers but may have significant state or value chain agency. Novel land systems such as international LSLAs or domestic larger-scale farms, occupy different positions on the diagram. The position of a given land system on the diagram informs the design of interventions to, for example, avoid, reduce or reverse land degradation, and indicates the primary partner(s) to address. Positions on the diagram can shift through time.

2.2.2. Synthesis of agency shifts and their implications for LDN

We combine quantitative and qualitative approaches to synthesize the extent and geography of agency shifts in land governance and their implications for LDN, in three steps.

First, we quantified and mapped agricultural land governance dynamics. Value chain coordination was approximated by the scientific literature describing contract farming arrangements. Recent literature (2007 and onwards) on contract farming was collected using Keywords “Contract farming” and “Contract Farm” in Web of Science. Papers were screened on relevance, retaining only those describing pre-harvest agreements between farmers and buyers. A cartography of retained papers was prepared by pinpointing the location of the case(s) described, and a timeline of publications was made. A distinction between local, regional and national case studies was made, with local case studies describing a relatively small area (e.g. a village), regional case studies describing a larger subnational area (e.g. a province) and national studies characterizing a country. Where a single paper described multiple cases, these were mapped separately.

International LSLAs were mapped and quantified using data available in the crowdsourced Land Matrix (Land Matrix, 2019) database. We used this database to map transnational land acquisitions for which contract negotiations have been concluded. Domestic Larger-Scale Farms (DLSFs) are not mapped, as this highly heterogeneous process is not easily captured under a single, quantifiable denominator. Instead, we discuss the various shapes DLSFs take in different parts of the world, and provide statistics where these are available.

Second, to describe the mechanisms by which agency shifts can lead to land degradation, we synthesize the current state of knowledge on the environmental impacts of value chain coordination, LSLAs, and DLSFs. We searched academic search engines and repositories, including Google Scholar and Web of Science, using keywords including "large-scale land acquisition", "land grab(bing)", "land tenure", "agricultural commercialization", and more, and identified papers or grey literature that address environmental impacts of LSLAs, DLSFs, and the many instances of value chain coordination. Retained documents were used for forward and backward snowballing to retrieve additional entries. The information gathered was used to distill key processes by which agency shifts cause or enable land degradation.

Third, to identify ways for VCAs, governmental actors, and other LDN brokers to reposition themselves and unlock novel, catalytic governance solutions for the attainment of LDN, we similarly performed a synthesis exercise on literature retrieved using keywords including "private land governance", "corporate sustainability", as well as keywords relating to specific instruments (e.g. "certification"). Adopting and combining existing frameworks (Rueda et al., 2017; Schaltegger and Burritt, 2018), we question to what extent VCAs can be instrumental for LDN, and how LDN brokers can leverage motivators to move VCAs to do so.

2.3. Land governance dynamics

Two interrelated trends of the 21st century, with relevance to the questions surrounding the distribution of agency to decide over land management, are of interest. We present literature on value chain coordination, where downstream and upstream actors in agricultural value chains use contracts and other mechanisms to influence land management of farmers embedded in the value chain. Subsequently we present evidence of the shift of land control rights have towards new actors.

Here, we focus specifically on LSLAs and DLSF, two highly visible trends that introduce new actors and break away from the family farming structure.

2.3.1. Value chain coordination: supermarkets, processors, and contract farming

Agricultural value chains can shape land management of farmers embedded within them, through predicating inputs and technologies that are available to farmers, and standardizing agricultural production (Reardon et al., 2009; Zagata and Sutherland, 2015). A major restructuring of the global agrifood industry is taking place, characterized by a closer direct involvement of VCAs with the land management of their producers, especially in areas near urban centers (Lee et al., 2012; Masters et al., 2013). Such value chain coordination can lead to on-the-ground land management changes (Rueda and Lambin, 2013). A highly visible symptom of this trend is the global rise of supermarkets (Blandon et al., 2009; das Nair, 2018; Reardon and Gulati, 2008). Supermarkets tend to set specific standards for how crops should be produced and impose quality standards on the products themselves (Hazell et al., 2010). This has the potential to influence land management practices (Handschuch et al., 2013; Neven et al., 2009).

Agricultural processors and large-scale trading firms are also increasing their market share and are increasingly engaging in closer relationships with supplying farmers. Documented sharp increases are reported in Kenya and Zambia, but the full extent of this dynamic is not yet fully understood (Sitko et al., 2018). Large-scale trading firms are often found to provide agricultural inputs and farmer trainings, thereby influencing land management (Sitko et al., 2018).

The relations between VCAs (supermarkets, trading firms, processors) and land managers are increasingly formalized through contract farming; which encompass a variety of agreements between farmers and buyers (Meemken and Bellemare, 2019). Three types of contract arrangements exist, each with increasing control over the land management of the contracted farmers (Prowse, 2012). Through marketing contracts, a processor and farmer only specify the quantity, price and quality of the product in a contract; resource-providing contracts require the processor to provide inputs (seeds, fertilizer, specific hardware), often as a loan, thereby exerting some control over the use of these inputs; whereas production-management contracts include specific production preconditions. A special form of contract farming associated with frontier contexts are crop boom-and-bust cycles (Hall, 2011; Ornetsmüller et al., 2019), often described in Southeast Asia. These cycles see smallholder farmers offered contracts which are to some extent predatory in nature, to grow cash crops. After a surge in contract adoption, a combination of land degradation and indebtedness creates a crop bust (Mahanty and Milne, 2016).

A global overview of the extent of contract farming is currently lacking. Data from the United States, Japan and Europe indicate that roughly more than a third of total agricultural production is produced under contracts (Otsuka et al., 2016). In the Global South, contract farming is important in some countries, (e.g. in Kenya, where 40% of farmers produce under contract), while in other countries (Vietnam, Ghana, Uganda), scarce evidence suggests that 5% of farmers produce under contract (Oya, 2012).

While empirical evidence is scarce, most literature reports on a rising importance of contract farming, both in developed and developing countries (Bellemare and Lim, 2018; Otsuka et al., 2016). Furthermore, a wealth of case studies (Figure 2.3) scrutinizing the micro- and macro-economic impacts of contract farms signals their increasing importance (Smalley, 2013; Wang et al., 2014). These case studies indicate that value chain coordination through contract farming is a global phenomenon, with case study hotspots in East Africa, Ghana, Southeast Asia and the Indian subcontinent.

Contract farming case studies

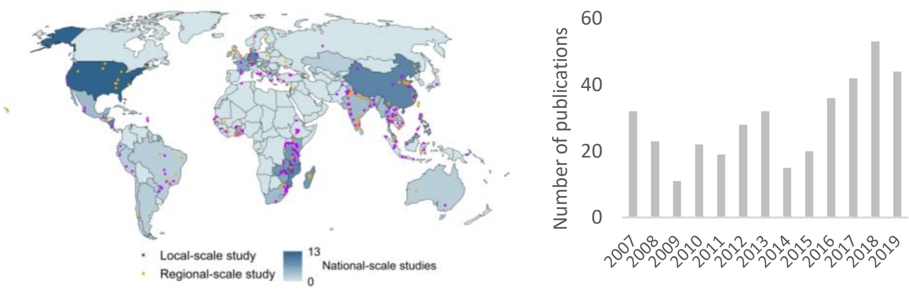

Figure 2.3: Timeline and locations of case studies reporting on contract farming as a proxy for the geographical extent and importance of value chain coordination. Hotspots of literature on contract farming are apparent in East Africa, Ghana, Southeast Asia, and the Indian subcontinent. Relative cold spots are Latin America and Australia. Developing countries are more often covered by local case studies, while developed countries have more national-scale studies.

2.3.2. Land control dynamics: international LSLAs and DLSFs

Concurrent with the trend towards increased value chain actor involvement with land management, major land control dynamics are taking place. Land control dynamics are changes in the *type* of actor that hold control rights over land (see Table

2.1), and can therefore decide on land use and land management. These land control dynamics introduce international actors (e.g. international LSLAs), or a variety of novel domestic actors that diverge from typical family farming operations.

International LSLAs are acquisitions through lease, concession, or sale of large tracts of land to international agribusinesses, investors, and foreign countries. The most extensive global repository of verified LSLAs indicates that, since 2000, over 80 million hectares of land has been acquired (Land Matrix, 2019). A timeline of LSLAs (Figure 2.4) shows a very rapid rise between 2007 and 2014, after which an apparent stagnation is observed. This stagnation could represent an actual trend, but is also partly explained by time lags between the land acquisition and its reporting in the Land Matrix database (Nolte et al., 2016).

Plantation-style agriculture managed by foreign parties is historically no novelty, with similar instances having existed in Roman, medieval, colonial and modern times (Alden Wily, 2012). However, in post-colonial times, the policy environment changed to foster small-scale, family farm production in most areas of the Global South. The sudden surge in plantation-style agriculture since 2007 is, therefore, a trend-breaking aberration (Byerlee, 2014)

The LSLA phenomenon is global in reach (Figure 2.3), with hotspots in Sub-Saharan Africa, Southeast Asia, Eastern Europe and Latin America (Constantin et al., 2017; Rulli et al., 2012). Land is acquired by an opaque plethora of international agribusinesses and investment funds (Cotula, 2012) mostly for agriculture, although forestry, tourism, industry, conservation projects and speculation are also notable intentions for such investments (Nolte et al., 2016).

LSLAs have been problematized from different disciplinary perspectives (Dell'Angelo et al., 2017). LSLA intentions often fail to come to fruition, because frequently, land rights have been transferred to nonviable businesses, or to actors interested in the speculative future value of the land rights (Deininger et al., 2011). Violations against local land rights have been widely reported (Anseeuw et al., 2011). The aspiration that LSLAs would develop intensive agriculture on non-forested, unused land (Deininger et al., 2011) has largely been debunked, as LSLAs target land with these characteristics in only a quarter of land deals globally. Oppositely, most deals target either populated croplands (displacing local people and creating secondary land expansion), or forests (Messerli et al., 2014).

International large-scale land acquisitions

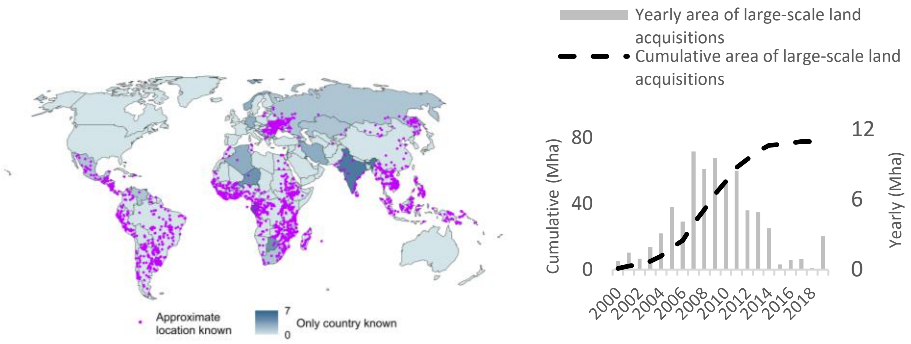

Figure 2.4: Timeline and location of international LSLAs as reported in the Land Matrix database. LSLAs for which the location is known with at least regional precision are shown as dots, while LSLAs for which only the country is known are shown as blue shades. The timeline shows a stagnation in recent years, which may be partly explained by a data gathering time lag but could also indicate actual stagnation. Figures represent concluded international deals since 2000.

Domestic larger-scale farms are observed in many countries and contexts. In general, these land systems capture a removal from family farming towards more capital-intensive, larger-scale farming controlled by domestic elites. Family farming is still the dominant mode of agricultural production worldwide when quantified in terms of the number of farms (Lowder et al., 2016). However, literature suggests that, across the globe, domestic elites are (re-)entering the agricultural sector, engaging in farming at larger spatial and capital scales using business models that diverge from family farming in numerous ways.

In Sub-Saharan Africa, DLSF is framed under the narrative of "the rise of medium-scale farms" (Jayne et al., 2016). These are entrepreneurial farms run by domestic, often urban-based managers operating at a larger scale and in a more capital-intensive way than is usual in their regional or national context. There are indications that medium-scale farms represent a relatively rapid urban takeover of the countryside. Empirical evidence on medium-scale farms comes from a number of national-scale case studies for Zambia (Sitko and Jayne, 2014), Malawi (Anseeuw et al., 2016), Ghana (Chapoto et al., 2013), Kenya (Debonne et al., 2020) as well as multi-country studies in West Africa (Hilhorst et al., 2011) and Southern Africa (Hall et al., 2017; Jayne et al., 2016). The most complete empirical study (Jayne et al., 2016) builds on repeated agricultural censuses (Kenya, Ghana, Tanzania, Zambia) and finds that the share of land belonging to the smallholder segment (defined as smaller than 5 hectares in the study) is generally declining, while the medium-scale segment

(5 – 100 hectares) is growing. Newcomers in this segment are often urban-based individuals, and depart from the family farm business logic (Anseeuw et al., 2016; Sitko et al., 2018; Sitko and Chamberlin, 2015). Geographical analyses find that medium-scale farms are located in highly accessible areas close to major towns and cities (Sitko and Chamberlin, 2015). However, results of a systematic survey of medium- and small-scale farms in the Kenyan Rift Valley finds that the qualities attached to this farm size bracket in earlier studies, such as their urban origin, entrepreneurship, or tendency to grow non-staple crops, are only valid for a subset of medium-scale farms, and are also found in a subset of small-scale farms (Debonne et al., 2020). This indicates that, while larger, business-oriented farms may be overtaking the African countryside in some places, the evidence is mixed and the extent of this dynamic remains difficult to estimate.

Medium-scale farms can either be characterized as an element of structural transformation which is part of other megatrends such as urbanization and the rise of supermarkets (Meyfroidt, 2017a; Neven et al., 2009), or as an elite capture akin to LSLA (Sitko and Jayne, 2014). The fragmented nature of landholdings under customary land tenure regimes in Africa has been noted as a major obstacle to the adoption of some agricultural technologies (notably mechanization), and the scope to consolidate landholdings from within a customary land tenure system is often limited (Asiama et al., 2019). Medium-scale farms break with customary tenure, and use statutory land tenure arrangements that, when backed by state power, can overrule existing customary land rights (Chimhowu, 2018). Whether this lateral entry of capital-intensive farmers is a necessary source of dynamism or a hostile takeover of customary spaces is an open debate (Hall et al., 2017).

In Latin America, DLSFs are captured under the umbrella of "land concentration", most notably in Argentina and Brazil. While land concentration is to a large extent a historical relict, it has intensified since 2000 (Gómez, 2014). In Argentina and Paraguay, small family farms are consolidated into larger farms, often for soy production, through leasing by capital-endowed individuals. These tenants lease and pool numerous adjacent farms, often without personally residing on-site (Elgert, 2016; Urcola et al., 2015). In Brazil, land concentration is partly attributed to elite capture of land for speculative and productive purposes, enabled by unclear land tenure regulations (Reydon et al., 2015; Sparovek et al., 2019). Rapid concentration has also been noted in Uruguay, where land is transferring from individuals to domestic corporations (Piñeiro, 2012). To varying extents, such processes are taking place across the continent (for an overview, see Borras et al., 2012).

Likewise, a fast-paced increment of farm scale enlargement is occurring in Europe. The number of farms in the European Union has decreased by 25% between 2005 and 2016. Most of the disappearing farms are small (<5 ha), and are being consolidated into larger farms; the only growing farm size segment is the one of 100 ha and above (EUROSTAT, 2018). The specific dynamics of farm consolidation in Europe are highly context-specific, and driving factors include demography, economic liberalization and competitiveness, and policy biases (Bartolini and Viaggi, 2013; van Vliet et al., 2015). A significant fraction of the resulting large farms (40% of 304 000 farms with an output of over 250 000 euro per year) are owned by various types of agribusiness holdings (EUROSTAT, 2018), signaling that European land is increasingly being managed and owned by business interests instead of family farmers.

2.3.3. Land governance agency shift

Value chain coordination and land control dynamics are shifting agency in land governance, causing a redistribution of agency over land management decisions (Figure 2.5). In other words, the answer to "who decides?" on land management is changing. As VCAs set production standards and provide access to agricultural inputs and technologies, they co-determine land management practices at global scales. This significant agency is, for example, leveraged to enforce health and safety standards across entire value chains, including soil and water management (Subervie and Vagneron, 2013).

Land control dynamics further contribute to these agency shifts. This occurs directly, as land control rights are being transferred away from state actors (e.g. when LSLAs target protected areas or other state land) and from individual land managers. Land becomes controlled by actors that are more closely associated with VCAs: they are wholly reliant on VCAs through contracts or, in the case of many LSLAs, are owned by agribusinesses.

Indirectly, land control dynamics are additionally found to override state regulations, either by clientelism or by unpenalized rule breaking (Cotula et al., 2011; Messerli et al., 2015; The World Bank, 2014), thereby significantly reducing state agency. The various modes of DLSFs are similarly associated with a redistribution of agency away from state actors. For example, African medium-scale farms managers have been found to dominate agricultural policy-making processes by occupying powerful positions in farmer organizations (Jayne et al., 2016).

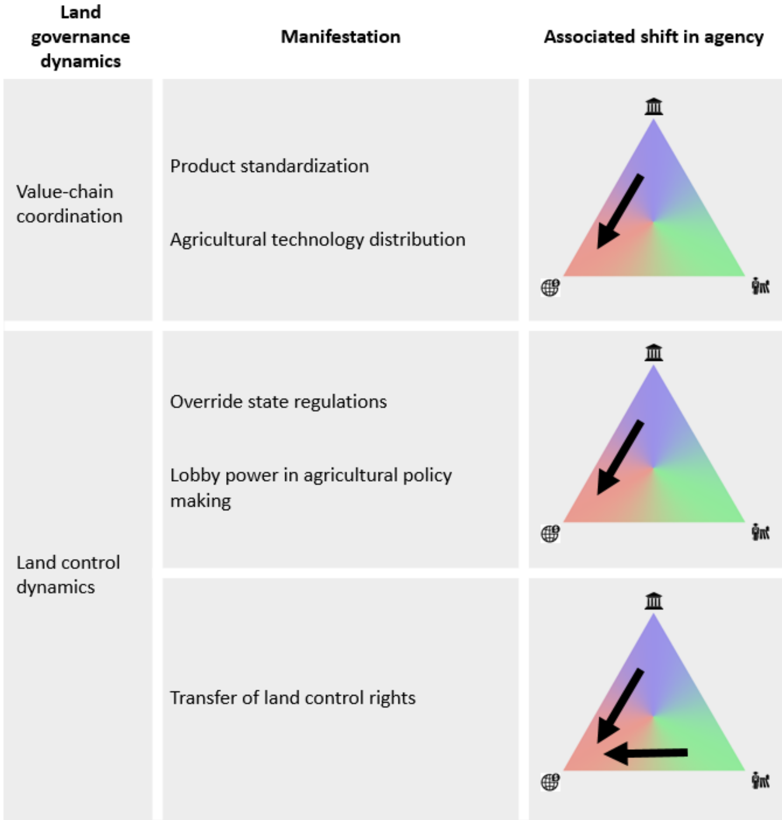

Figure 2.5: Agency shifts as a consequence of value chain coordination and land control dynamics.

2.4. Agency shifts as enablers of land degradation

2.4.1. Conversion of natural areas: ecological and institutional unlocking

The scope for expansion of global cultivated areas at the cost of natural areas is dependent on ecological limitations and institutional rulesets (Eitelberg et al., 2015). Ecological limitations and institutional rulesets limit where agriculture is feasible and allowed, thereby safeguarding areas that are ecologically too unsuitable for agriculture and/or are adequately protected. We indicate below how VCAs have ecologically and institutionally unlocked some of these safe havens.

First, ecological limitations can to some extent be overcome by technology-intensive farming systems using, for example, irrigation technology or synthetic fertilizers

(Angelsen and Kaimowitz, 2001; Hall et al., 2017). This "ecological unlocking" is described in a number of case studies. For example, the conversion of an extensively used dryland area to a biofuel LSLA in Mozambique was made possible by developing irrigation infrastructure at a scale unattainable by local smallholders (Borras et al., 2011). For LSLAs, ecological unlocking has not been an accidental by-product, but rather an explicit element of its supporting narrative to develop "underused", "marginal" lands in "land-abundant areas" (Deininger and Byerlee, 2012).

Ecological unlocking is also a central tenet of many contract farming schemes where downstream VCAs provide inputs or hardware to farmers to enable them to adopt crops. A prime example is the rapid spread of rubber in Southeast Asia, which is replacing shifting cultivation landscapes and forests (Ahrends et al., 2015). Similarly, boom and bust dynamics build on dispersion of technologies such as hybrid maize and synthetic fertilizers through middle men, thus allowing crops to be grown outside of their ecologically suitable range, albeit only for a limited time and at the cost of severe land degradation (Ornetsmüller et al., 2019).

Second, institutional unlocking denotes the diminishing power of regulation, land use planning, or protected areas, in limiting where agriculture can expand into. This further enables conversions of natural areas, again especially in the case of LSLAs. The apparent disregard of LSLAs to respect the integrity of protected areas or stay clear of valuable ecosystems (Koh and Wilcove, 2008; Messerli et al., 2015) indicates that institutional barriers against degradation have become largely irrelevant in an LSLA context.

Many LSLAs are expansionist in nature and thereby often claim new areas beyond the extent of current agricultural areas at the expense of nature. Geographic analysis has shown that, globally, LSLAs often target forested areas (e.g. in Brazil, Papua New Guinea, Indonesia, Congo), and acquired areas and their surroundings are found to be deforested at faster rates than comparable non-acquired areas (Davis et al., 2015; Eakin et al., 2014; Magliocca et al., 2019). Besides forests, other important habitats such as savannas are lost to LSLAs, thereby undermining efforts to safeguard biodiversity (Debonne et al., 2019).

In contrast to the expansionist nature of LSLAs, preliminary spatial analyses of DLSFs in Africa indicates that these farms predominantly develop in areas with high agricultural potential (Sitko and Chamberlin, 2015), and may, therefore, be less likely to cause natural ecosystem losses (as target areas are usually already cultivated). For contract farming, natural area loss is found when the short-term lucrativeness and/or indebtedness drive farmers to expand their landholdings, as has been observed in the Southeast Asian rubber sector (Ahrends et al., 2015), cattle rearing in the Brazilian Amazon (Pereira et al., 2016), or the many oil palm outgrower schemes in the global tropics (e.g. in Indonesia: Euler et al. (2015) and Peru: Bennett et al. (2018)).

2.4.2. Introduction and incentivization of unsustainable land management

Agency shifts in land governance may also enable land degradation in cases where the affected areas were already under agricultural use, if the agency shift incentivizes or introduces unsustainable land management practices. As VCAs increase their agency over land management decisions and land control dynamics introduce new actors, three causal links explain an often-observed shift to more unsustainable land management practices.

First, capital and technology can significantly intensify land management. Value chain coordination delivers capital and technology, notably through input-providing contract farming. Moreover, compared to smallholder farms, LSLAs and DLSFs are typically more capital-intensive. Conventional agricultural intensification, while able to increase crop yields in the short term, can come at the expense of other ecosystem functions and can be unsustainable in the longer term (Deguines et al., 2014). For example, crop boom and bust cycles are instigated by VCAs introducing seeds and inputs for intensive agriculture in extensively used landscapes, leaving depleted and eroded soils after the bust phase (Ornetsmüller et al., 2019). Overuse of inputs and a switch from diverse cropping systems to monocultures has also been described for LSLAs (e.g. Friis, 2015; Mann and Bonanomi, 2017). A World Bank study found that 32 out of 33 surveyed LSLAs engaged in patently deleterious land management, including unsustainable mono-cropping, excessive use of pesticides, and water resource depletion and pollution (The World Bank, 2014). Similarly, a multi-country West-African study found anecdotal evidence of more soil erosion occurring in DLSFs relative to smallholder farmers (Hilhorst et al., 2011).

Second, land control dynamics have introduced actors that often act as absentee, distant land owners/managers, creating a situation where land management decisions are made by people who are physically disconnected from the land they manage. Similarly, VCAs up- or downstream of the farm influence land management of farms without residing on, or near to, these farms. It can be hypothesized that absentee land owners/managers are less inclined to value sustainability, as they are protected from immediate negative effects of unsustainable practices. Corroborating evidence for this hypothesis is found in several cases; in the United States, absentee land owners have been found to be less likely to manage against soil erosion or participate in soil conservation programs (Petrzelka and Armstrong, 2015; Stroman and Kreuter, 2015); in a case study from the Philippines, Ravnborg (2003) found that absentee land managers were the only land manager group contesting restrictions on adverse agricultural practices, pushing for more lenience in the use of chemical inputs and opposing to land restoration projects. Contrastingly, in Australia, absentee land owners using their land mostly for recreational purposes have been found to engage in conservation efforts (Kam et al., 2019). Currently, the evidence concerning this hypothesis is still too anecdotal to warrant strong claims.

Third, the agency shift may promote a short-term economic interest in land, undermining longer-term sustenance of productive capacity. Growing crops in suboptimal environments can cause severe or even irreparable land degradation, yet still make business sense to actors who do not rely on that specific land for their long-term sustenance and livelihood. This is a defining characteristic of crop booms (Hall, 2011; Mahanty and Milne, 2016). Furthermore, many studies have noted the surprisingly large amount of failed LSLAs, where production stops within a few years after startup (Nolte et al., 2016), often due to ecological unsustainability and soil depletion (Messerli et al., 2015; Schönweger and Messerli, 2015). DLSFs are estimated to be more embedded within their local communities and to create long-term economic linkages, but empirical evidence is scarce (Hilhorst et al., 2011; Meyfroidt, 2017b).

2.5. Responses to the agency shift

Responses and measures to attain the LDN target may be more effective if they are tailored to the new global land governance contexts. Hereafter we outline how value chain coordination and land control dynamics can be leveraged to implement LDN measures at scale. First, we discuss the instruments that VCAs have at their disposal to avoid, reduce, and reverse land degradation. Second, we identify motivators for the adoption of these instruments, and how state actors and other LDN brokers can interact with these motivators.

2.5.1. Instruments of value chain actors

VCAs may use a mix of metaphorical carrots, sticks, and sermons to, respectively, promote LDN, penalize unsustainable land management, and foster awareness, knowledge, and partnership towards LDN in their value chain (Figure 2.6). Following Rueda et al. (2017), we organize the possible value chain instruments based on stringency. We further assess to what extent, and how, instruments can be used in either step of the LDN response hierarchy. Instruments aiming to avoid land degradation must be able to purge the value chain from products associated with ongoing processes of land degradation. Reduction of land degradation in value chains can be achieved by ensuring that suppliers transition to SLM and abandon degrading land management practices. Land degradation reversal requires that the productive potential and ecological functioning of degraded landscapes is (partially) restored.

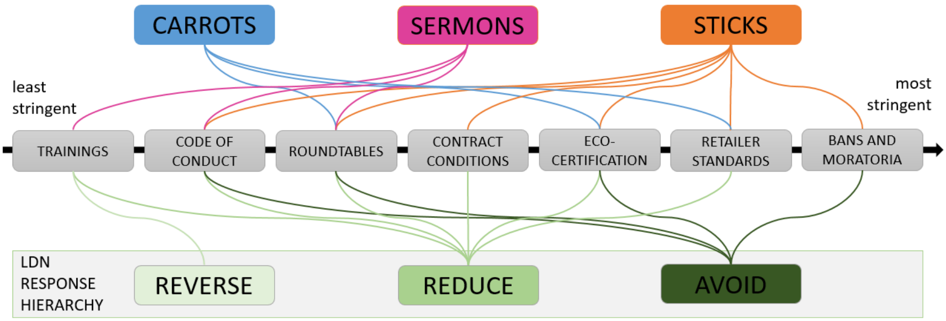

Figure 2.6: Instruments available to VCAs to promote SLM and self-regulate sustainability take the form of carrots (rewarding positive action), sticks (penalizing negative action) or sermons (sharing information and best practices). Interventions are ordered from least to most stringent (left to right). There are numerous interventions that can be instrumental in avoiding or reducing the land degradation associated with a value chain. The scope for reversal of land degradation remains limited.

Trainings are often used by agribusinesses, in a fashion similar to governmental or NGO-led agricultural extension (Anderson, 2008). While the overall focus of such trainings is usually farm yield maximization, sustainability can be part of the curriculum too. For example, Callebaut, a major chocolate processing company, assists its suppliers to enhance the carbon sequestration potential of cocoa farms, among others by promoting tree-shaded cocoa (Barry Callebaut, 2018; Cocoa Horizons, 2018). Such interventions constitute an effort to not only avoid and reduce degradation, but also to reverse it.

Codes of conduct are intentions and targets set and evaluated by companies. They are low-stringency interventions because, while their goal is a modicum of self-regulation, non-adherence is not penalized - and in many cases not made public. Their effectiveness is, therefore, entirely dependent on the internal discipline of the company and the extent to which the code of conduct is able to affect the core business model (Mårtensson and Westerberg, 2016). In most cases, a supplier's non-compliance will not constitute grounds for exclusion from the supply chain (Lund-

Thomsen and Lindgreen, 2014). Unilever provides an example of a wide-ranging environmental code of conduct. Their Sustainable Agriculture Programme defines 11 standards, among which are soil health, soil loss, nutrients, pest management, and biodiversity. Supplying farmers and companies are encouraged to comply with these standards, and develop strategies to book incremental progress. Despite the non-compulsory nature of the standards, the code of conduct provides a common definition of sustainability and allows Unilever to track its progress (Unilever, 2019).

Roundtables are sector-wide platforms where multiple stakeholders (farmers, processors, retailers, NGOs) meet to share best practices and strive towards sector-wide sustainability (Schouten and Glasbergen, 2011). Typically, roundtables produce a shared code of conduct to which participating companies commit to comply. Examples include the Roundtable on Sustainable Palm Oil, the Roundtable on Sustainable Biofuels, and the Roundtable on Sustainable Soy. Their scope is similar to the codes of conduct for individual companies, although the focus of roundtables has typically been on halting rampant deforestation rather than the promotion of SLM practices. Roundtables can issue certificates for compliant producers, thereby setting stricter requirements than are provided in the national laws of producers (Garrett et al., 2016).

Eco-certification is a communication tool developed to allow producers to ascertain the sustainability of their products to obtain a premium price from consumers with a sustainability preference (Defries et al., 2017). The certification is performed by an external auditor based on a set of criteria and allows for a label to be displayed on certified products. For example, the Rainforest Alliance currently certifies 1.3 million farmers operating on 3.5 million hectares and auditing based on 23 mandatory and 77 flexible criteria. Criteria include nature conservation and proper agricultural input use (Rainforest Alliance, 2018). Whether eco-certification (or the certification issued by roundtables) is able to spread SLM rather than merely reward current SLM practitioners remains unclear (Blackman and Rivera, 2011).

Contract conditions are clauses attached to contract farming schemes. Where contract farming takes the form of a production-management contract, downstream VCAs can demand crops to be produced under a specific land management (Abebe et al., 2013; Bellemare and Lim, 2018). These conditions are often related to food safety, imposing, for example, specific food storage conditions. However, sustainability can be part of these conditions as well. For example, in Madagascar, Minten et al. (2009) reported that farmers producing vegetables under contract for European markets face strict requirements, and as a consequence show more sustainable management of resources. Similarly, Van Hoi et al. (2010) describe input limitations imposed on Vietnamese farmers that produce vegetables for export.

Retailer standards are developed to enable retailers to perform due diligence, and share similarities with eco-certification schemes. For example, GlobalGAP (Global Partnership for Good Agricultural Practices) is used by over 40 large retailers in 15 countries (mainly in Western Europe). These retailers thereby ensure that products in their shelves meet all GlobalGAP criteria. The certification is very broad, incorporating elements of hygiene, traceability, on-farm labor, and food safety. While sustainability and environmental criteria are present, these are typically "recommended" rather than imposed. For example, GlobalGAP asks that consideration be given to enhancing the environment and to minimize environmental impact (GlobalGAP, 2017). For farmers wishing to export to the United Kingdom, the Netherlands or Germany, being certified by GlobalGAP is a de facto requirement as virtually all retailers in these countries require it (Colen et al., 2012). In Vietnam, rice farmers certified by GlobalGAP and VietGAP (the Vietnamese certification institution) are found to use significantly less inputs (fertilizers and pesticides) compared to non-certified farmers (Stuart et al., 2018).

Bans and *moratoria* are high-stringency tools that aim to completely remove producers that practice degrading land management from the value chain. The Amazon Soy Moratorium, for example, precludes farmers operating within recently deforested areas of the Amazon rainforest to sell to participating processors. Because participants include major processors like Cargill and Bunge, a significant part of the soybean sector could be cornered. If complemented by remote sensing-based monitoring, deforestation can be attributed to individual producers, thus creating a major disincentive to further degradation (Nepstad et al., 2014). However, critics argue that this moratorium ignores the stepwise nature of land use changes (e.g. where forest is first converted to pastures, and only later these pastures are converted to soy plantations; Arima et al. (2011). Furthermore, as soy expansion is effectively curtailed in the regulated area, it moves towards unregulated areas instead (Gibbs et al., 2015).

Whether or not VCAs can be effective environmental stewards is heavily debated. In the field of forest conservation, value chain initiatives have been found to exert relatively minor and often unverifiable impacts, and where local effectiveness is evident, it is often offset by leakage of deforestation to other areas (Blackman and Rivera, 2011; Gibbs et al., 2015; Lambin et al., 2018). However, as an increasing amount of brands and companies are adopting standards, incremental positive changes are occurring (Defries et al., 2017). Whether or not current approaches are effective, the increasingly consolidated nature of many food supply chains, where a handful of companies control the markets for e.g. coffee, banana, palm oil or cocoa, creates an imperative to interact with VCAs to develop more effective measures (Folke et al., 2019).

2.5.2. Motivators for value chain action towards LDN and options for policy makers

Following the previous section, we now question why VCAs would adopt instruments in line with the LDN target. Instruments are adopted when there is a business case to do so, and these can range from reactionary appeasement of environmental criticism to reputational business cases or the recognition of LDN as an inherent quality of responsible agribusiness (Schaltegger and Burritt, 2018). We identify four motivators that interfere with such business cases and explore the role of policy-making to stimulate, enable, or push VCAs (Table 2.2).

First, to motivate VCAs concerned with building or maintaining a brand reputation, the link between products and their associated land degradation should be made transparent. Innovative tools, such as the TRASE database (www.trase.earth) are allowing researchers to scrutinize commitments (e.g. zu Ermgassen et al., 2020). However, agricultural value chains remain opaque (Keene et al., 2015; McSweeney and Coomes, 2020), and attributing land degradation to specific actors or products continues to be challenging (Paitan and Verburg, 2019).

Second, land degradation often leads to reduced yields. Therefore, SLM can — in many cases— maintain or increase yields, although effects may not be immediate (Schmidt and Tadesse, 2019). However, for some forms of SLM and in certain contexts, yields will not increase but will rather be part of a trade-off against other co-benefits (Seufert and Ramankutty, 2017). When SLM increases yield or reduces risks, it is well-aligned with business interests. Governments can enable this motivator by supporting innovation, e.g. by providing transitional funding, microfinance, or linkups with research institutes. For example, the LDN Fund is a global initiative to provide structural funding to businesses aiming to contribute to LDN (Global Mechanism, 2019b; Quatrini and Crossman, 2018). However, as described above, institutional and ecological unlocking processes imply that, from the perspective of a VCA, degraded land can easily be replaced by tapping into frontier land. A disregard for the long-term productive capacity in a context of narratives of available land (Deininger et al., 2011) may therefore pose a challenge to triggering this motivator. Secure land tenure for smallholders and stringent land zoning policies can dissuade unmitigated agricultural expansion and encourage VCAs to maintain or enhance the soil quality of current agricultural land.

A third motivator is the ability for sustainability leaders to tap into niche markets, using certificates and labels to attest to sustainable practices. The potency of this motivator grows when more consumers are willing to pay higher premiums. Policy makers can further mainstream and regulate certificates and labels, create awareness among consumers, and provide financial assistance to support sustainable transitions and certification. However, the amount of consumers willing to pay for less degrading products is limited (Wei et al., 2018). Certification may help to support an ecological vanguard, but niche markets are easily saturated and therefore relying on consumer preferences is unlikely to be sufficient (Rueda et al., 2017).

Fourth, VCAs may be pushed towards sustainability by legal requirements, taxes, or subsidies. These motivators are especially required to move environmental laggards (i.e. those who fail to find a business case for action against land degradation). Governments can for example turn existing voluntary certification into a minimum production prerequisite, thus requiring due diligence from, for example, supermarkets (Colen et al., 2012). More classical approaches include using land use planning to require or restrict specific land management in specific places (Metternicht, 2018), or the banning or taxing of specific practices (e.g. pesticide bans; Maggi et al., 2019). However, beyond issues of attributing land degradation to products or companies, a major challenge lies in the globalized nature of the agrifood industry and the limitations of national governments in a context of international trade agreements (Eyhorn et al., 2019). Transnational companies may flee countries with strong environmental governance (Le Polain De Waroux et al., 2016). Supranational organizations and conventions, such as the UNCCD, may therefore have a role in facilitating a harmonized and sufficiently ambitious policy framework, as is also requested by the business community (WBCSD, 2019).

Table 2.2: Motivators for value chain action towards LDN, and their respective enablers, triggers, and challenges.

Motivator	Enablement / trigger	Challenges
Reputational damage	- Scrutiny, naming and shaming - Value chain transparency (e.g. TRASE)	- Lack of traceability and value chain opaqueness
Land degradation reduces yields, SLM provides long-term yield stability and/or increases yields	- Support SLM innovation (transitional funding, microfinance) - Limit agricultural expansion by securing land rights and enforcing deliberate land use plans - Provide transitional funding / microfinance	- Ecological and institutional unlocking makes new, non-degraded land available, removing the incentive to invest in maintenance of productive capacity - Trade-offs between SLM and short-term yields for many crops
Access to sustainable niche markets	- Support and regulate certification schemes - Increase consumer awareness	- Saturation of niche markets limits potential
Legal requirements, taxes and subsidies	- Set standards, adopt existing certification as minimum requirement - Make specific, highly degrading practices illegal (e.g. pesticide bans) - Financial incentives	- Lack of traceability and value chain opaqueness - VCAs seeking lowest governance denominator

2.5.3. Towards a new strategy for LDN

Governments and other LDN brokers have several ways to reposition themselves given the agency shifts and the implications thereof, outlined above. This repositioning can take three forms, which we discuss below.

First, a re-appreciation of territorial land governance implies that state actors reclaim some agency at the expense of VCAs. In this, they acknowledge that the agency shift, if left unchecked, enables new forms of intensified land degradation. State actors may reclaim agency, e.g. through enforcement of environmental regulations. While market-based policies and instruments may have a potential to regulate value chains (Baumber et al., 2019), issues arising from land control dynamics (agricultural expansion and unsustainable land management) remain unresolved. Therefore, enforcement of environmental regulations becomes necessary to reestablish the agency of state actors where it has shifted excessively towards VCAs. Interestingly, such regulations are requested by VCAs (WBCSD, 2019). For example, a survey among LSLAs (The World Bank, 2014) found that most LSLA managers welcome stricter environmental impact assessments. Insofar as these are equally applied to all competitors, they would enable the adoption of required SLM measures.

Second, a hybridization of land governance recognizes that spontaneous private environmental governance, while promising, is not sufficient (Dauvergne and Lister, 2012; Lambin et al., 2014). This is especially so for LDN, where the scope of VCAs to turn degradation reversal into a business case is limited. Therefore, there are calls for governments to collaborate with private actors in hybrid land governance arrangements, where they complement each other's possibilities and constraints (Rueda et al., 2017). Sikor et al. (2013) define such governance applied to value chains as flow-centered governance, which stands in contrast with traditional territory-centered governance. Flow-centered governance has significant benefits in terms of scalability. Baumber et al. (2019) assess to what extent existing market-based instruments, such as the offsetting of damaging practices, mandates and obligations, grants, subsidies, or tax instruments, could be applicable and effective for LDN. These instruments are currently being applied in the realm of carbon emissions, biodiversity and other ecosystem services, and the authors conclude that LDN could be integrated in such existing instruments, although this hasn't been done yet.

Third, the coordination of the LDN target is primarily in the hands of the UNCCD, and their role may increase in importance because of the agency shift. The current policy dialogue to attain LDN is mostly a dialogue between state actors and the parties of the convention. As an example, the UNFCCC has since 2011 organized the Momentum for Change initiative, which takes the shape of a platform where businesses can share best practices in the fight against climate change. As a result, numerous partnerships between businesses have arisen (Hickmann et al., 2019). The UNCCD is finding a similar strategy, engaging with business platforms in the Conference of the Parties (Decision 6 COP.14), organizing seed funding for private LDN action through the LDN Fund (Global Mechanism, 2019b), and engaging with existing business platforms (WBCSD, 2019). Furthermore, the profile of LDN as an urgent and worthwhile international target with multiple co-benefits (Allen et al., 2020) can be raised among business communities. Moving further on this pathway, LDN could become part of existing or new sustainability standards, retailer standards, certification boards, and roundtables.

2.6. Conclusion

Our findings are based on a broad literature review in which the multiple dynamics in agricultural land governance are confronted with the current approach towards LDN. LDN does not only pertain to agricultural land, and further inquiries into similar dynamics in, for example, the forestry or mining sectors, could complement our findings. Furthermore, we note that certain aspects of the interface between land governance agency shifts and environmental management remain understudied. For example, while gender dimensions of (the efforts against) land degradation are found to be a key aspect of LDN (Collantes et al., 2018), there are currently no studies into gender dimensions of LDN in relation to the land governance dynamics described here. Lastly, while this chapter includes perspectives from research institutes, international organizations, and other grey literature, it can only serve as a proxy of the agency shifts described here. Continued efforts to map and track global agricultural dynamics could complement and improve our approximations, while a dialogue with stakeholders may bring additional nuance to the perspectives in this chapter. With these limitations in mind, our literature review has indicated that:

1) Land governance is undergoing drastic changes, mostly manifested in a considerable agency shift towards VCAs at the expense of state actors and land managers.
2) This agency shift can lead to conversion of natural land to agricultural land and incentivize unsustainable agricultural intensification, thereby undermining progress towards LDN.
3) Newly empowered VCAs have instruments and business cases for actions aligned with the LDN target.

The UNCCD, state actors, and other LDN brokers can reposition themselves to respond to this changing context in three ways: regaining control to curtail VCAs driving land degradation, hybridizing land governance to leverage the many tools and business cases VCAs have to be instrumental towards LDN, and coordinating an intensified dialogue between VCAs and LDN brokers to mainstream LDN in agribusiness value chains.

Acknowledgements
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3. Farm scale as a driver of agricultural development in the Kenyan Rift Valley

Farming in Sub-Saharan Africa (SSA) is historically dominated by small-scale farms (SSFs), but evidence suggests that medium-scale farms (MSFs) are becoming increasingly prominent. These MSFs are often portrayed as entrepreneurial innovators, bringing dynamism and commercialization to SSA agriculture without displaying the negative features of land grabbing processes. However, there is little empirical evidence supporting these claims. We deployed a survey of 319 farmers covering a wide range of sizes in the Kenyan Rift Valley. Results show that MSFs are not a new phenomenon in the area, and are mostly farms that incrementally increased in size by buying or renting additional land. Furthermore, we find no differences in yields for various crop types between SSFs and MSFs. On average, MSFs use a higher share of their land for grazing, and have more dairy cattle per farm but less per hectare. The average MSF has a higher propensity to grow cash crops and serve non-local markets than the average SSF, and they employ significantly fewer people per hectare. However, within-category heterogeneity is high for all investigated dimensions, while past decision-making and future aspirations reveal entrepreneurship to occur in all farm size categories. We conclude that only a subset of all MSFs can be characterized as entrepreneurial, while these qualities can also be attached to many SSFs. Hence, we find that farm scale is an imperfect proxy to gauge the characteristics of a farm system, and presenting MSFs as a developmental panacea for SSA's rural areas is therefore unwarranted.

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3.1. Introduction

The African agricultural sector is undergoing major reconfigurations, as large-scale land acquisitions and contract farming are reorienting vast areas of land towards export production (Deininger and Byerlee, 2012; Otsuka et al., 2016). These high-profile land dynamics may have obfuscated other changes that have a smaller individual scale but potentially a larger combined effect. This is signaled by the evaluation of repetitive agricultural surveys in multiple Sub-Saharan African (SSA) countries, which shows that the distribution of farm sizes is shifting rapidly (Jayne et al., 2016). After a long period of small-scale farm (SSF) domination, there has been an increase in land managed as medium-scale farms (MSFs) since the year 2000. MSFs are loosely defined as farms that are relatively larger than what is usual in their immediate context (Hall et al., 2017), and empirical studies for SSA tend to set the lower threshold to distinguish MSF at 5 hectares (Samberg et al., 2016). Observed trends in MSF may signal that agriculture in SSA is experiencing a watershed moment, as a continuation of current trends would vest the majority of land in the hands of MSFs in many SSA countries in the near future. This observation is in contrast with theoretical expectations, which generally posit that demographic and economic trends predicate a persistence of small-scale family farming across most of SSA (Hazell et al., 2010).

The emergence of MSFs is attracting academic interest to understand the drivers and consequences of these developments. Farm size is an element of wider debates around food security, agricultural productivity, poverty, and economic growth (Meyfroidt, 2017b). Yet, little is currently known about the characteristics of MSFs, the actors owning and managing them, the drivers of their emergence, their geographical contexts, their environmental consequences, and the future pathways they may signal.

To study this phenomenon, two general approaches are often used. First, available agricultural censuses are mined to distill farm size distributions and their trends. On a global scale, such studies reassert the dominant role of smallholders in developing countries in producing food (Samberg et al., 2016). Furthermore, they show that the majority of low- to lower-middle-income countries are experiencing a drop in average farm size (Lowder et al., 2016). However, reporting regional averages can obscure intraregional heterogeneity. Average farm sizes can decrease while the number of MSFs increases, and a rise in larger-scale farms can be a driver of decreases in farm size of the smallest farms (Masters et al., 2013). On a national scale, in-depth analysis of agricultural censuses illuminates MSF dynamics specifically (Jayne et al., 2016). These analyses not only reveal the increasing importance of MSF, but also offer some preliminary insights on the types of actors behind MSF. Second, a number of pioneering case studies try to profile MSFs in SSA (e.g. Anseeuw et al., 2016; Chapoto et al., 2013; Sitko and Jayne, 2014). These case studies are essential building blocks to arrive at more general knowledge on MSFs. Traits of MSFs that are found in these studies include entrepreneurship, an orientation towards export or urban markets, and a capacity to assert state-backed land tenure claims, often at the expense of existing customary land tenure arrangements. The actors are often urban-based individuals with current or former urban employment, although examples of rural elites who successfully expand their farms have also been described.

The interpretability of observed trends in national-scale agricultural censuses is limited, because their agronomical focus does not provide insight into other characteristics of MSFs, such as the background of their owners. Meanwhile, case studies with a focus on MSF remain scarce. Surveys have mostly sampled only MSF (Anseeuw et al., 2016), which allows for exploratory profiling exercises but not for comparisons between groups. Hence, it is difficult to assess whether MSF are, as is suggested, really different from SSF in aspects other than total farm area, and whether they truly represent a new pathway with different socio-environmental traits.

Here, we aim to provide new empirical insights to assess to what extent MSF are different from small-scale farms (SSFs), and to what extent they represent a novel dynamic that may act as a driver of socio-environmental change. To that end, we have conducted a survey including farms of different sizes in the Rift Valley of Kenya. We sampled farms in an area characterized by a high agricultural potential and rapid urbanization, and hence a potential hotspot for the agricultural dynamics addressed in this chapter. Survey results allow us to compare MSFs with SSF in terms of the crop types they grow, the markets they serve, their labor characteristics, and their farm development. In addition, we surveyed a number of large-scale farms (LSFs) for further contextualization of these results.

The rest of the chapter first presents a theoretical background on the developmental, political, economic, and agronomic debates around farm scale. Building on this background, research questions are formulated. We then present the survey results and discuss their implications for wider rural development debates, as well as the extent to which they match commonly held beliefs concerning MSFs.

3.2. Theoretical background

Because agriculture is the dominant sector in terms of employment and revenue, and also the primary driver of environmental degradation in most developing countries (UNCCD, 2017), the evolution of agricultural systems takes center-stage in both developmental and environmental debates. In this respect, the impact of different farm sizes, for example in terms of agricultural production, employment, and income, is highly relevant. Insights into these matters can inform the tenuous discussion on what constitutes an "appropriate" or "optimal" farm scale (Carr, 2013; Collier and Dercon, 2009). In this debate, opinions range between a vision of large-scale, highly mechanized farms to small-scale, labor-intensive farms (Meyfroidt, 2017b). A major agronomical dimension of this wider debate is the question on optimal scales of production to maximize yields. The advantages and disadvantages of different farming systems have been discussed extensively in literature on development studies (Lipton, 2006; Wiggins et al., 2010) and provide a background for the assessment of MSF as discussed below.

The rich literature concerning large-scale land acquisitions could be instructive to explain the rise in MSF. The rapid and ongoing acquisition of large tracts of land, often by international business interests and investors, is an aberration that goes against prevailing demographic and economic trends in SSA. An incremental increase in farm size, accompanied and mutually reinforced by urbanization and productivity increases, is expected in SSA following structural transformation processes (McMillan and Headey, 2014). However, large-scale land acquisitions do not develop gradually , but appear as a result of power inequalities in global and national land governance, and are thereby able to claim smallholder-dominated or natural areas (Debonne et al., 2019; Messerli et al., 2014). MSFs could be conceptualized as a domestic version of large-scale land acquisitions, with national instead of international investors. Some commonalities are apparent, namely the involvement of non-local actors and the instrumentalization of power imbalances in land governance. Agricultural censuses show that, in SSA, a large and rising fraction of agricultural land is owned by urban households, who often own significantly more land per household than average rural households (Jayne et al., 2016). This indicates that MSF could be a product of urban households acquiring land resources, but national-scale surveys lack sufficient depth to warrant strong conclusions. Urban elites can mobilize capital and lobby power to acquire land, at smaller scales compared to large-scale land acquisitions but at larger scales than what is within the reach of smallholders (Hilhorst et al., 2011; Sitko and Jayne, 2014). This urban, non-local appropriation of agricultural land is facilitated by the fluid nature of land governance and land tenure arrangements in SSA. Customary land tenure, where the relations governing the ownership and use of land are strongly localized and where authority is vested in traditional authorities, remains highly important in SSA (Alden Wily, 2018; Higgins et al., 2018). However, African states are increasingly formalizing land tenure, thereby overthrowing customary institutions or creating bifurcated, legally pluralistic land tenure systems (Stellmacher and Eguavoen, 2011; Ubink and Quan, 2008). This legal ambiguity is often exploited by the lateral, urban entrants in SSA agriculture that constitute many MSFs. These actors are better able to navigate bureaucracies to acquire statutory (state-backed) land titles on customary land, in many cases overruling local people and their customary rulesets (Chimhowu, 2018; Chitonge et al., 2017).

Counterbalancing this negative narrative of expropriation, MSF may also be seen as a source of dynamism (Jayne et al., 2016). For at least five decades, visions on the pathways to SSA economic development and poverty reduction have tended to include a central role for smallholders (Wiggins et al., 2010). The smallholder sector is the dominant provider of food and livelihoods in SSA, and those engaged in this sector are disproportionally more likely to be poor and food insecure (Kamara et al., 2019). An inverse relationship between farm size and productivity is argued to exist, owing to diseconomies of scale and the absence of economies of scale in agriculture (Wiggins et al., 2010). Small farms rely on family labor, which is self-motivated to maximize yields, contrary to large farms where hired labor may not have such incentives. However, the causality or even the existence of an inverse relation is contested (Carletto et al., 2013; Muyanga and Jayne, 2019).

Taking inspiration from successes associated with the Green Revolution in Asia, transformative agricultural modernization is argued to be the most effective engine for broader development (De Schutter, 2011; Diao et al., 2010). However, the persistence of low-input subsistence agriculture and rural poverty has led to doubts on this conventional wisdom (Sitko and Jayne, 2014). As the agricultural sector globalizes, the question is raised whether African smallholders, who typically achieve relatively high land productivity but low labor productivity, can be competitive on a world stage (Dercon and Gollin, 2014). Taking this line of thought one step further, MSFs could be a necessary advancement to break the developmental impasse and deliver technological innovation and competitiveness.

The smallholder sector is faced with significant institutional and logistical handicaps in accessing markets beyond the local village market. Supermarkets and exporters are increasingly setting production, quality, and consistency requirements, which in turn create higher transaction costs that can act as a barrier for small producers

(Colen et al., 2012). For the procurement of fresh produce for urban centers, SSA retailers tend to favor farmers that can deliver year-round (often requiring irrigation), have sufficient storage and transport capabilities, and have the necessary human capital to handle value chain paperwork (Neven et al., 2009). While institutional innovations can help overcome these challenges, e.g. in the form of cooperatives, smallholders often cannot meet these requirements and resort to staple crops instead (Verhofstadt and Maertens, 2015). Instead, markets for high-value cash crops are often more readily available for larger-scale farmers. MSFs could thus be a solution for market failures apparent in SSA. Whether this is optimal in terms of, for example, poverty reduction vis-à-vis institutional innovations to enable smallholders is debatable (Hall et al., 2017). This depends, among others, on the ability of MSFs to create high-quality employment (Neven et al., 2009).

Against this backdrop, MSF have been framed as a "best of both worlds" solution. They may be able to combine high labor productivity with better access to capital and markets (Meyfroidt, 2017b). Meanwhile, their local linkages are likely stronger compared to large-scale land acquisitions, which are mostly managed by foreign interests in an enclave-like fashion (Hall et al., 2017). This could provide MSFs with the ability to generate local benefits and mitigate negative regional impacts often associated with large-scale land acquisitions. In this framing, MSFs act as seeds of local dynamism, with a potential to create positive technological and institutional spillovers to neighboring smallholders (Deininger and Xia, 2016).

It is highly relevant to gain insight into whether MSFs are a "best of both worlds" solution, or rather an inferior development pathway with opportunity costs vis-à-vis a smallholder-led pathway, or neither. Farm scale is a product of agricultural policies, and policy biases can drive farm scale increases or decreases. Globally, governments explicitly or implicitly favor larger or smaller farms (Bartolini and Viaggi, 2013; Byerlee, 2014). In SSA, preliminary findings suggest that MSFs tend to hold strong positions in agricultural lobby groups, thereby ensuring that public agricultural spending disproportionally favors their business model (Jayne et al., 2016). Such policy biases can hold significant opportunity costs: the beneficial effects of agricultural development on poverty reduction or food security may be much higher when smallholders are the focus of governance. In the context of large-scale land acquisitions, the empirical evidence of local benefits and threats clearly points to the existence of such opportunity costs (De Schutter, 2011) while for MSF, this is less clear (Hall et al., 2017).

Based on the discourses and debates discussed above the research questions we address in this chapter are: (1) whether MSFs are a recently emerging class of farmers, as is suggested by recent literature (Jayne et al., 2016); (2) Whether land tenure regimes are different for MSFs compared to SSFs; (3) Whether MSFs have a higher or lower crop productivity and different crop mixes; (4) Whether MSFs use different amounts and different sources of labor; (5) and whether MSFs are providing for different markets and are embedded in different networks. Furthermore, using the LSF data points, we provide further context concerning these dimensions.

3.3. Survey and data analysis

3.3.1. Study area

The study was undertaken in, Nakuru County, Kenya (Figure 3.1). The area is part of the Kenyan highlands as well as the Great Rift Valley and is considered to be among the agriculturally high-potential areas of Kenya. People in Nakuru are dominantly of either Kikuyu or Kalenjin ethnic background. Within this county, a large variety of agro-ecological zones exists, with altitudes of sampled areas ranging between 1900 and 2800 meters a.s.l. Farms in the county are often integrated cropland-livestock operations, although a large diversity exists (Herrero et al., 2014). The main food crops produced include maize, beans, Irish potatoes, and wheat, as well as various fruits and vegetables and a thriving livestock sector (van de Steeg et al., 2010).

Kenya, and the Rift Valley specifically, has had a dynamic history in terms of land governance and farm scales. During British colonial rule, many areas in the Rift Valley were part of the White Highlands, a region of settlement by British farmers operating large farms and ranches using newly landless Kenyans as labor sources. Apart from these settler areas, Kenyan farmers persisted in designated "native reserves", and this colonial dichotomy forms the precursor of many farm scale patterns observed today (Hakizimana et al., 2017). The Swynnerton plan (1954) aimed to be a comprehensive colonial solution to modernize Kenyan agriculture, among others by issuing title deeds to promote land tenure security, providing technical assistance, and provide pathways to farm consolidation (Thurston, 1987). This plan thus forms the historical basis of the current land tenure system in Kenya. After Kenya attained independence, the Million Acre Settlement Scheme constituted a major land reform to redistribute White Highland landholdings to Kenyan families. This resulted in a repopulation of the area by a diverse group of farmers originating from a variety of Kenyan provinces, although much land was also granted to elites as a patronage tool (Kiplimo and Ngeno, 2016). In recent decades, population pressures have led to severe land fragmentation, leading to a broad pattern of relative large, intensive farms in many former White Highland Areas and very small, fragmented and degraded farms in many former "native reserves" (Syagga, 2006).

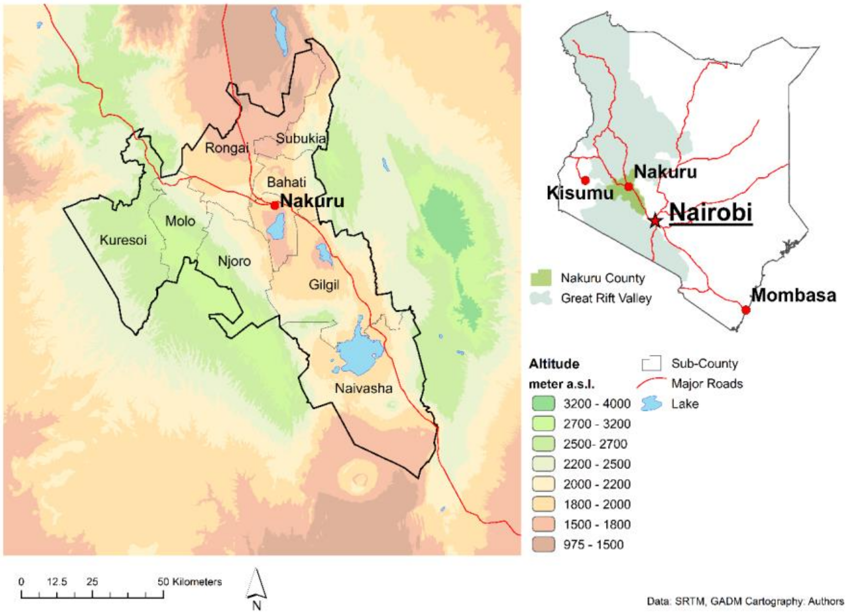

Figure 3.1: Map and location of the study area, Nakuru, in the Great Rift and Kenya, with sub-counties indicated. The survey was conducted in the sub-counties Kuresoi, Njoro, Bahati, and Subukia.

The study area was chosen because it has a high agricultural potential and includes the fast-growing and dynamic urban center of Nakuru City, which makes it a prime area to study dimensions of rural change (Migose et al., 2018). Parts of the county are used for horticulture, floriculture, and other cash cropping, which is often controlled by foreign interests or domestic value chain actors (supermarkets, processors, breweries) through ownership or contracts (Neven et al., 2009; Wanjala et al., 2018). The majority of farms in Nakuru county is small, averaging 0.77 ha. However, the majority of the land is occupied by MSFs and LSFs. Consecutive generational farm subdivision is increasingly creating economically unviable farm sizes among the SSFs. The county is relying on agribusinesses, notably horticultural and floricultural enterprises, to generate employment for land-poor households (Nakuru County Government, 2013).

3.3.2. Survey

A survey was conducted between November 2018 and January 2019 in sub-counties of Bahati, Kuresoi, Njoro and Subukia. For every sub-county, the sampling frame were all SSFs (managed land <5 ha), MSFs (managed land 5 – 50 ha), and LSFs (managed land >50 ha)[4]. In line with recent other work on MSFs (Anseeuw et al., 2016; Sitko and Jayne, 2014), and recognizing that what constitutes a small or large farm is highly context-dependent (Meyfroidt, 2017a), these size brackets were defined to represent an intermediate position between what is understood to be a smallholder and a large farm in the Kenyan Rift Valley. The sampling frame was obtained from the sub-county Ministry of Agriculture farmer registries. These farmer registries were subdivided based on farm size categories (SSFs and MSFs), and from these two lists, every n^{th} farmer was selected to be a respondent, n being dependent on the population of the sub-county. The LSFs were purposefully sampled, and were not used in subsequent statistical analyses, but only to contextualize our findings. Hence, a total of 332 respondents were visited. After a pilot (n = 9) and subsequent revisions, the survey was conducted in Swahili by three trained enumerators.

Questionnaires were conducted with the household head or another knowledgeable family or farm staff member. In some cases, a farm manager or accountant answered at the behest of an absent farm owner. Prior to conducting an interview, respondents were informed of the purpose and nature of the questions, and were given the opportunity to grant or deny consent to participate. Refusal to participate occurred in no more than a handful of cases, although refusal to answer specific questions was more common (e.g. questions concerning wages), resulting in no-data for these questions. Questionnaires were digitally transcribed using Kobo Toolbox.

The questionnaire consisted of mostly closed-ended questions on (1) farm history and household characteristics, (2) farm owner characteristics, (3) land tenure, (4) farm land use, crop production, and livestock, (5) water management, (6) social networks, (7) markets, and (8) threats and opportunities. The survey received ethical approval from the nationally accredited Moi University College of Health Sciences / Moi Teaching and Referral Hospital Institutional Research and Ethics Committee.

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[4] Note that different studies have defined "medium-scale" differently. Samberg et al. (2016), working at the scale of the Global South, distinguish medium-scale farms between 5 and 15 ha, large-scale farms between 15 and 50 ha, and very large-scale farms beyond 50 ha. Jayne et al. (2016), who discuss MSF for Sub-Saharan Africa, define medium-scale to be between 5 and 100 ha. Local case studies tailor the definition of MSF to the relevant context (e.g. Anseeuw et al. (2016) use 5 to 50 ha to represent MSFs in Malawi).

3.3.3. Data analysis

Questionnaires were subjected to a validation procedure, checking for internal consistency of answers, completeness, and adherence to the sampling frame. After validation, 319 interviews were retained, including 186 SSFs, 120 MSFs and 13 LSFs. The SSF and MSF data points were subsequently used for statistical analysis, while LSF data were only used to add context. In this statistical analysis, we compared SSFs and MSFs across a number of dimensions, corresponding to the research questions outlined above. We used two-tailed t-tests to test for differences in quantitative data, and χ^2-tests to test for differences in categorical data. Each test is performed for the full SSF and MSF dataset, and additionally for the subset of SSFs and MSFs that were established with the current farm owner in or after the year 2000. The latter tests provide information on whether recently established MSFs are different from recently established SSFs, building on the idea that recent newcomers are different in origin or characteristics. Statistics were performed in the R statistical package.

3.4. Results and discussion

3.4.1. Farm and farmer characteristics

Contrary to reports of a recent surge in the establishment of MSFs in SSA (Jayne et al., 2014a), MSFs are not new in our study area, and there is no significant difference in the year of establishment of MSF and SSF (Table 3.1). Farms in both categories have been established throughout post-colonial history. Figure 3.2 further details this diversity in time of farm establishment. Table 3.1 presents key figures concerning the year of establishment, alongside other farm and farmer characteristics.

The study area is known for an increasing land scarcity that has led to progressively smaller farms, in line with general trends in Kenya (Hakizimana et al., 2017; Kiplimo and Ngeno, 2016) and other SSA nations (Jayne et al., 2014a). Our results show that, in tandem with this farm fragmentation process, MSFs continue to emerge, in contrast with this process. This suggests that the establishment dynamics of MSFs show signs of continuity, as farms of this size were never uncommon. At the same time, it shows signs of discontinuity, because where overall trends in SSA tend towards ever smaller farms, MSFs continue to be established unabatedly in the study area.

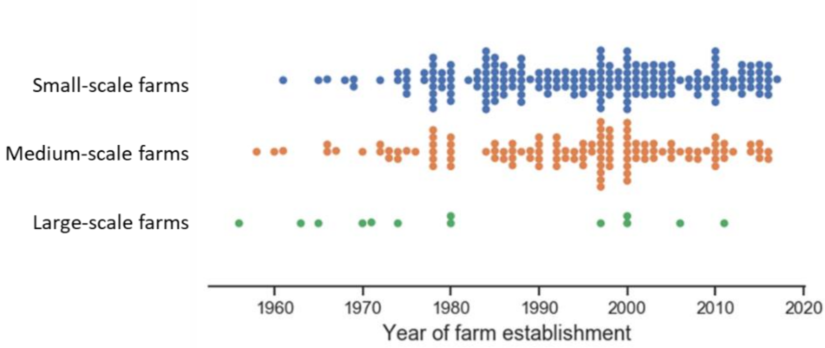

Figure 3.2: Year of farm establishment with current farmers. Each dot represents a survey respondent.

In our study, perceived land tenure security is high overall, with 73% of respondents indicating that a loss of land rights is not an important risk and only 9% indicating this to be a moderately to very important risk. Differences in land tenure arrangements and security are often quoted to explain why MSFs continue to emerge amidst an overall trend of farm fragmentation (Chimhowu, 2018). MSFs are significantly more likely to have a state-backed land title for their land. However, having a title does not seem to influence perceived land tenure security (χ^2-test: P=0.54). Many MSF respondents were aware of their relatively privileged land endowment and expressed fears of land claims by squatters, tenants, or local officials. The reason why MSFs are more inclined to have a title may therefore be that they perceive themselves to be more vulnerable to hostile land claims and conflicts. Another possible reason is the costs involved in obtaining a land title, which many SSFs may not be able or willing to pay.

Signs that MSFs are able to leverage power differentials to acquire land are not apparent. MSFs are significantly more likely to have used transactional methods (renting or buying) to acquire land. For the full sample, transactional acquisition was used by 67% of respondents, although only 50% used only transactional methods and not relational (inheritance, marriage, intra-family transfer) methods. Hence, our findings suggest that, amidst an overall trend of land fragmentation, MSFs are consolidating land by buying or renting from fragmenting smallholder farms. This aligns with findings in Meru County (Hakizimana et al., 2017) and implies that a willing buyer/willing seller system appears to prevail. However, insofar as land transactions are driven by distress sales (e.g. following a failed harvest or other livelihood shocks), this accumulation process could be detrimental to the livelihood assets of a growing landless class. Whether this is occurring or not cannot be deduced from our survey but remains a highly relevant rural policy question.

MSFs are more likely to have increased their farm size after establishment, and this difference is more outspoken for farms established after 2000. This lends credibility to a profile of entrepreneurial smallholders who use the land market to attain MSF status. MSFs are also significantly more likely to rent part or all of their farmland. While MSFs are more likely to have increased their land size, farm size increases are also found for the majority of SSFs. Although relational methods to increase farm size are important, transactions are the dominant method (86% of expansive farmers rented and/or bought the additional land). SSFs and MSFs are equally likely to use transactional methods (χ^2-test: P=0.30). It is noteworthy that a vision of land redistribution via land markets and a freehold land tenure system was central to the colonial Swynnerton Plan (Thurston, 1987). This plan held the believe that, to modernize agriculture, smallholders should able to use land transactions to develop their farms with the assurance that their tenure status would remain upheld. These results suggest that such a land market is indeed at work today, although the importance of land titles is not as important as envisioned.

Farm owners of an MSF have received significantly more years of formal education, and are significantly more likely to have received a tertiary education. However, there is no indication that many MSF farm owners are people who acquired capital or bureaucratic agility by being or having been employed in non-farm jobs, because they are not more likely to have been employed as public servant, business manager, politician or other high-profile jobs. MSF owners are more likely to live away from the farm, but farm owner absenteeism is low in general. MSF farm owners are not more or less likely to have grown up locally, and a majority of respondents indicates to have migrated towards their current farm (Table 3.1). Furthermore, there is no significant ethnic over- or underrepresentation in the MSF category (Table 3.1), nor are farm sizes of non-Kalenjin/Kikuyu farmers significantly larger or smaller (t-test, P = 0.76). This indicates that, while land issues in the Rift valley can have ethnic dimensions, MSF dynamics are not particularly ethnic in nature.

From these characteristics, a preliminary generalization may be drawn: MSFs, though not new, are emerging alongside land fragmentation, yet power disparities or land tenure issues cannot fully explain this. Instead, MSFs are often successful expanders, using land markets to acquire land from exiting, non-viable fragmented farms. This dual fragmentation-consolidation process has also been found in Meru, Kenya (Hakizimana et al., 2017). However, it should be noted that there is diversity within farm scale categories: a large minority of MSFs are more accurately typified as older farmers who acquired land in times when larger farms were the norm.

The LSFs in our sample often trace their origins to colonial times, with owners indicating that they are either direct descendants of British colonial farmers or (have ancestors who) occupied high positions in colonial bureaucracies. Other very large farms in our sample are government-owned or collectively managed by a community. These arrangements are likewise rooted in the land redistribution programs immediately after decolonization. Among LSFs, fears of losing land rights were generally high except for government-owned farms. LSFs mostly had experienced instances of squatting or unauthorized cattle grazing on their land, and feared that redistributive land reforms could target them.

Table 3.1: Summary statistics concerning farm dynamics and farmer characteristics. Significance tests are the result of student's t-tests and χ^2 tests for, respectively, continuous and categorical dependent variables.

Survey question	Full survey			Post-2000 subset		
	SSF (n=186)	MSF (n=120)		SSF (n=76)	MSF (n=44)	
Farm establishment, tenure and size dynamics						
Average farm establishment year with current farm owner	1995	1993	-	2008	2006	-
% of respondents without land title [a]	41.9	26.7	***	57.1	31.8	**
% of respondents indicating land loss due to dispossession or poor land rights to be a moderate or very important risk	7.0	10.0	-	10.5	15.9	-
% of respondents who initially acquired all or part of their land using transactional methods (buying or renting)	65.9	80.0	**	60.5	70.5	-
% of respondents leasing or renting all or part of their land	30.1	45.8	***	32.9	68.2	***
% of respondents that have increased their farmland area	58.6	73.3	**	53.9	86.4	***
% of respondents that have decreased their farmland area	10.2	12.5	-	7.9	4.5	-
Farm owner characteristics						
Mean age of farm owner	55.4	55.5	-	46.3	47.1	-
% farms in female ownership	17.5	15.7	-	17.3	9.3	-
% farms in dual ownership (male and female)	65.0	67.8	-	65.3	67.7	-
Farm owner mean years of formal education	10.2	11.5	***	10.9	11.6	-
% farm owners with a tertiary education	25.5	32.8	***	28.0	35.7	-
% farm owners ever employed in any other wage-paying job	63.4	62.5	-	65.8	61.3	-
% of farmers ever employed in high-profile jobs[b]	31.7	36.7	-	36.8	34.1	-
% absentee farm owners	4.3	10.1	**	6.6	18.2	*
% farm owners who grew up locally	41.4	45.0	-	50.0	53.7	-
% Farm owners with ethnicity other than Kikuyu or Kalenjin	9.1	4.8	-	15.9	6.6	-

- P > 0.1 *P ≤ 0.1 ** P ≤ 0.05 *** P ≤ 0.01

[a] Land lease or rent is considered equivalent to titled land tenure.

[b] High-profile jobs include public servant, police, politician, or business manager.

3.4.2. Crop productivity, crop mixes, and farm strategies

MSF and SSF are comparable in terms of their crop productivity for each of the five crops for which our survey has sufficient data to allow for comparison (Table 3.2). This absence of difference in crop yields suggests an absence of (dis)economies of scale in productivity. This implies that our results do not support inverse farm size – productivity relationship found elsewhere (Carletto et al., 2013), nor can we find indications that larger-sized farms are a requirement to meet growing agricultural demands or to use land more efficiently (Sender and Johnston, 2004). Conceivably, these finding are the compound result of two counteracting drivers: smaller farmers may attain a yield bonus following the logic of the inverse farm size – productivity relationship (i.e. self-motivated family labor), and a yield penalty as they have less access to inputs and technologies.

Table 3.2: Summary statistics concerning crop production and productivity. Significance tests are the result of student-t tests. Because not all crop are grown on all farms, comparisons of yields per crop are based on subsamples only.

Survey question	Full survey			Post-2000 subset		
	SSF (n=186)	**MSF** (n=120)	**Sig.**	**SSF** (n=76)	**MSF** (n=44)	**Sig.**
% of land used for staple crops (cereals and pulses)	52.4	46.6	*	57.1	48.0	*
% of land used as grazing land	16.6	28.6	***	14.2	26.6	***
Number of crop types grown[a]	4.0	3.9	-	3.8	4.2	-
Self-reported maize yield (kg/ha)	4377 (n=160)	4927 (n=92)	-	5135 (n=64)	5494 (n=35)	-
Self-reported beans yield (kg/ha)[b]	1077 (n=39)	989 (n=24)	-	1142 (n=16)	934 (n=9)	-
Self-reported wheat yield (kg/ha)[b]	6034 (n=5)	4141 (n=20)	-	3830 (n=3)	3374 (n=8)	-
Self-reported potato yield (kg/ha)[b]	9535 (n=81)	8365 (n=63)	-	7862 (n=32)	7059 (n=24)	-
Self-reported peas yield (kg/ha)[b]	5171 (n=28)	4177 (n=29)	-	3566 (n=14)	4291 (n=15)	-
Number of dairy cattle per farm (excluding beef cattle)	3.6	9.7	***	4.4	9.1	**
Dairy cattle per hectare of on-farm grazing land (excluding farms without cattle)	18.4 (n=142)	7.5 (n=105)	***	19.3 (n=51)	7.8 (n=8)	***

- $P > 0.1$ $*P \leq 0.1$ $**P \leq 0.05$ $***P \leq 0.01$

[a] Crop types: Cereals, pulses, tubers and roots, vegetables, fruits, flowers, coffee and tea, grazing land.

[b] Yields are reported per plot and are aggregated per farm for all plots with crop as main crop last growing season. Where multiple crops are grown on a single plot, this plot was excluded from this analysis.

While productivity is highly similar, crop mixes, as expressed by share of farmland dedicated to various crop groups, differ to a large extent (Figure 3.3). On average, MSFs are using significantly less land for staple crops. Still, the average MSF uses 46.6% of land for staple crops (Table 3.2,Figure 3.3). Instead, MSFs often use their larger land endowment to accommodate cattle, as they have significantly more cattle per farm and a higher fraction of farmland used as grazing land (Table 3.2). However, SSFs are rearing cattle considerably more intensively, with 2.5 times more cattle per hectare of on-farm grazing land. SSFs are able to accommodate high numbers of cattle on limited space by deploying zero-grazing or semi-zero-grazing systems, thereby relying on fodder which is often bought from neighboring larger farmers. This highlights that different farm scales can be complementary to each other: zero-grazing systems labor-intensive but require little space, while fodder crop growing requires the opposite. Many respondents indicated an ambition to further intensify dairy farming, and move towards zero-grazing systems and away from mixed crop-livestock systems.

SSFs are more inclined to grow vegetables (Figure 3.3), which typically has high labor requirements per hectare compared to cattle grazing. This suggests that, to some extent, land substitutes labor and vice versa, in livelihood and farm management strategies. Where land is relatively limited (SSFs), labor-intensive crops are more frequently cultivated, while labor-extensive practices with high land demands are more frequently applied where labor is relatively limited (MSFs, LSFs). The role of SSFs as vegetable growers puts them in a central position to guarantee nutrition security at the local level (Ogutu et al., 2019).

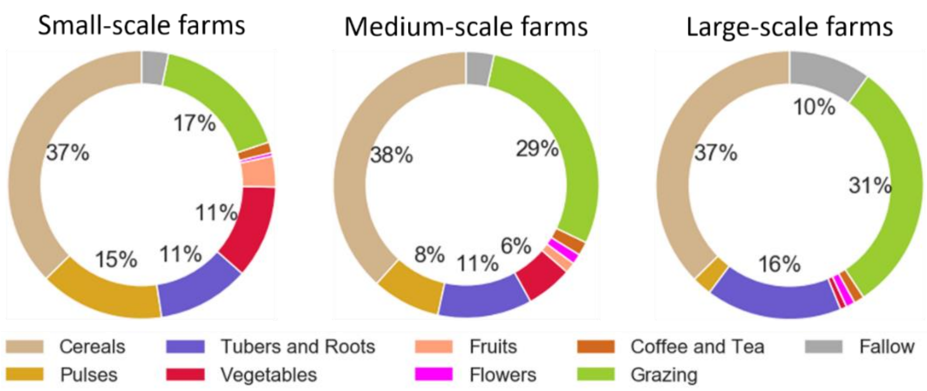

Figure 3.3: Crop mixes on SSFs, MSFs, and LSFs, as average percentages of farm land area.

The average crop mixes offer an informative snapshot of current practices, but obfuscate the large heterogeneity within categories and do not reveal the past and future strategies of farmers. In Figure 3.4, respondents are subdivided into either staple crop farms (>75% of land is cereals or pulses), cash crop farms (<25% of land is cereals or pulses), or mixed farms (everything in between). Circles indicate share of the respondents in each category at start (five years ago for left panels, current for right panels), and arrows indicate transitions pursued in the last five years (left) or aspired for the next five years (right). A mixed portfolio with both cash and staple crops is dominant for SSF and MSF (Figure 3.4, circles in panels c and d), and a persistence of this portfolio is the most pursued and most aspired dynamic. The share of staple crop farms is remarkably similar for SSFs and MSFs (22% compared to 20%) in the current situation (Figure 3.4 c-d), and both SSFs and MSFs have seen a major reduction of this share in the last five years(arrows Figure 3.4 a-b). Moves towards cash crop-focused portfolios have been marginal in the past five years but are relatively often aspired, especially by SSF. Moreover, the vast majority of current cash crop farms intends to persist (arrows Figure 3.4 c-d).

These observations partly resemble archetypical notions of entrepreneurial MSFs with a strong focus on cash crops (the share of MSFs that can be categorized as cash crop farms is indeed much larger than for SSFs), but also add nuance. Farm scale is an imperfect proxy for entrepreneurship at best, as almost half of MSFs are mixed farms and one in five are staple crop farms. Conversely, a large fraction of cash crop farms are small, implying that it is attainable for small farms to focus on cash crops. The most important aspired transitions for SSFs are shifts away from staple crop farms and towards mixed or cash crop farms. However, there is a discrepancy between stated future aspirations and the observed strategies in the past five years: while a transition towards cash crop farms is often aspired, such transitions have only rarely been pursued in the past five years. This has two explanations: First, respondents have likely not performed a feasibility analysis when expressing aspirations, and as such aspirations are not concrete plans. Second, aspired shifts away from staple crops could be hindered by financial, food security or logistical constraints. For example, moving away from staple crops has transition costs and requires market access (both to sell cash crops and to reliably buy food). Identifying and addressing these constraints may assure that stated aspirations have a higher chance to materialize in the coming years. MSFs, on the other hand, appear to have less dynamic aspirations and are more inclined to keep their crop mix as-is. This could mean that MSFs are less constrained to materialize their aspirations and already find themselves in a preferred position.

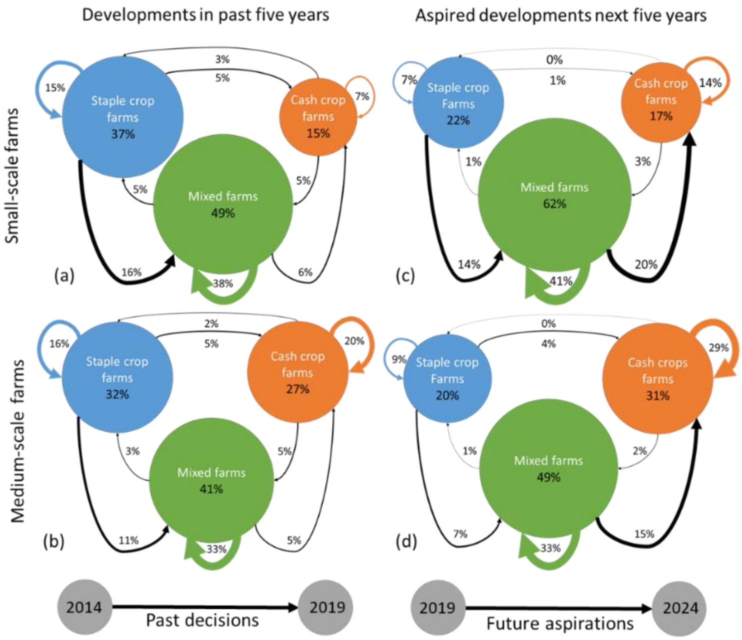

Figure 3.4: Developments in farm types. Farms are considered staple crop farms if grains and pulses cover at least 75% of the farm area, and are considered cash crop farms if this share is below 25%. Farms in between these thresholds are considered mixed farms. Circles indicate share of the respondents in each category at start (five years ago for left panels, current for right panels). Arrows indicate share of respondents moving from category to category as reported for the last five years (a, b) and as aspired for the next five years (c, d).

Over the past five years, farmers have, on average, diversified (i.e. increased the number of crop groups they grow (t-test, $p < 0.001$)). However, average aspirations for the future are to specialize and drop one or more crop groups (t-test, $p < 0.001$). This past diversification and aspired specialization are farm scale-independent. Beyond these average trends lies a large heterogeneity: 50% of respondents neither diversified nor specialized, and 41% diversified (Figure 3.5). Over the past five years, farmers have experimented with new crops beyond the typical maize-beans mix, which can be caused by an increased accessibility of alternative market outlets and input providers. Many respondents indeed indicated having started growing potato or vegetables as a side project. This abandonment of maize was, according to respondents, due in part to competition from imported maize, which reduced selling prices, and in part to reduced yields and weather predictability.

Concerning aspirations for the next five years, respondents would often state that a certain crop is not profitable anymore and that they aspire to move land and labor resources to their more profitable activities, mainly dairy, potatoes, and fruits. Yet, both SSF and MSF plan to change less in the near future then in the near past (Figure 3.5 b-d). The lack of any meaningful difference in term of specialization or diversification between SSFs and MSFs indicates that SSFs and MSFs have similarly varied strategies and aspirations.

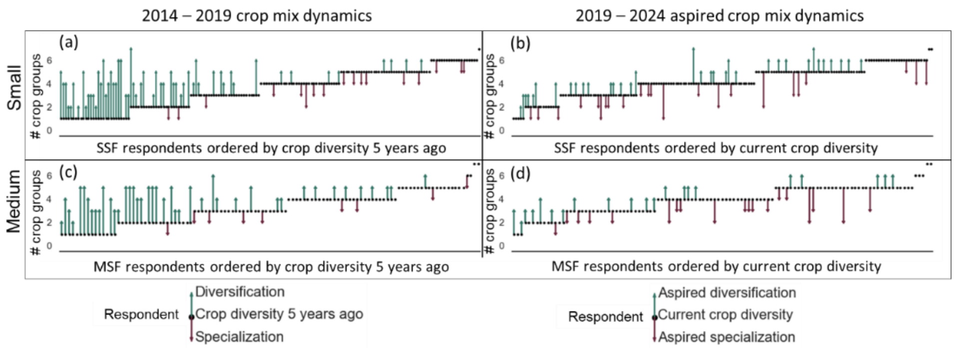

Figure 3.5: Crop mix diversification and specialization for SSF and MSF, as observed in the past five years (left) and as aspired for the next five years (right). Crop groups are "cereals", "pulses", "tubers and roots", "vegetables", "fruits", "flowers", "grazing land" and "coffee and tea".

Relative to both SSF and MSF, LSFs are more inclined to leave some land fallow and dedicate somewhat more land to grazing. Potato growing is more prevalent among LSFs (Figure 3.3), and aspirations point to a further expansion of this crop's importance among LSFs. Moreover, labor-intensive crops, such as vegetables, take up only a small fraction of LSF area.

3.4.3. Farm labor and labor productivity

Multiple results indicate that the nature and organization of farm labor is scale-dependent (Figure 3.6). Overall, MSFs employ on average over four times fewer people per hectare when counting both casual (day labor) and non-casual (permanent or seasonally fixed labor) employment (Table 3.3). While the vast majority of respondents use at least some family labor, MSFs additionally source non-casual labor from outside the family four times more often . This signals a departure from the family farming system at larger scales. 31 of 319 surveyed farms rely only on non-family labor and can thereby be profiled as company farms rather than family farms. We find these company farms predominantly in the MSF (18 farms) and LSF (6 farms) categories. The use of casual labor, expressed in Kenyan Shillings spent per hectare per year, is characterized by a high variability and does not differ significantly between SSFs and MSFs.

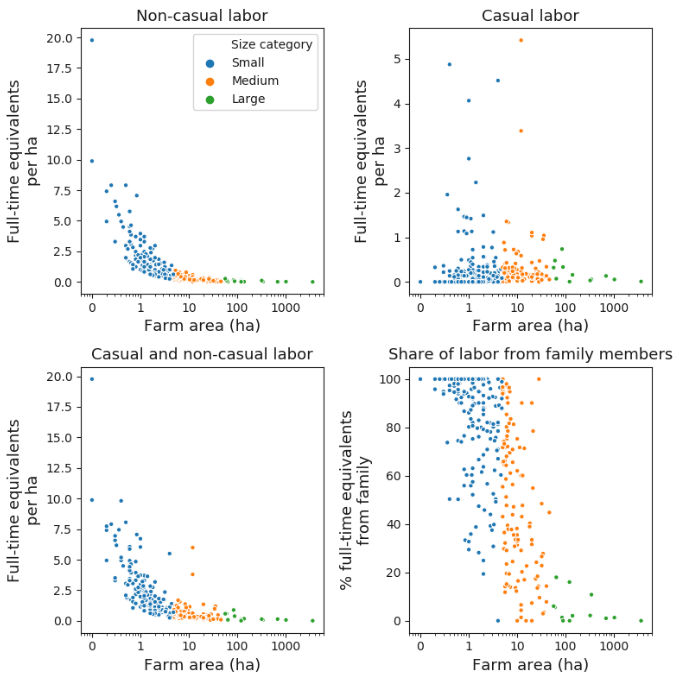

Figure 3.6: Relations between farm area and labor. Note logarithmic scale on x-axis.

The difference between farm labor in MSF and SSF implies that, on a per-hectare basis, larger farms provide less employment and that the same area of land managed as MSFs may provide livelihoods to fewer people. This could be explained by a host of factors, including higher mechanization, higher labor productivity, and a less labor-intensive crop mix. The average SSF is closer to the typical family farm structure, employing less non-family or casual labor.

Labor on LSFs shows a high diversity between the sampled farms. Some LSFs show very low labor use per hectare. These are either highly mechanized farms or farms managed by old people nearing retirement who leave much land fallow. Other LSFs employ relatively abundant amounts of mostly casual labor. One LSF respondent explicitly mentioned that he deliberately keeps mechanization levels low and labor levels high because hiring local labor grants him goodwill from neighboring communities and decreases chances of conflict. This shows that some LSF owners do not take their privileged position for granted and tend to have strategies to maintain a positive image.

Table 3.3: Summary statistics concerning farm labor. Significance tests are the result of student-t tests and χ^2 tests for, respectively, continuous and categorical dependent variables.

Survey question	Full survey			Post-2000 subset		
	SSF (n=186)	MSF (n=120)	Sig.	SSF (n=76)	MSF (n=44)	Sig
Total labor to land ratio (casual and permanent full-time equivalents per hectare)	2.64	0.63	***	3.34	0.75	***
Labor-to-land ratio (full-time equivalents for permanent workers per hectare, averaged across farms)	2.34	0.34	***	3.07	0.35	***
Labor to land ratio (permanent workers per hectares aggregated over total land used by farmer group)	1.34	0.25	n.a.	1.42	0.25	n.a.
% of respondents using non-family permanent labor	13.4	55.0	***	14.5	56.8	***
% of respondents using only non-family labor	3.9	15	***	5.2	11.4	-
Casual labor to land ratio (Kenyan Shilling spent per hectare per year)	25256	20719	-	24838	35118	-

- P > 0.1 *P ≤ 0.1 ** P ≤ 0.05 *** P ≤ 0.01

3.4.4. Market orientation and agricultural networks

Farmers working at different scales have a different market orientation and are embedded in different networks. Specifically, MSFs use a more diverse set of market outlets and are less likely to identify the village market as their most important market outlet (Table 3.4). Furthermore, they are significantly more often a member of a cooperative or association and are more likely to use private extension services (e.g. from agrochemical companies or seed farms). Contract farming is widespread among both SSFs and MSFs, in line with the generally high prevalence of such schemes in Kenya (Oya, 2012).

Although MSF have a more diverse set of markets and more connections to professional organizations, the results do not clearly show a profile of strictly entrepreneurial, urban- or export-oriented MSFs. For 61% of MSFs, the village market remains the most important outlet, and this does not decrease by much for the more recently established MSFs. When asked to give relative weights to the various market outlets used, MSF respondents on average gave the village market

63% of the total weight (Figure 3.7). Although this is a lower importance compared to SSFs (74%), this means that the majority of MSFs are dominantly producing for similar markets as the majority of SSFs. Export markets are marginal for both SSFs and MSFs[5].

The archetype of entrepreneurial, business-minded farmers can only be assigned to a minority of MSFs, as well as to a minority of SSFs. Among respondents indicating that non-village markets constitute at least three quarters of their self-assessed market importance (n=52), 20, 23, and 9 are SSF, MSF, and LSF, respectively. Insofar as this is a measure for entrepreneurship, this means that 11% and 19% of SSFs and MSFs respectively are entrepreneurial. This subset is not necessarily recently established: their average establishment year of these entrepreneurial farmers is statistically equal to that of the full sample. Measured this way, entrepreneurship may be more common among MSFs, but it is not unique or dominant for MSFs.

For the surveyed LSFs, village markets are less important, with only 4 out of 13 LSFs serving village markets and only one identifying it as the most important market. Instead, factories (e.g. grain processors) are dominant, which could be due to a general preference of such factories to work with a few large farms instead of many small farms (Reardon et al., 2009). LSFs are also active on highly specialized markets, with respondents rearing and exporting race horses, and cultivating and distributing potato seed.

[5] Commonly mentioned export crops include avocado, pyrethrum, cut flowers, and French beans.

Table 3.4: Summary statistics concerning market orientation and agricultural networks. Significance tests are the result of student-t tests and χ^2tests for, respectively, continuous and categorical dependent variables.

Survey question	Full survey			Post-2000 subset		
	SSF (n=186)	MSF (n=120)	Sig.	SSF (n=76)	MSF (n=44)	Sig.
% of respondents identifying village market as most important market	73	61	**	76	57	**
Number of market outlets used	1.29	1.48	***	1.23	1.45	***
Membership of farmer cooperative or association	16.1	27.5	**	15.8	29.5	-
% using farming contracts	71.5	76.5	-	77.1	77.3	-
% relying on private extension programs	3.8	10.8	**	2.6	13.6	*

- P > 0.1 *P ≤ 0.1 ** P ≤ 0.05 *** P ≤ 0.01

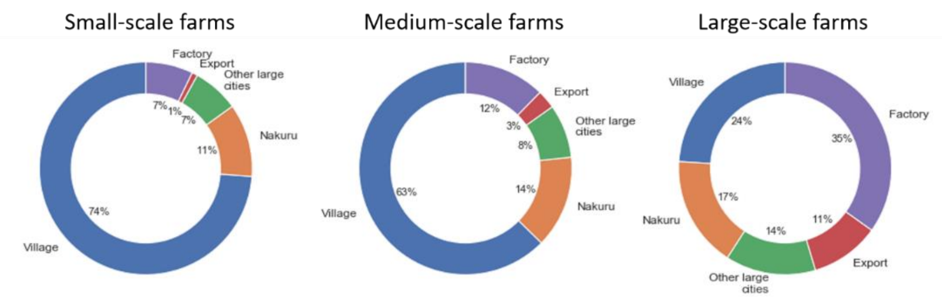

Figure 3.7: Average self-assessed importance of different market outlets. Respondents were asked to rank all market outlets they used, and assign numbers corresponding to how important each outlet is to their farm business. On average, the village market is almost three times as important as all other outlets for SSFs (74% of SSFs), while it is 1.7 times more important for MSFs (63% of MSFs). 73% of smallholders consider the village market to be the most important (or only) market, while this is 61% for MSFs (Table 4).

3.5. Implications and conclusions

In SSA, the agricultural sector continues to represent the foundation of the majority of livelihoods and agricultural dynamics remain the primary drivers of environmental change. Understanding shifts in farm systems and the consequences in terms of employment, market orientation, or crop production is therefore crucial. Both anecdotal and statistical evidence have suggested a recent increase in the amount of MSF in SSA. This chapter provides empirical evidence to further assess this development and to assess to what extent MSF are different from SSF in terms of their period of establishment, tenure situation, productivity and crop mixes, labor, and market orientation. In doing so, this chapter calls into question whether farm scale or farm scale category, simple measures that are easily derived from census data, are sufficiently informative to describe an agricultural system in terms of its entrepreneurial qualities or its association with unequal land access, as is currently common (Jayne et al., 2016).

The portraits of MSFs that we sketch based on our survey results are only partly in line with the archetypical MSF described in recent literature. We find that MSFs in our study area are not a recently emerging phenomenon, and neither are many of them lateral entrants in agriculture who acquire land using capital gained in urban employment. Such profiles are reported in our survey, but they remain a small minority. Instead, MSFs are often found to have been SSFs at establishment who have used transactional methods (renting in or buying) to acquire incrementally more land. Another fraction of MSFs in our survey are relatively older farmers who acquired land in a time when larger farms were the norm. Only a small minority can reasonably be portrayed as urban-based entrepreneurial farmers. The most clear factor to distinguish such farmers is farm owner absenteeism, which is indeed significantly higher for MSFs, especially the post-2000 subset of our survey. Still, this concerns only one in ten MSFs. These findings are in contrast with findings for Zambia, where MSF growth is mostly attributed to urban-based elites (Sitko and Jayne, 2014).

Highly unequal abilities to acquire land, which is a major tenet of global large-scale land acquisitions in the global land rush (Anseeuw et al., 2011), are not apparent among the SSFs, MSFs and LSFs in our study area: farm size inequalities are mostly found to be colonial relics or the result of incremental farm size increases using transactional methods. A profile of MSFs as elites who are able to leverage power imbalances to acquire land (Chimhowu, 2018) is not dominant in our study. We find that MSF are more often engaged in growing cash crops for non-village markets, but similar profiles are far from rare among SSFs. MSFs tend to reserve more land as grazing land, but SSFs run significantly more intensive animal production systems, and innovate towards labor-intensive zero-grazing systems using limited land resources. Even among MSFs, the village market is most often ranked as the most important outlet, and close to 50% of their farmland is used for staple crops. From this, we conclude that while the average MSF differs from the average SSF in terms of markets and crop mixes, most MSFs are highly similar to most SSFs.

Agricultural labor is a dimension for which farm size does matter, as larger farms provide fewer jobs per hectare and rely more on non-family labor. This implies that, insofar as the total agricultural area remains constant, any rise in larger-scale farms is associated with a decrease in rural livelihood provisioning. In the absence of a considerable rise in urban and off-farm livelihoods, this will have negative effects such as landlessness and unemployment. Today, employment in the non-agricultural sectors is growing faster than agricultural employment (Timmis, 2018), but the World Bank (2016) qualifies these trends as a slow structural transformation at best, which is insufficient to drive an agricultural exodus (and thus a discernable average farm scale increase).

This case study was undertaken in an area that is, in many ways, unique. The (post-)colonial history, the specific agro-ecology and demographic dimensions are among many factors that set the area apart from other Kenyan or SSA sites. However, while each context is particular, issues surrounding rural development and the rise of MSFs will likely be similarly characterized by a mix of persistence and novelty. Positioning the rise of MSF as a new dimension of the land rush or an urban takeover of the SSA countryside is missing the fact that MSFs are mostly not new and often not so different from SSFs. Likewise, positioning MSFs as a necessary source of dynamism and engine of growth for the purportedly stagnant smallholder sector misses the fact that, in our survey and throughout SSA, entrepreneurial SSFs are appearing where conditions are favorable. We conclude that farm scale represents entrepreneurial or elitist qualities poorly, and more holistic measures should be developed to baseline and track farm system developments in SSA.

Throughout SSA, colonial and postcolonial historical land governance have left different signatures that continue to shape current land distribution dynamics. The scale of farms in a region is generally determined by the height of salaries in the non-farming economy, the crop mix, and policy biases (Byerlee, 2014). In Kenya, processes of land consolidation and land fragmentation (a product of the inheritance system which divides land across generations) are co-occurring. This is to a large extent a result of consecutive colonial and post-colonial land policies (for an overview, see Hakizimana et al., 2017). There are trade-offs between two policy goals: on the one hand, larger farms achieving higher labor productivity could be deemed desirable to achieve a competitive market position (Collier and Dercon, 2009). On the other hand, policies could be supportive of smaller farms, that provide livelihoods for a growing rural population that cannot be fully absorbed by the non-farming sectors. Our results indicate that, beyond these considerations of labor productivity, which are central to rural development issues, there are few other differences in performance between SSFs and MSFs. Farms of different scales tend to show high within-category diversity and tend to fulfill different functions. Labelling the rise of MSFs as either a source of dynamism or a new land rush fails to acknowledge this, and therefore risks, respectively, to miss the dynamism in SSFs or to exaggerate the extent of domestic land issues.

Acknowledgements
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4. Representing large-scale land acquisitions in land use change scenarios for the Lao PDR

Agricultural large-scale land acquisition (LSLA) is a process that is currently not captured by land change models. We present a novel land change modelling approach that includes processes governing LSLAs and simulates their interactions with other land systems. LSLAs differ from other land change processes in two ways: (1) their changes affect hundreds to thousands of contiguous hectares at a time, far surpassing other land change processes, e.g. smallholder agriculture, and (2) as policy makers value LSLA as desirable or undesirable, their agency significantly affects LSLA occurrence. To represent these characteristics in a land change model, we allocate LSLAs as multi-cell patches to represent them at scale while preserving detail in the representation of other dynamics. Moreover, LSLA land systems are characterized to respond to an explicit political demand for LSLA effects, in addition to a demand for various agricultural commodities. The model is applied to simulate land change in Laos until 2030, using three contrasting scenarios: 1) a target to quadruple the area of LSLA, 2) a moratorium for new LSLA, and 3) no target for LSLA. Scenarios yield drastically different land change trajectories despite having similar demands for agricultural commodities. A high level of LSLA impedes smallholders' engagement with rubber or cash crops, while a moratorium on LSLA results in increased smallholder involvement in cash cropping and rubber production. This model goes beyond existing land change models by capturing the heterogeneity of scales of land change processes, and the competition between different land users instigated by LSLA.

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4.1. Introduction

Large-scale land acquisitions (LSLAs) have become a significant global land changing force since their proliferation following the 2008 food crisis (Deininger et al., 2011; Messerli et al., 2014). These transactions of relatively large tracts of land to agribusinesses, investment funds, and foreign governmental players have been welcomed as a long-overdue investment in the agricultural sector, initiating new value chains, introducing new agricultural technology, and creating employment (Arezki et al., 2011). However, others emphasize concerns over human rights, land rights and biodiversity losses (Cotula, 2012; Davis et al., 2015; De Schutter, 2011). Although data on LSLA is scarce and not flawless (Oya, 2013), the best-available database reports 1501 known concluded LSLAs, constituting 50 million hectares of land to be dedicated to food, energy, and industrial crops (Land Matrix 2019). An additional 20 million hectares constitute known intended land deals, marking the on-going nature of the phenomenon. LSLA has globally targeted densely populated, accessible croplands, and to lesser extents also remote forestlands and moderately populated areas (Messerli et al., 2014). While neither plantation agriculture nor foreign large-scale agricultural investments are exceptional in history (Baglioni and Gibbon, 2013; Mazoyer and Roudart, 2006), the scale of the recent upsurge is trend-breaking (Byerlee, 2014) and deserves the attention of land change scientists to study drivers, trends and impacts of the phenomenon (Messerli et al., 2013).

The concept of land systems, human-induced transformations of ecosystems and landscapes and the resulting changes in land cover, provides a framework for the representation of the human-environment interactions on land (Verburg et al., 2013). LSLA systems set themselves apart from more traditional trajectories such as smallholder intensification and conversion to urban land, for two reasons. Firstly, the conversion that an LSLA instigates is orders of magnitude larger than conversions related to traditional smallholder farming. In this way, LSLAs break away from the traditional approach towards studying land system dynamics, which typically frames changes as being small and incremental. However, these large-scale, abrupt conversions caused by LSLAs occur within the context of, and interact with, continuous small-scale incremental land system changes (Cramb et al., 2015). Therefore, in a LSLA context, a multi-scalar approach is necessary for the explanation of current and the projection of future land system changes. Secondly, LSLAs distinguish themselves from smallholder systems in that they are often used as a policy tool to reach development targets, such as increasing land productivity, developing land identified as idle, and extending state control over the domestic rural hinterland (Borras and Franco, 2012; Cotula et al., 2014; Lavers, 2012). Therefore, LSLAs are often negotiated as package deals in which the investor is expected to develop road, water, or agricultural processing infrastructure, provide employment, or create technology spillovers (Lu, 2015; Schönweger and Messerli, 2015). This way, LSLA can be seen as an attempt at outsourcing rural development (Peeters, 2015). LSLAs produce commodities that are also produced by smallholders, making them direct competitors (Byerlee, 2014). In a context of smallholder transitions to cash crops, such as maize, sugar cane, and rubber (Cramb et al., 2009; Hall, 2011; Thanichanon, 2015), LSLAs manifest themselves as an alternative pathway to fulfilling the same land-based demands.

The distinct nature of LSLAs described above constitutes a challenge to land change models (LCMs). In land system science, LCMs are used to study land system change processes, provide projections to inform policy makers, or to perform scenario analysis (Turner et al., 2007). However, the multi-scalar approach and the specific political steering of LSLAs are not adequately represented in current LCMs. Usually, the choice of resolution in these tools reflects the scale of the processes being modeled, with pixels being the units at which conversion decisions are represented (van Delden et al., 2011). However, LSLAs instigate an interaction of small-scale, pixel level changes with large-scale changes involving multiple pixels at the same time. Furthermore, when defining the drivers of land change, it should be acknowledged that LSLAs provide more than simply the plantation products - they also potentially generate a host of effects that policy makers may either find desirable or undesirable. In recent history, countries have therefore taken on very different attitudes towards LSLA in their territory, ranging from permissive to restrictive stances, depending on the effects emphasized by policy makers (Cotula et al., 2014). Therefore, there is a need to reevaluate the way drivers are defined and land-use changes are allocated in LCMs.

The objective of this chapter is to represent the characteristics that distinguish LSLA dynamics in a land change modelling framework, and use this model to explore different LSLA development trajectories as they interact with smallholder land use dynamics. To that effect we build on the CLUMondo land system model (van Asselen and Verburg, 2013). We augmented the CLUMondo model by adding a multi-cell allocation algorithm, which is able to convert multiple contiguous cells and thereby mimics the large-scale nature of LSLAs while preserving detail in the representation of other dynamics (e.g. smallholder agriculture or urbanization). To translate possible policies towards LSLAs (from LSLA-restrictive to LSLA-encouraging), we represent the effects of LSLA perceived by policy makers in a specific demand (driver) in our model. These perceived effects can be positive or negative depending on the scenario. To our knowledge, the resulting model is the first to explicitly simulate LSLA and its interaction with smallholder agriculture. To illustrate how LSLAs can cause different land change trajectories, we applied it for the Lao PDR, a country subject to many land acquisitions, as there is a relative abundance of data on LSLA location and types available.

4.2. Methods

4.2.1. Study area

The Lao People's Democratic Republic (hereafter called Laos) is a lower-middle income country in Southeast Asia of 6.8 million inhabitants (2015 situation). With an average GDP growth of 8 percent over the last decade, it is one of the fastest growing economies, and this growth has been driven for a third by use of water, mineral, and forest resources (World Bank, 2017). Poverty eradication is high on the national agenda, but is still a challenge, especially in remote areas (Epprecht et al., 2008; World Bank, 2017). Agriculture constitutes a quarter of the GDP and employs 75% of the population (2010 situation). The sector is dominated by rice-based subsistence agriculture, both as upland swidden agriculture and as permanent paddy rice fields (FAO, 2017a; Schmidt-Vogt et al., 2009). However, the agricultural sector is characterized by rapid commercialization (Heinimann et al., 2013). These changes manifest themselves in both LSLAs and smallholder transitions to market-oriented crops.

LSLAs in Laos are usually granted by the government in the form of land concessions or leases. A nationwide inventory in 2010 identified 1.1 million hectares, or 5% of the territory of Laos, to be an agricultural land concession or lease (Schönweger et al., 2012), although not all of these projects are large-scale (defined in this study as larger than 100 ha). The granting of concessions and leases started in 2000, and proliferated from 2005 onwards. In a follow-up of this inventory, Hett et al., (2015) found that between 2010 and 2015, the number of concessions and leases rose by 71% in the provinces of Luang Prabang and Xiengkhouang, showing that despite moratoria in 2007 (for forestry plantations) and 2012 (for eucalyptus and rubber plantations), LSLA continued. Only 30% of projects are foreign-owned, these projects constitute 72% of the total acquired area (Schönweger et al., 2012). LSLAs intend to produce rubber, timber, and cash crops such as sugar cane, biofuel crops, and coffee.

Amidst the ongoing LSLA dynamics, changes in smallholder agriculture are drastically reshaping the Lao agricultural landscape. Smallholders are intensifying and integrating into global markets (Ornetsmüller et al., 2016; Thanichanon, 2015), thereby competing in the same markets as LSLAs. The still extensive swidden landscapes are rapidly transforming to permanent agriculture. Additionally, smallholders are increasingly engaging in rubber production (Fox and Castella, 2013; Manivong and Cramb, 2008).

4.2.2. Characterizing novel land systems in Laos in 2010[6]

We start our modelling exercise with a land system map representing the year 2010, based on a combination of national land cover maps, census data, and a collection of best-available data on LSLAs. All input data was first aggregated or resampled to the same spatial resolution and the same extent, to ensure consistency. We classify land systems, which denote typical combinations of land cover, land use, and land management (van Asselen and Verburg, 2012), using a hierarchical decision tree (Appendix A-2) yielding 15 land systems. The characterization of swidden is based on Ornetsmüller et al. (2018). Because recent land-use changes in Laos are characterized by both a rapid increase in large-scale land acquisitions and a smallholder transition to more diverse and marketable crops, we designed our classification to represent both these trajectories. An overview of all land systems is given in Table 4.1, and the resulting land system map is shown in Figure 4.1. Given the resolution of available input data, we opted for a resolution of 2000 meter. Details, data sources, and classification procedures are given in Appendix A-1, 2 and 3.

Seven out of the 15 land systems represent LSLAs. For the remainder of this study, we define LSLA as an acquisition (transfer of use rights) of land of more than 100 ha, with the intention to use this land for agriculture or forestry. This definition includes industrial commodities such as rubber, but excludes acquisitions for mining, tourism, or special economic zones. While 100 ha is not particularly large in a global context, we use this threshold for Laos following Schönweger and Ullenberg (2009) because the average farm size in Laos is 1.6 ha (USAID, 2013). Hence by comparison, 100 ha can justifiably be considered large-scale. Spatial data of LSLA was obtained from the Land Observatory (Land Observatory Project, 2017) and the Centre for Development and Environment (Hett et al., 2015; Schönweger et al., 2012). We classified LSLAs into seven systems based on their main produce – rubber, timber (e.g. teak or eucalyptus), arable crops, and coffee – and size (small and large, threshold arbitrarily set at 500 ha). As almost no coffee plantations are

[6] Additional details on mapping and modelling procedures, and parameters used, are given in Appendix A.

larger than 500 ha, all coffee plantations are included in one class. Furthermore, we distinguish four smallholder agriculture systems: (1) *swidden* (also known as shifting cultivation) is a rotational system where a short cultivation phase is alternated with a long fallow phase. The dominant crop in the cultivation phase is upland rice (Mertz et al., 2009); (2*) Mixed cash crop – subsistence mosaics* cultivate a mix of paddy rice for subsistence and other crops for market purposes; (3) In *cash crop focused smallholder* systems, farmers specialize towards marketable crops such as coffee, fruits or sugar cane; And (4) *rubber smallholder mosaics* are systems with a large rubber component. The land system map is completed with *dense forest, urban, bare land,* and *water*.

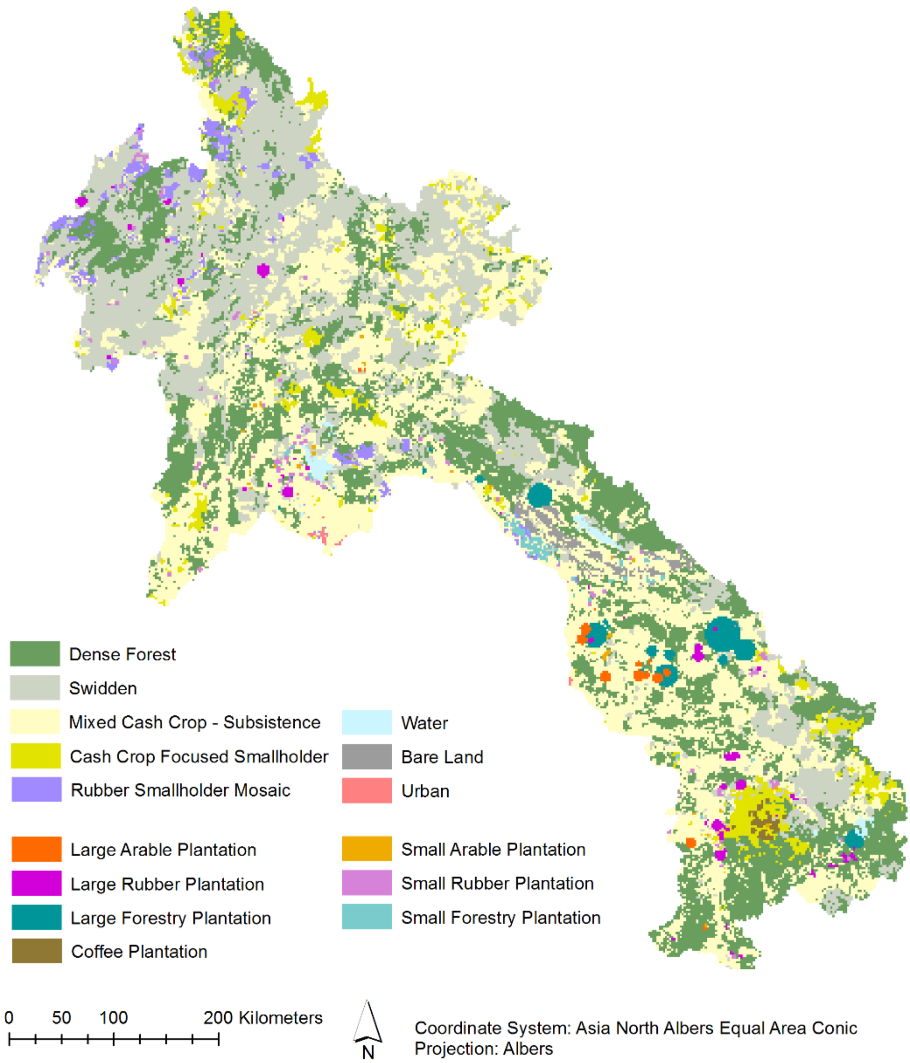

Figure 4.1: Land system map of Laos in 2010

We parameterize each land system with six commodities, services, or effects of land use it can produce in a single cell per time step (Table 4.1). A commodity or service can be provided by multiple land systems, and a land system can potentially provide multiple commodities, services, and effects at once, or none (e.g. water). The commodities and services are: (1) *subsistence crops*, which are those crops that are predominantly produced for consumption by the producer and her family and local community; (2) *cash crops*, which are all crops except rubber that are predominantly produced for sale on regional to global commodity markets; (3) *rubber*, although also a cash crop, is represented as a separate commodity given its importance in Laos; (4) *timber*, which captures all output from forestry plantations; (5) *urban area*, representing all services the urban centers provide, including living space and infrastructure; (6) *large-scale land acquisition* itself, which is a way of quantifying the effects LSLAs are perceived to have by the host government. Whether the effects of LSLA are perceived by policy makers as positive or negative is scenario-dependent (see scenarios below). Each plantation system therefore produces one unit of 'LSLA', allowing for the definition of explicit targets on the amount of LSLAs in parameterization (e.g. a target to increase the amount of LSLAs, or to cease granting of LSLAs). The empirical quantification of land system services is further described in SI-1. Note that small plantation systems also produce subsistence crops, because at the scale of a 400 ha cell, these systems are defined as a mosaic of plantations and smallholders. In contrast, large plantation systems are typified as monocultures.

The land system classification and associated commodities instigate a dichotomy between subsistence agriculture and cash crop agriculture. For smallholders, this allows the simulation of market integration, while at the same time the competition between smallholders and LSLAs can be modeled. We empirically defined the two commodity groups based on proportions of land dedicated to cash crops, derived from the Agricultural Census (see Appendix A-3). Commodity production figures where then calculated using typical yields reported by (FAO, 2017b).

Table 4.1: Overview of land systems and their land system commodity production or services. Calculations and data sources are given in Appendix A.

Group	Land System	Land system commodities and services (production per 400 ha grid cell)					
		Subsistence Crops	Cash Crops	Rubber	Timber	Urban Area	LSLA
Large-Scale Systems	Small Arable Plantation	260 ton	358 ton				1 unit
	Small Rubber Plantation	142 ton		81 ton			1 unit
	Small Forestry Plantation	237 ton			312 m³		1 unit
	Large Arable Plantation		1265 ton				1 unit
	Large Rubber Plantation			286 ton			1 unit
	Large Forestry Plantation				1100 m³		1 unit
	Coffee Plantation	47 ton	1600 ton				1 unit
Smallholder Systems	Swidden	296 ton	155 ton				
	Mixed Cash Crop – Subsistence Mosaic	426 ton	604 ton				
	Cash Crop-Focused Smallholder	83 ton	1173 ton				
	Rubber Smallholder Mosaic	142 ton	345 ton	207 ton			
Urban System	Urban					400 ha	
Forest System	Dense Forest						
Static Land Covers	Water						
	Bare Land						

4.2.3. Model description and implementation

To simulate land system changes until 2030, we applied the CLUMondo model (van Asselen and Verburg, 2013). CLUMondo allocates land system changes in response to an exogenously defined demand for commodities, services or effects in yearly time steps, using an iterative allocation procedure. In the model, alternative land systems are competing for space, based on the suitability of locations for each land system, the current land system configuration, and the competitive advantage of each system to supply the demands. The characterization of a land system includes stating the commodities, services and effects it can provide (see previous section), the land systems it can convert into, and the system's resistance to conversion. Yearly changes in demand for the defined land system commodities and services drive land system conversion in the model. See Appendix B-6 and van Asselen and Verburg (2013) for an in-depth explanation of the model.

We empirically determined location suitability following the assumption that the physical and socio-economic characteristics of the current locations of land systems reflect the suitability for these systems (e.g. when more rubber is needed, rubber-producing systems will emerge in areas which have a suitable climate and/or soil for rubber tree growth and that are accessible to markets) (Van Dessel et al., 2011). The relations between these location characteristics were identified using a logistic regression analysis. We selected a set of 28 maps as candidate explanatory variables, covering climate, soil, terrain, accessibility, ethnicity, and natural hazards. Candidate explanatory variables were checked for multicollinearity, and pairs of variables that correlate too much (Pearsons $r > 0.8$) were not used in the same model. Details on variables and fitted logistic regression models can be found in Appendix A-5.

As a consequence of the heterogeneity in scale of land change processes in a context of LSLA, a multi-scalar approach is warranted. We made two specific adjustments to the standard modeling procedures of CLUMondo: multi-cell allocation and wider-region suitability assessment (Figure 4.2).

Firstly, recognizing that the large plantation systems in our application change on a multi-cellular basis, we developed a multi-cell allocation algorithm. This algorithm allocates multiple contiguous cells (patches) of a single land system, without deviating from the competition-based iteration algorithm and conversion rules. The algorithm accepts for each land system the desired patch size (stated as the maximum distance from a central cell), the minimum suitability each cell has to have to be included in a patch, and the minimum amount of cells included in each patch in order to be retained. For example, a land system can be parameterized to have patches with radius equal to 1 cell, a minimum location suitability of 0.5 and minimum number of cells included equal to 4. In that case, CLUMondo will find a seed cell at a location with high suitability for that land system and try to allocate all nine cells within the radius distance (i.e. a 3x3 kernel), but will be restrained by general conversion rules (e.g. water cannot be converted) and by the minimum suitability (cells with suitability lower than 0.5 for the land system will not be included). If after applying these rules, the patch has four cells or more, the patch is allocated. Otherwise, it is discarded and another location for a patch of that land system is found.

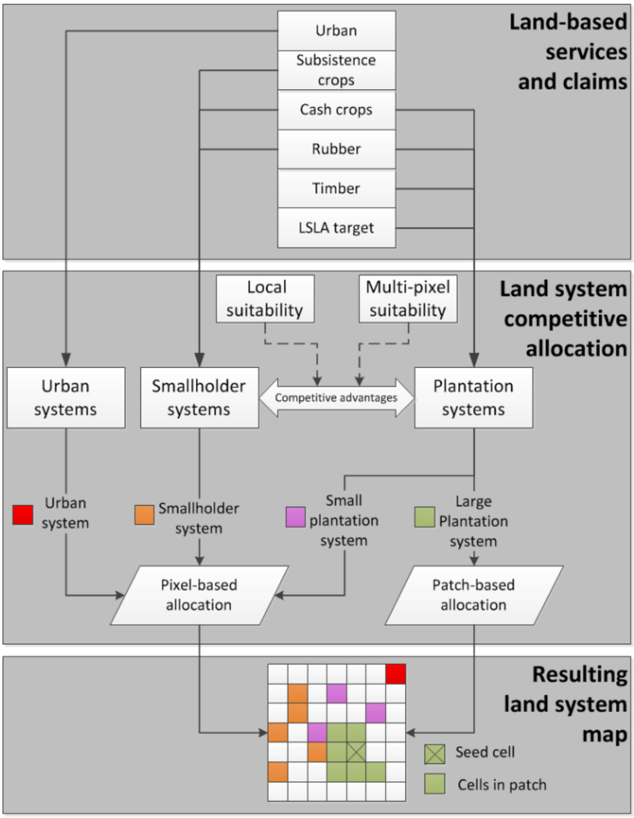

Figure 4.2: Model framework

Second, when allocating large contiguous land systems, location suitability should reflect the suitability of the wider area and not simply that of a single pixel in the model. A single suitable cell surrounded by unsuitable cells is not a prime location to consider for a large scale land system. Therefore, logistic regression models that quantify the suitability for large scale land systems use versions of the explanatory factors that have been smoothed using a moving window focal analysis (9 cell window). Each factor has a normal layer, which quantifies a factor (e.g. flood risk) at that cell location and is used for regressions of small-scale systems, and a smoothed layer, which quantifies the average of that factor in the wider area around that cell location and is used for regressions of large-scale systems.

For our implementation of LSLAs in the model the parameters are provided in Table 4.2. We set the radii and minimum amount of cells per patch to correspond to the current average size of LSLAs in Laos. The minimum suitability quantifies the extent to which the multi-cell algorithm can be selective in creating patches, and when this selectiveness is too high, no location that meets all criteria will be found. Therefore, we manually calibrated minimum suitability by adjusting it downwards until the iterative allocation procedure could find a solution.

Table 4.2: Multi-cell allocation parameters for large plantation systems

Land system	Radius (# cells)	Minimum suitability	Minimum amount of cells (400 ha) in patch
Large Arable Plantation	2	0.3	10
Large Rubber Plantation	1	0.3	6
Large Forestry Plantation	3	0.1	34

Because a commodity can be produced by different land systems in different quantities, a change in demand for the commodity can be resolved by seven land system change processes that summarize the possible dynamics between LSLAs and smallholders when these two producer types are in competition (visualized in Appendix A-6). *Smallholder intensification* occurs when one smallholder system converts into another smallholder system that produces more of the commodity (e.g. from swidden to cash-crop focused smallholder system for the cash crop commodity). Smallholder *disintensification* is the opposite (a smallholder system converts into another smallholder system that produces less of the commodity in question). *LSLA takeover* is the conversion of smallholder systems into LSLA systems, which can result in a *net gain* or *net loss* of commodity production, depending on the smallholder system that is being converted. *LSLA expansion* or *smallholder expansion* occurs when, respectively, LSLA or smallholders put dense forest systems to commodity-productive use. In our application, we restricted some trajectories that are hypothetically possible as they are deemed to be unlikely. Specifically, we restricted the conversion from LSLA to other land systems (i.e. LSLAs do not disappear), because the high capital investment and long contract times make such conversion unlikely in our time frame.

4.2.4. Scenarios for land system change

We illustrate our model functionality using three contrasting scenarios of future land system change in Laos. These scenarios are characterized by (1) a high governmental encouragement of LSLA, (2) a moratorium on LSLA, and (3) no specific LSLA policy. The scenario storylines build on the notion that policy biases for or against plantation agriculture are a strong (but not the only) determinant of the occurrence of large-scale agriculture (Byerlee, 2014). The scenarios are highly contrasting and serve to show a wide range of alternative trajectories, rather than a most likely future. A complete overview of all parameters and their calculations is given in Appendix

A-6. As shown in Table 4.3, we assume that demands for rubber, cash crops, subsistence crops, and urban area are equal in the three scenarios. In all scenarios, it is assumed that there is an interest in LSLA in Laos, i.e., LSLA in Laos is a "seller's market" and the amount of LSLAs in Laos can be controlled by the Government of Laos (GoL).

In a first scenario, '*High LSLA'*, the GoL aims to include LSLA in their development strategies by granting land concessions. Policy makers thus perceive or emphasize mostly positive effects of LSLA and therefore offer attractive conditions for land investors. In the past decade, this strategy was indeed followed under the denominator of 'Turning Land into Capital' and was seen as a way to increase rural accessibility to markets and infrastructure (Lestrelin et al., 2012; Schönweger et al., 2012). This scenario continues on the land capitalization track by parameterizing the model to quadruple the area of LSLAs by 2030 compared to 2010.

The second scenario, named '*Moratorium*', imposes a moratorium on new LSLAs starting from 2010. Existing LSLAs are allowed to continue operation and are not cancelled. While such a moratorium has not been issued in reality in 2010, it has in 2007 (for new timber plantations) and in 2012 (for new rubber and eucalyptus plantations) (Hett et al., 2015). Scenario two is a stylized, extreme version of these experiences, where the moratorium encompasses all LSLAs and is assumed to be effective on the ground. Here, we assume policy makers perceive negative effects of LSLA, which they want to stop. The demand for LSLA is kept constant at the 2010 level. Timber demand is also kept constant because smallholders cannot, in our model implementation, substitute as a producer of this commodity.

The third scenario, '*No LSLA Policy'* creates a situation without restrictions or requirements for the area of new LSLAs (i.e. this specific land system effect is dropped, increasing the degrees of freedom the model has in allocating land systems). Policy makers are assumed to be indifferent and/or ineffectual towards LSLA, and do not intervene in the competitive dynamics between LSLAs and smallholders. This scenario highlights the competition between smallholders and LSLAs, and allocates land systems only based on their suitability and competitive advantages.

Table 4.3: Increase in demands of land system services until 2030 as a percentage of demand in 2010.

Scenario	Timber	Cash crops	Rubber	Subsistence crops	Urban area[A]	LSLA
High LSLA	160 %	120%	200%	110%	182%	400%
Moratorium	100%	120%	200%	110%	182%	100%
No LSLA Policy	160%	120%	200%	110%	182%	n.a.

A: average yearly growth rate of 4.1%, based on calculations of on UN projections

4.3. Results

The three scenarios provide land system projections for Laos in 2030. After a general overview, the results from the three scenarios are presented in terms of the simulated land systems changes and the processes leading to these changes.

Figure 4.3 shows the resulting land system maps in 2030 under the three future scenarios. The maps show three quite different land system patterns, even though the demands for most land system commodities and services are similar across all scenarios. Zoomed maps show how plantation systems are allocated, with small plantation systems allocated in the standard single-pixel mode. Large plantation systems are allocated using the multi-cell allocation algorithm, with sizes varying following Table 4.2. Figure 4.4 shows that the extent to which different land change processes contribute to the fulfillment of rubber and cash crop demands varies highly. This section describes detailed results per scenario, in terms of the simulated land system patterns and the land change processes that contribute to the fulfillment of the commodity demands.

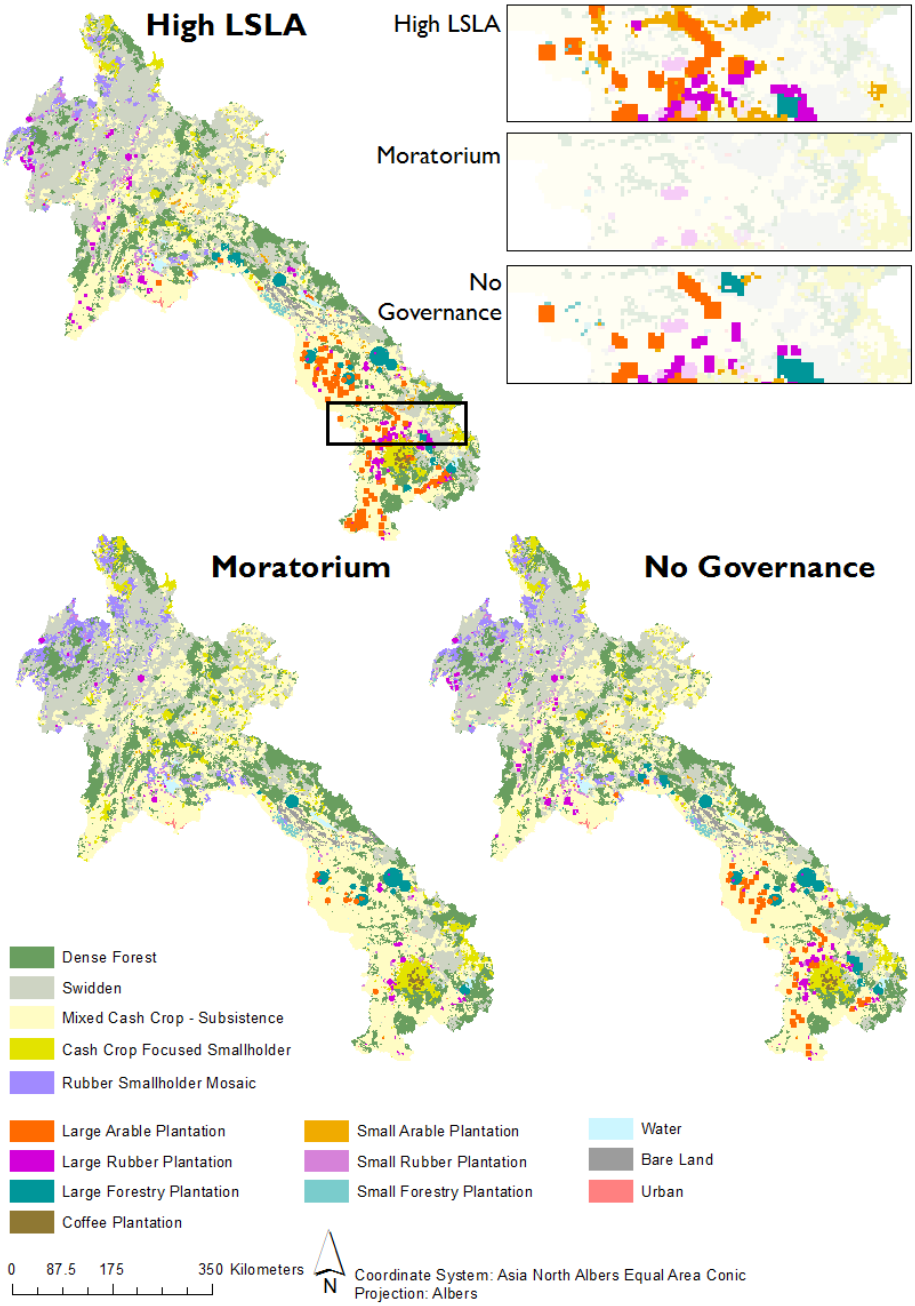

Figure 4.3: Land systems in 2030 under three scenarios. Zoomed maps visualize how scenarios differ locally and the ways in which the multi-cell allocation algorithm creates distinctively patched land systems.

The High LSLA scenario is parameterized to quadruple the area of LSLA by 2030. The immediate effect of this policy is proliferation of LSLAs, both by expansion into dense forest systems and takeovers of smallholder farmland. This is the only scenario where LSLA takeovers result in a reduction of cash crop and rubber production (Figure 4.4). Smallholder intensification is almost non-existent in this scenario, while some disintensification takes place. Smallholder expansion is negligible for rubber, but contributes significantly to the additional cash crop production. However, this entails only conversions from dense forest to either swidden (2.01 million ha) or mixed cash crop subsistence mosaics (1.04 million ha) systems, with expansions into cash crop focused systems being non-existent. This means that smallholders are driven to subsistence agriculture (i.e. swidden and mixed subsistence – cash crop systems), because LSLAs occupy a major part of the cash crop market as well as the land. However, these subsistence-based land systems also produce some cash crops in our model, according to the empirical characterization of these systems (Table 4.1). Therefore, smallholders still contribute in the provision of cash crops (Figure 4.4). A surprising effect of an LSLA promotion is thus an increase in swidden extent by 18%.

The Moratorium scenario restricts LSLA proliferation, thus requiring the demands for cash crops and rubber to be met by smallholders only. Under this scenario, the Chinese border area undergoes a transformation from swidden and dense forest to rubber smallholder mosaics, and Southern Laos loses dense forest systems to mixed cash crop – subsistence mosaics. While smallholder expansion is the dominant process, this scenario also results in the most pronounced intensification by smallholders. Intensification is predominantly attained by conversions from swidden to other smallholder systems producing more cash crops and/or rubber, resulting in a net reduction of swidden extent by 11%.

In the final scenario, where no specific policy related to LSLA is in place, LSLAs supply only 18% of the increase in cash crop demand and 46% of the additional demand for rubber, compared to 48% and 98% for cash crops and rubber respectively in the High LSLA scenario. This result is significant: in the absence of policies, the land system changes are the result of the empirical characterization of land system suitability in combination with land system specific parameters. This result shows that neither smallholder nor LSLA systems are superior in terms of competitiveness in the model (i.e. the model is not significantly biased towards a specific production method). Instead, the merit of one system over the other is spatially heterogeneous. Small rubber and arable plantations are allocated significantly less in this scenario compared to the High LSLA scenario (see detail boxes in Figure 4.3). This indicates that without an explicit policy demand for LSLAs, small plantation systems are only marginally competitive. Under this scenario, swidden extent decreases only by 3%.

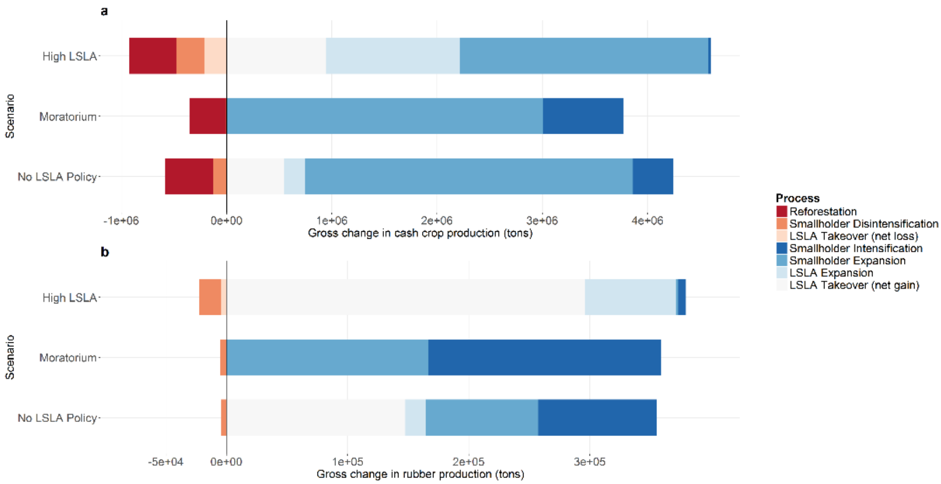

Figure 4.4: Contribution of different land system change processes to fulfilling the demand for cash crops (a) and rubber (b) in all three scenarios. Terminology for different land system change processes is given in text. The demand for both commodities is the same in all scenarios.

4.4. Discussion

4.4.1. Interactions between smallholders and LSLA

Our three scenarios show that, while the demand for rubber and cash crops can be provided by both smallholders and LSLAs, the encouragement or discouragement of LSLA results in very different spatial patterns of land system change. In our model, the distribution of the production between smallholders and LSLA depends only on the policies that govern LSLA. While LSLAs have specific economic (dis-)advantages, especially related to processing infrastructure and labor organization, policy biases for or against LSLA have historically been decisive in this distribution between LSLA and smallholder production modes in Southeast Asia (Byerlee, 2014). The scenarios laid out here indicate some possible consequences of these policies on land system changes.

Results highlight that while smallholders and LSLAs are spatially segregated, they are nonetheless strongly linked. The land change processes LSLAs instigate are therefore shown to go far beyond the immediate enclosure of large tracts of land. The notion that LSLAs interact with smallholders has been identified for individual case studies (e.g. Baird and Fox, 2015; Friis et al., 2016). These local studies have provided insights concerning consequences of LSLA on land systems, livelihoods, or local environments. Our study reveals larger-scale links between LSLA and smallholder agriculture through competition in common markets and land resources.

The model projects a decrease of swidden extent in the Moratorium scenario, and an increase in the High LSLA scenario. Decreasing swidden extent has been a policy goal in Laos for decades (Lestrelin et al., 2013). These results highlight that swidden extent may reduce mainly through smallholder intensification processes, where smallholders increase production for commodity markets by transformation from swidden agriculture to permanent cropping, but also retain some level of production for subsistence needs. However, everything else being equal, LSLAs are projected to impede smallholder intensification and market integration, and lead to a continuation of subsistence farming, and specifically swidden farming by smallholders. Other authors have identified increased accessibility and market integration as major drivers of swidden transformations (Cramb et al., 2009; Vliet et al., 2012). However, there are limits to converting swidden into cash crop or rubber producing systems, related to biophysical and cultural limitations and labor needs, making conversion to agroforestry and tree crops more likely pathways of intensification (Cramb et al., 2009; Ducourtieux et al., 2006; Vongvisouk et al., 2014). The model partly reflects these constraints using biophysical and socio-economic variables in the suitability calculations. In any case, smallholders will require organization, capital (seedlings, processing capacity), support (credit, agricultural extension programs) and infrastructure development to engage with cash crops or rubber (Ducourtieux et al., 2006; Vliet et al., 2012). This should be seen as a prerequisite for the smallholder transformations to occur as simulated in the Moratorium scenario.

4.4.2. Modelling the dynamics of LSLA

We identified two specific characteristics of LSLAs that are relevant for their representation in land change models: heterogeneity in the scale of land change processes, and the additional, policy-driven, demand for the (avoidance of the) effects of LSLAs irrespective of the goods and services produced. Both are explicitly included in our presented modelling approach. The newly developed multi-cell allocation algorithm can represent the different spatial extents covered by particular land systems, which is necessary when the interaction between LSLAs and smallholder systems is addressed. The CLUMondo approach allows the inclusion of multiple demands for goods and services that drive land system changes. However, the presented application is the first in which demands for specific types of land systems are included, in addition to the still existing demand for agricultural commodities.

The multi-cell allocation algorithm gives adequate flexibility to simulate LSLAs with varying sizes (see for example the difference between large arable, forestry, and rubber plantations in zoomed maps, Figure 4.3). The minimum suitability threshold can furthermore be used to simulate how much attention is given to land suitability in including individual pixels inside LSLAs, where a low threshold indicates an 'anything goes' attitude, while a high threshold reflects that some attention is given to the quality of individual pixels. Unless more is known about underlying processes, the choice of these settings is arbitrary.

Simulation results are shaped by the amount of change and the location of these changes, and uncertainties or inaccuracies may appear in both (van Vliet et al., 2016). A crucial modeling step is linking current land system locations with underlying factors that determine the location choice. In the case of LSLAs relatively little is known about location choice (Messerli et al., 2014) and our empirical analysis is based on a relatively low number of plantations (396 projects split up in seven land systems) covering a low number of cells per system. The pixels involved are, due to the patch character of LSLAs, highly autocorrelated and regression models may suffer from overfitting. Nevertheless, the approach is well-suited to embed empirical evidence into the parameterization of the model. Similarly, because the exact delineation of LSLA in Laos is not known precisely, the values for the production of commodities might be over- or underestimated as well. On-going efforts to delineate granted, surveyed, allocated and ultimately developed area (Hett et al., 2015) can serve to fine-tune such analysis.

Results indicate that, in all scenarios, the majority of the increase in production of rubber and cash crops may be attained by cropland expansion (to mixed extents by smallholders and LSLAs), entailing the loss of dense forest. While this signals that the commercial pressure on land may endanger current forests, the extent of this deforestation cannot be directly read from the land system change maps. A land system should be interpreted as a mosaic of various land covers, of which tree cover is one. Therefore, systems other than dense forest also contain tree cover, and net tree cover loss is contingent on the mosaic compositions. For example, LSLAs are often underused and therefore LSLA systems likely contain significant shares of forest cover (figures of productive use in this study: Appendix A-4).

In our model, we assume that the governance of LSLA, or lack thereof, does not affect the national-level demand for commodities. However, while cash crops and rubber can be produced by smallholders as well as LSLA, their production does not necessarily respond to the same market demand. Countries and companies acquiring land are often specifically looking to control large tracts of land or speculate on future use. This interest in the control over land itself, rather than the specific land-based commodities, is referred to as 'control grabbing' (Borras and Franco, 2012; Hall et al., 2015), and may limit the assumed interchangeability between smallholder and LSLA production.

Differences and interactions between LSLA and smallholder agriculture in our model are to the extent possible based on existing literature. Some hypothetical differences and interactions have not been included. Firstly, there is an ongoing debate on whether the advantages of a larger scale trump the disadvantages. Large operations are arguably better at organizing supply to a processing plant or pioneering a crop in a new area, while smallholders enjoy significantly lower costs of labor management, and often acquire higher yields due to higher-precision management for different crops (Byerlee, 2014; Cramb et al., 2016). Empirical studies on this debate indicate that throughout Southeast Asian history, there has been a transition from large-scale to small-scale agriculture, making the recent surge in LSLA an aberration (Bissonnette and Koninck, 2017). Our model does not explicitly include any (dis-)economies of scale in the production distribution of crops (see Deininger and Byerlee (2012) and Hall (2011) for an in-depth discussion). Second, we have not included potential synergies between LSLA and smallholders (e.g. contract farming schemes). In such schemes, plantations may offer capital, technique, and marketing, while smallholders provide labor and land (Cramb et al., 2016; Shi, 2008). However, how and to what extent such synergies result in land change processes is unclear and could be addressed in future research.

4.4.3. Implications for model-based land change assessments

Since 2007, LSLA has globally become a significant land system change trajectory (Nolte et al., 2016). The interactions between LSLA and smallholders have been studied in local case studies (e.g. Friis et al., 2016; Hall et al., 2017). However, interactions at a larger scale have received far less attention (but see Baird and Fox, 2015). Smallholders around the globe are stepping up as producers for the world markets of rubber, biofuel crops, and other cash crops, responding to the same global demands as LSLAs (Bissonnette and Koninck, 2015; Cramb et al., 2015; Fox and Castella, 2013). The current study highlights the different potential roles of LSLA and smallholders in land system change trajectories under different scenarios.

Rather than aiming at predictions of the future, these scenarios form a boundary object for discussing the option space for governments in dealing with high pressures on their land-based commodity markets and the different land system futures that may emerge from such choices, without forming normative judgments. Whether rubber and cash crop demand are met by smallholders, LSLAs, or a combination of both makes a strong difference in the emergent landscapes and the future of rural livelihoods.

Given the high impact LSLAs have on livelihoods, commodity markets, biodiversity and forest cover, globally, it is paramount to include them in model-based land-change assessments. Building sophisticated scenarios of LSLA dynamics will continue to be challenging given their regime shift-nature (Müller et al., 2014). Additionally, these systems respond to global commodity prices, which can be hard to predict. At the same time, LSLA-agnostic projections may lead to naive projections of future land change dynamics that ignore the changes in agency governing land change.

A few challenges remain. Firstly, it is widely reported that many allotted LSLAs are not actually planted or abundant for reasons of low commodity prices, local resistance, or speculative intentions of the land investor (Liao et al., 2016). Therefore, land system changes simulated here will in many cases be merely a legal change, while actual land cover change could be limited or restricted to deforestation. More detailed, local scale assessments could provide further insights in these dynamics. Furthermore communities that have been expropriated or otherwise affected by LSLAs may give rise to indirect land use changes. These lower-scale impacts on livelihoods and labor are thus a key to further understanding the impacts of LSLAs in general (Li, 2011; Oberlack et al., 2016), and on land system changes specifically.

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5. Future governance options for large-scale land acquisition in Cambodia: Impacts on tree cover and tiger landscapes

This chapter investigates how large-scale land acquisitions (LSLAs) can be governed to avoid underuse and thereby spare room for other land claims, specifically nature conservation. LSLA underuse occurs when land in LSLAs is not converted to its intended use. Taking Cambodia as a case, we map converted and unconverted areas within LSLAs using remote sensing. We develop three scenarios of alternative LSLA policies until 2040, and use a land system change model to evaluate how governing the underuse of LSLAs affects overall land use. Specifically, we evaluate the impact of these policies on future tree cover, the size and spatial integrity of natural areas, and the potential these natural areas can offer to meet the conservation target of a successful tiger reintroduction. In 2015, only 32% of LSLA area was converted. Simulations suggest that both interventionist (reclaim unconverted areas) and preventive (avoid non-conversion) policies dramatically reduce underuse. Interventionist policies perform best in limiting tree cover loss and in preserving natural areas, but preventive measures lead to significantly less fragmentation. Noninterventionist policies (no enforced policies) make tiger reintroduction in the Eastern Plains impossible. Preventive policies with well-enforced protected areas succeed in creating the largest potential for tiger reintroduction. Our results suggest that Cambodia can reconcile LSLAs with tiger reintroduction in the Eastern Plains only when using preventive land use policies. In the absence of such policies, tiger survival in the Eastern Plains is unlikely and only the Cardamom or Virachey forest may offer such potential.

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5.1. Introduction

Following the 2007-08 crises in food, fuel, and finance, demand for the control over land resources has surged (Arezki et al., 2011). Large-scale land acquisitions (LSLAs) are the prime manifestation of this demand, resulting in the reported acquisition of over 49 million hectares of land globally, predominantly in developing countries (Land Matrix, 2019) The rapid proliferation of LSLA has spurred societal and academic debate on the desirability of these investments.

Some dismiss the idea that LSLAs can provide benefits that outweigh the negative social and environmental effects and the opportunity costs they incur and argue against optimizing land governance as it will not solve the fundamental problems with LSLA (Borras and Franco, 2010a; De Schutter, 2011). Others argue that LSLA is a necessary way to meet growing agricultural commodity demands. In this line of reasoning, LSLAs hold the potential to close yield gaps and increase labor productivity by bringing technological improvements to rural areas that have hitherto seen little rural innovation (Collier and Dercon, 2009). Countries with large land endowments may benefit from LSLAs provided that they streamline the process in a transparent way and with sufficient land governance guardrails (Deininger and Byerlee, 2012).

The fundamental discourse legitimizing LSLA, the notion that 'unused' or 'waste' land should be allocated to more efficient (large-scale) producers to boost global agricultural production, is scrutinized in a number of ways (De Schutter, 2011; Scoones et al., 2018). Firstly, the existence of 'unused' land is doubted, because often such land is in common use (D'Odorico et al., 2017; Eitelberg et al., 2015). Marking land as 'waste' land is an underappreciation of the many services land can supply (Borras et al., 2011b). Second, the alleged higher efficiency of larger-scale farm units is not supported by empirical evidence. Instead, small owner-producers outperform corporate farms in all but a few crops, and even for crops where e.g. post-harvest processes warrant large-scale supply, it can suffice to organize smallholders in cooperatives (Deininger and Byerlee, 2012; Holden and Otsuka, 2014). Third, the local livelihood and land system impacts of LSLAs are often deemed unacceptable (Friis et al., 2016). Fourth, the secondary positive effects that are claimed to accrue from land investments, such as employment, poverty reduction, or food security, often do not materialize or are insufficient to compensate for lost opportunities (Nolte and Ostermeier, 2017; Oberlack et al., 2016; Rulli and D'Odorico, 2014). The core of this debate is a choice between two development pathways: a pathway of smallholder enablement or a pathway of scale enlargement and foreign investment. While LSLAs can be an engine of agricultural production growth, the enablement of small farmers has the same potential while also providing stronger gains in rural poverty alleviation and development. From this perspective, LSLA is loaded with a high opportunity cost (De Schutter, 2011).

Amidst this debate, a less discussed aspect is the governance and functioning of granted LSLAs. While LSLAs are granted as large, contiguous areas intended for commercial agriculture, a significant share of areas claimed by LSLAs is not converted to its intended use. This is problematic as land resources are becoming scarcer and more contested. Underuse of LSLAs is caused by a host of factors. Often, land is acquired for its speculative value. Although the extent of mere speculative land acquisition is unknown, it has global significance (De Schutter, 2011). In other cases, investors lack agronomic or logistic capacity and knowhow, or meet effective opposition from local land users (Buxton et al., 2012; Schönweger and Messerli, 2015). Agronomical challenges become especially significant when new crops are pioneered (Pearce, 2012; Wendimu, 2016).

The implication of LSLA underuse is a potentially inefficient land use distribution. Unproductive LSLA areas could instead be farmed by smallholder farmers or designated as natural areas. While the full extent of underuse is unknown, the Land Matrix reports 7.5 million hectares of failed LSLA deals globally. For 918 deals, the productive use is known, revealing that only 56% of the area of those deals is converted to its intended use, and only 24% of LSLA projects converted all area they acquired (Land Matrix, 2019). More reliable figures of LSLA underuse are not available, highlighting the need for empirical research to inform policy. Even when unconverted LSLA areas are still being farmed by smallholders, the LSLA creates insecure land tenure conditions for these land users. This means that the original land use/cover (e.g. forest, smallholder agriculture) persists, but land ownership and tenure become highly insecure. This insecurity is problematic in its own right, but also potentially creates second-order negative effects such as lower land productivity (Higgins et al., 2018). Large tracts of land are effectively locked in by high transaction costs (Deininger and Byerlee, 2012), and cannot easily be rededicated to e.g. smallholder agriculture or nature conservation.

Countries hosting LSLAs are now faced with the challenge of governing these novel land tenure arrangements. This is a pertinent, yet rarely addressed issue: new tenure systems demand new regulatory frameworks, and effective management may have the potential to maximize LSLA benefits while minimizing its negative impacts. Most academic work on LSLA has scrutinized the discourses by which LSLAs are (un)justified (e.g. De Schutter, 2011; Scoones et al., 2018), the motives of stakeholders in the global network of land buyers and sellers (e.g. Zoomers, 2010), or the impacts of LSLAs on local and national socio-ecological systems (e.g. Davis et al., 2015; Oberlack et al., 2016). Such studies tell a precautionary tale and warn against the undesirable outcomes and missed opportunities associated with an LSLA pathway. We do not argue against these analyses, but depart from this debate by considering governance options for those countries that, despite the abovementioned issues, have already embarked on an LSLA pathway nonetheless. Such countries must deal with a different problem set: how to govern novel land tenure arrangements and deal with a new type of land user. This challenge has two interrelated sides: first, policy makers may wish to grant more land as LSLAs, raising questions concerning the amount, size, and location of new projects. Second, effective regulation of existing LSLAs can be challenging in the absence of best practices. Because land resources are limited and claimed for a multitude of purposes, the management of LSLA has often come at the cost of other land users (Messerli et al., 2014), and competitive interactions with smallholder farmers at the national level have been identified (Debonne et al., 2018). Moreover, as LSLA is having an impact on forests and natural habitats (Davis et al., 2015), countries with an environmental policy agenda should reconcile their LSLA policies with their environmental policies, and have the tools to do so.

Countries have established a number of governance approaches to manage the amount of new LSLAs and regulate existing LSLAs. In terms of amount of new LSLAs, policies range from moratoria on all or specific types of LSLAs, to active stimulation of new LSLA (Debonne et al., 2018; Sperfeldt et al., 2012). Those countries accepting and/or stimulating LSLA are using various regulatory frameworks to control location and use of existing and new LSLAs, which we group into three categories. First, some host countries opt for a *noninterventionist* policy, where land acquirers do not need (or are not enforced) to meet any requirements. There are no prior checks on the suitability of the granted land for the intended purpose or the overall feasibility of the project, and LSLA underuse is not penalized. Noninterventionist governance has for example been reported in Myanmar and Zambia where existing regulations are only rarely enforced because responsible administrations are underfinanced and legal pluralism (the co-existence of formal and customary law) undermines formal regulations (Byerlee et al., 2014; Nolte, 2014). Second, *interventionist* policies demand from land acquirers that they present a plan detailing the intended land use conversions and their timing. Failure to adhere to these plans can result in the revocation of the contract. This policy is for example used in Madagascar and Mozambique, where the LSLA performance and adherence to land use plans is checked after 5 years and 2 years, respectively, and the contract can either be extended or voided (Andriamanalina and Burnod, 2014). Such policies are especially implemented to avoid speculative use of the acquisitions (Nolte et al., 2016). Third, as host governments become more experienced with LSLA and land is becoming scarcer, there are signs that countries are increasingly considering local populations and biophysical suitability of the land for the intended use (Messerli et al., 2015). This creates the perspective for a *preventive* policy style, where host governments allocate LSLAs on land suitable for the intended purposes, and only when the aspiring investors can present solid business plans.

Cambodia is one of the countries where the governance challenges instigated by LSLA have become pertinent. Land is claimed for commodity production by domestic and international producers, but also for biodiversity conservation and urban expansion. Cambodia has granted approximately 2.3 million hectares of agricultural LSLAs, using the Economic Land Concessions system (LICADHO, 2017). LSLAs are intended for the production of, among others, rubber, sugar cane, cassava, fast-growing tree species and palm oil (Sophal, 2015). The de jure policies regulating LSLAs theoretically contain safeguards against LSLA underuse and excessive environmental damage. Among others, a maximum size of 10000 ha per LSLA is set, environmental and social impact assessments should be conducted, protected areas are off-limits, and contracts can be revoked. However, the de facto policies before 2012 have been implemented less stringently. LSLAs have been granted in protected areas, maximum areas have been exceeded, and LSLAs were often used only to extract timber. Underuse of LSLAs is reported to be a large problem (Löhr, 2011; Neef et al., 2013; Oldenburg and Neef, 2014). This has lead the Government of Cambodia to launch Order 01 in 2012, which includes a full review of currently existing LSLAs and a ban on new LSLAs (Sophal, 2015). Meanwhile, Cambodia hosts a large stock of tree cover, often within large, contiguous natural areas. These natural areas contain a wide range of globally endangered species (WWF, 2018). 34% of Cambodia's territory is officially protected (World Bank, 2018), although this protection is often not effective (Souter et al., 2016). In the context of the WWF Tx2 project, which aims to double the global population of wild tigers (*Panthera Tigris*) by 2022 (Wikramanayake et al., 2011), Cambodia has committed itself to reintroduce the currently extirpated tiger. This reintroduction requires, among other factors, a large contiguous habitat and therefore constitutes a large claim on land resources (Gray et al., 2017).

The objective of this chapter is to assess to what extent and how Cambodian LSLA policies can be reconciled with their nature conservation ambitions. This assessment is carried out using a forward-looking land system change model, able to project future land use under different policy scenarios. We assess the impacts of projected land system changes to future tree cover, area and integrity of natural areas, and the ensuing potential of a successful tiger introduction. Land change models are valuable tools to explore the possible impacts of land policies in the future, and find out which policies may succeed in reaching stated targets. Currently, some LSLAs have been revoked or downsized following Order 01, but there are currently no protocols or guidelines on the management or use of the land of reclaimed LSLAs (Grimsditch and Schoenberger, 2015). With such large areas of land in the balance, Cambodia's policies on these issues will likely have a highly significant effect on land use and the environment, with perpetuating effects in the future.

5.2. Methods

To assess how LSLA policies will shape future land system patterns in Cambodia by 2040, we use CLUMondo, a land system change model that can explicitly address LSLA (Debonne et al., 2018; van Asselen and Verburg, 2013). The model is described in detail in Appendix B-6. In the following sections, we first develop a land system map for 2015, distinguishing the productive use of LSLAs. Next we explain the modeling of future land system changes until 2040. Lastly, we present and parameterize three LSLA policy scenarios.

5.2.1. Mapping large-scale land acquisitions as land systems in Cambodia

We characterize Cambodian land systems based on their land cover composition as well as their land management regime. Land systems combine information on land cover, land use, and land management. They capture the different purposes land has and to what extent specific combinations of land cover, use, and management can fulfill demands for these purposes (van Asselen and Verburg, 2012). Land systems are classified at a spatial resolution of 1000m, because this best captures the land change processes of interest and the detail of available data. The starting land system map depicts the situation in 2015 for mainland Cambodia. We operationalized the classification using a decision tree that combines a 2015 land cover map (Miettinen et al., 2016), a forest classification (Open Development Cambodia, 2016a), and the spatial delineation of LSLAs (Open Development Cambodia, 2016b). The resulting land systems are defined in Table 5.1. A detailed procedure is presented Appendix B-1 and B-2.

To be able to reflect differences between LSLAs, we use the Cambodian LSLA spatial database by Open Development Cambodia (2016), and mapped the areas that are converted into a plantation. We interpreted LSLAs to be 'converted' when (1) it falls within a mapped LSLA area (Open Development Cambodia, 2016b) (2) a plantation-like land cover pattern is present (large-scale monocultures planted in a noticeably structured way), and (3) the land was converted after the contract date of the LSLA. We used high resolution Google Earth data and Landsat time series with yearly images to perform the visual interpretation. We further subdivided used LSLAs into annual crops, forestry, and perennial crops, based on their intended production as stated in the LSLA database. Unconverted LSLAs are subdivided into forested and other unconverted LSLAs , based on forest cover (Table 5.1). Other unconverted LSLAs may be fallow, or in use for smallholder agriculture, but this was not classified in more detail.

Table 5.1: Land systems and explanation. The decision tree and specific data sources are provided in Appendix B-1.

Land system	Description
Water	Rivers and lakes
Floodplain/Mangrove	Floodplains or mangroves
Urban	Cities and towns based on Miettinen et al. (2016)
Converted annual crops LSLA	Plantations located within an LSLA and intended for the production of annual crops (cassava, sugar cane, maize, and others)
Converted forestry LSLA	Plantations located within an LSLA and intended for the production of timber (acacia and teak) or paper pulp
Converted perennial crops LSLA	Plantations located within an LSLA and intended for the production of rubber or palm oil
Forested unconverted LSLA	Areas claimed as LSLA but not currently in use as a plantation, covered with forest
Other unconverted LSLA	Areas claimed as LSLA but not currently in use as a plantation, not covered with forest
Evergreen forest	Tropical evergreen forest
Deciduous forest	Deciduous dipterocarp forest, also known as tropical dry forest
Cropland	Smallholder cropland dominantly used for paddy rice cultivation and to lesser extent for the production of annual and perennial crops or timber
Cropland – Evergreen forest mosaic	Variant of the Cropland system in mosaic with evergreen forest
Cropland – Deciduous forest mosaic	Variant of the Cropland system in mosaic with deciduous forest

5.2.2. Modelling land system changes in response to multiple demands for commodities and services

The CLUMondo model (van Asselen and Verburg, 2013) is used to simulate future land system changes until 2040. CLUMondo combines information on local suitability for different land systems, conversion rules, and future demands for land system commodities and services, and uses an iterative procedure to allocate land systems in order to meet these demands. Conceptually, the model assumes that if there is an increase in demand for a commodity or service, land systems producing this commodity or service will appear where the biophysical and socio-economic context is most suitable for those land systems. Suitability is quantified using logistic regressions performed with eighteen socio-economic and biophysical factors Appendix B-3. Importantly, because land system can produce zero to many commodities and services, and any single commodity or service can be produced by multiple land systems, they drastically increase the complexity of the model. Each time step, the model essentially aims to supply all the land-based goods and services that are provided as exogenous inputs while maximizing the total allocation likelihood defined by the suitability and conversion resistances. The resulting land system changes (e.g. the choice between agricultural intensification or expansion pathways) are the result of a numerical optimization procedure balancing these demands, constraints, suitability and other specifications (van Vliet and Verburg, 2018). Within each time step (year), land use changes are simulated in an iterative procedure. Each cell is initially given the land system that is (1) allowed in that location (depending on original land system and location) and (2) has the highest transition potential (suitability) on that location. Then, the amount of commodities and services this new landscape produces is calculated, and based on the imbalance between demand and supply, land systems producing undersupplied demands are given a higher transition potential and vice versa. This is repeated until all demands are fulfilled within a margin of 5%, while the overall average deviation is below 1%.

In our application, each land system produces, in varying quantities, five defined commodities and services: annual cash crops (cassava, sugar cane, and others), timber, perennial crops (predominantly rubber, but also palm oil), and rice. 'Urban' is a land system service grouping all urban functions such as residential functions. LSLAs are assumed to specialize in one of three commodity groups (annual cash crops, perennial cash crops or forestry). Smallholder systems also produce these commodities, but focus mostly on rice. Furthermore, smallholders are assumed to experience increasing yields, representing partial closures of the yield gap. We control the area of new LSLAs added each year by defining a specific policy demand for LSLA, and allocate LSLAs using a multi-cell allocation algorithm to represent them as large contiguous entities (Appendix B-6). A detailed description of the quantification of demands and productivities is given in Appendix B.

5.2.3. LSLA policy scenarios towards 2040

We developed three scenarios to address alternative LSLA governance options for Cambodia and their possible consequences. We explain these scenarios with storylines and present model parameters that differ among scenarios in Table 5.2. The first scenario assumes no reform or no implementation of a reform and is therefore noninterventionist, while the next two scenarios assume a policy reform towards an interventionist and a preventive LSLA policy, respectively.

Hands-off: In this scenario, a noninterventionist approach towards LSLAs is assumed. No restrictions are in place to regulate LSLA. Upon acquiring land, there is no penalization if the investor does not develop a plantation, making it possible to leave the land undeveloped. We assume that each year, between 40000 and 60000 ha of new LSLAs are granted, and each individual LSLA is between 8000 and 12000 ha large. In the last 15 years, the average yearly area of new LSLA amounted to 111239 ha. Our estimates are therefore conservative, because (1) since 2012, Cambodia has signaled a less expeditious LSLA policy (Oldenburg and Neef, 2014), and (2) we assume the already high pressure on land in Cambodia (Löhr, 2011) makes a continuation of past trends unlikely. In this scenario, LSLA contracts are permanent and cannot be revoked or downsized. This scenario resembles a continuation of the LSLA policies prior to the 2012 Order 01, where LSLAs were granted without any effective management efforts (ADHOC, 2014; Dwyer et al., 2015).

Penalization: In this scenario, land acquirers are required to develop the acquired land within three years after the LSLA was granted. If they fail to do so, the contract is voided for the unconverted areas. These areas will convert to a non-LSLA land system. This scenario simulates a continuation of the interventionist policy effectively introduced by Order 01 in 2012, when the revision of granted LSLAs resulted in the downsizing or outright revocation of unconverted LSLAs. These areas where then granted to smallholders as Social Land Concessions, or (re-) integrated into protected areas (Oldenburg and Neef, 2014; Schoenberger, 2017). As LSLA contracts are revoked, we assume that the demand for commodities produced by LSLAs in Cambodia (timber, annual and perennial cash crops) decreases. This process mimics the globalized nature of the markets for these commodities: if land is not available or used in Cambodia, we assume production will move elsewhere. Specifically, the expected demand for LSLA area instigated by the three commodities in the next simulation year cannot exceed 50% of the total unconverted LSLA area. If this threshold is exceeded, the demands for the three commodities are evenly lowered until the criteria is met.

Proactive granting: In this scenario, Cambodia takes a preventive stance by granting smaller concessions on highly suitable land only. New LSLAs cannot be allocated within protected areas. Furthermore, new LSLAs are only granted if there is sufficient market demand for the commodities LSLAs produce. Specifically, only when the expected demand for LSLA area instigated by commodity demands in the next year exceeds 50% of the current LSLA stock new LSLAs can be granted. Note that in this scenario LSLA availability is adjusted upward based on commodity demand, while in the Penalization scenario commodity demand is adjusted downward based on LSLA availability.

Table 5.2: Scenario parameters. Maximum vacancy time is the number of years an LSLA is allowed to be unconverted before its contract is revoked. The LSLA size and minimum suitability are controlled by the multi-cell allocation algorithm described Appendix B-6.

	Hands-off	**Penalization**	**Proactive granting**
Protected areas	None or not effective	None or not effective	No LSLA in protected areas as delineated by Open Development Cambodia (2018b)
Maximum unconverted time	Indefinite	3 years	3 years
LSLA size	8000 – 12000 ha	8000 – 12000 ha	600 – 900 ha
LSLA minimum suitability	Very low (0.3)	Very low (0.3)	High (0.5)
New LSLA area yearly	40000 – 60000 ha	40000 – 60000 ha	Matching commodity demand
Total cash crop demand increase until 2040	100%	Depending on LSLA availability	100%
Total Timber demand increase until 2040	100%	Depending on LSLA availability	100%
Total Perennial cash crop demand increase until 2040	152%	Depending on LSLA availability	152%

5.2.4. Scenario impact assessment

5.2.4.1. Impact on tree cover

We quantify the total tree cover change during the simulated period. Conceptually, a land system is composed of various land covers, among which is tree cover. We quantify average tree cover for each land system and assume this will remain constant. This is operationalized using overlay analysis of the initial land system map with a tree cover map by Open Development Cambodia (2016a). We analyze total tree cover at the end of the simulation to assess the effectiveness of different policies. We also break down total tree cover into tree cover situated in natural, LSLA, and other land systems.

5.2.4.2. Impact on core natural areas and tiger reintroduction potential

We assess how land system changes impact core natural areas by defining a core area as a forested area (evergreen or deciduous land system) that is at least 5 km away from any large (>300 ha) unnatural disturbance. Non-core natural areas are defined as edge areas, and we assume that disturbance and edge effects pose a threat to biodiversity there. 5 km is frequently used as a distance to define core areas (Thatte et al., 2018). Further details on core area delineation are presented in Appendix B-4.

In a next step, we evaluate the impact of the modeled natural area dynamics on the potential of a tiger reintroduction. Tiger reintroduction success depends, amongst other factors, on the availability of a sufficiently large contiguous natural area. For a reintroduction to be successful, it is estimated that a habitat must be at least 0.2 Mha. The risk for human-tiger conflict is high in Cambodia, with low support rates reported for coexistence with tigers in potential tiger reintroduction sites (Gray et al., 2017). Therefore, we assume that tiger reintroduction is only feasible within the core natural areas, as defined above. Evergreen and deciduous forest systems can sustain 3 and 10 tigers/10000 ha, respectively (Wikramanayake et al., 2011). Using these figures, we quantify how many tigers can potentially be sustained by the remaining core areas larger than 0.2 Mha in 2040, in case other inhibiting factors (poaching, human-wildlife conflict, adequate prey densities; see Gray et al., (2017)) are dealt with.

5.3. Results

5.3.1. Cambodian land systems and large-scale land acquisition in 2015

In 2015, Cambodia consists of a central valley of cropland systems, and a number of large and relatively intact patches of evergreen or deciduous forests (Figure 5.1a). The Eastern Plains have been fragmented by a number of LSLAs, mostly for perennial crop production. Other natural areas marked in Figure 5.1a form relatively undisturbed core areas.

The majority of the land included in LSLAs in the year 2015 is not in use for their intended production (Figure 5.1b-c). Only 32% of all LSLA area is used productively, while the other 68% remains in its original state. Yet, the fractions differ between LSLAs, and according to the intended use. Area-wise, only 18% of forestry LSLAs, 33% of perennial cash crops LSLAs, and 55% of annual cash crops LSLAs were in use. The total area of undeveloped LSLAs is 1.15 Mha.

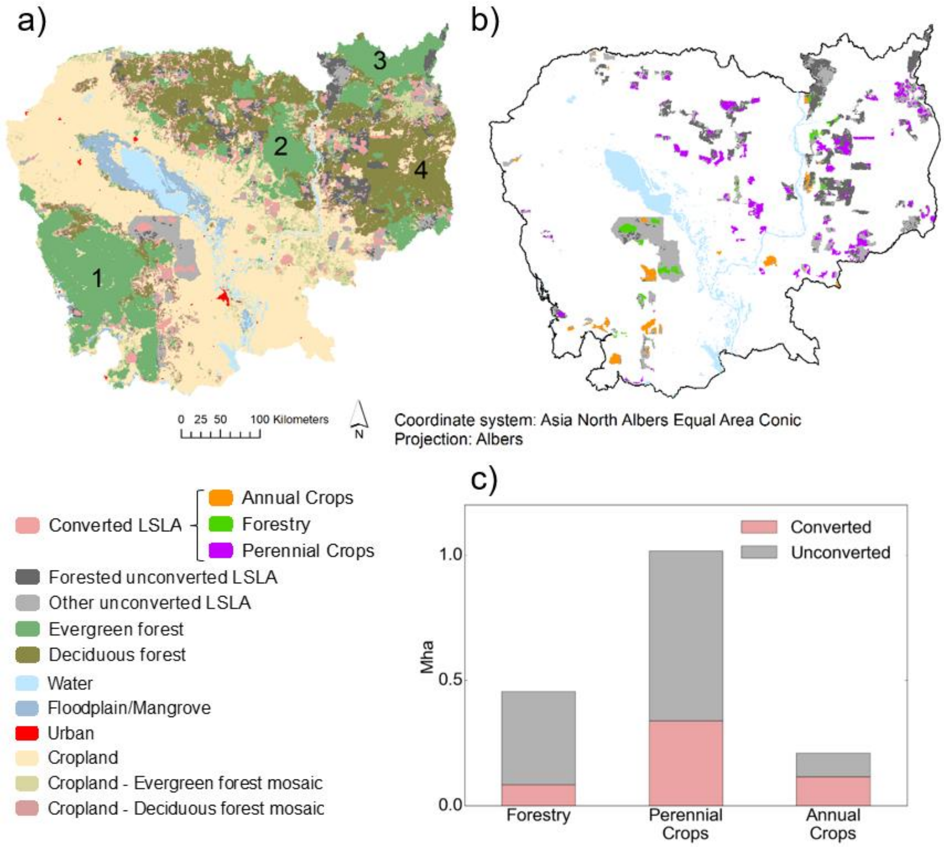

Figure 5.1: a) Cambodian land systems in 2015. Numbers mark the Cardamom forest (1), Prey Lang Forest (2), Virachey Forest (3), and the Eastern Plains Deciduous Forest (4). b) LSLA areas detailing the c) Productive use of LSLAs. Production group is determined by the stated intention in the LSLA database.

5.3.2. Cambodian land systems from 2015 to 2040 under different LSLA policies

Figure 5.2 shows the evolution of LSLA productive use in the three scenarios, and Figure 5.3 shows the scenario results for the year 2040.

In the Hands-off scenario, the total area of LSLA rises from 1.95 Mha to 3.03 Mha by 2040. 2.06 Mha (68%) of these LSLA areas are converted to plantations. The fraction of LSLAs converted to plantations rises over time as a consequence of the parameterization assumptions: the yearly area of new LSLAs is lower than the area required to meet yearly commodity demands. The LSLA areas present in 2015 are fully preserved, because there is no mechanism to cancel LSLAs. 0.83 Mha, or 43%

of the unconverted LSLA areas in 2015 are never converted, because these areas are not very suitable for the growth of any of the commodity types. Furthermore, new LSLAs are allocated mostly in lowland forests, such as the Prey Lang National Park, which is almost completely converted to perennial LSLA, and large parts of the Eastern Plains.

In the Penalization scenario, the total area of LSLA decreases to 1.8 Mha in 2040. Figure 5.2 shows that the area of LSLA decreases sharply until 2022, when the area of unconverted LSLAs stabilizes at about 0.1 Mha (6% of total area), while the area of converted LSLA increases steadily. The policies simulated in this scenario manage to remove surplus LSLA areas that are not suitable for plantation use. However, because of the assumed feedback on the commodity demands, the total area of converted LSLAs is lower than in the other two scenarios (1.7 Mha in this scenario versus 2.1 Mha in the other two scenarios). As in the Hands-off scenario, large parts of protected areas are lost to LSLA.

In the Proactive Granting scenario, the total area of LSLA increases slightly, to 2.3 Mha, of which 0.16 Mha (7% of total area) is unconverted. Because the area of granted LSLAs is parameterized to match closely the area needed for the production of demanded commodities, the converted LSLA area is higher in this scenario as compared to the Penalization scenario. The same quantities of commodities are produced as in the Hands-off scenario, but the amount of unconverted LSLA is significantly lower. The results further show that commodity demands can be met while protecting 34% of the Cambodian territory. In the other two scenarios, LSLA encroachment into protected areas leads to the conversion of Prey Lang Forest, as well as large areas of the Eastern Plains, into plantations (see Figure 5.3). The assumed effective nature protection in this scenario moves plantation development outside of protected areas.

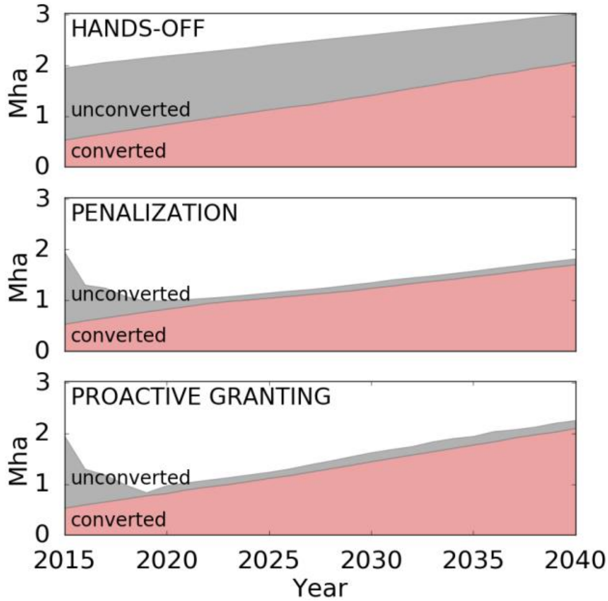

Figure 5.2: Evolution of vacant and used economic land concessions

5.3.3. Scenario impact assessment

5.3.3.1. Impact on tree cover

Table 5.3 shows the impacts in terms of tree cover. We present tree cover in three categories: (1) tree cover in LSLA systems, (2) tree cover in natural systems (deciduous and evergreen forest systems), and (3) tree cover in all other systems. The highest area of total tree cover is achieved under Penalization scenario (7.6 Mha), 0.4 Mha more than under the Hands-off scenario. The fraction within natural land systems differs more starkly. In the Proactive Granting scenario, 20% more tree cover area resides within natural systems as compared to the Hands-off scenario, and this difference increases to 26% under the Penalization scenario. Tree cover within LSLA systems is minimal under the Penalization scenario, where 50% less tree cover is in LSLA systems as compared to the Hands-off scenario.

Table 5.3: Tree cover (Mha) in 2015 and 2040 under three simulation scenarios broken down into three categories: (1) LSLA land systems, (2) natural land systems, which is evergreen and deciduous forest systems, and (3) all other land systems.

Situation / scenarios	Tree cover area included in different land systems			
	Natural systems (Mha)	LSLA systems (Mha)	Other systems (Mha)	Total (Mha)
2015	5.6	1.0	1.2	7.8
2040 - Hands-off	4.6	1.2	1.4	7.2
2040 - Penalization	5.8	0.6	1.2	7.6
2040 - Proactive Granting	5.5	0.8	1.1	7.4

5.3.3.2. Impact on core natural areas and tiger reintroduction potential

The three policies impact the core natural areas and the ensuing potential for a tiger reintroduction differently (Table 5.4 and Table 5.5). The Hands-off scenario results in a 19% loss of total natural area, and a 46% loss of core natural areas. The decline in average and median core patch size indicate that this scenario results in reduced extent and integrity of natural areas. The Penalization scenario results in the highest total natural area, but 74% of this natural area is situated at edges and 35% of core natural areas is lost. The Proactive Granting scenario limit core natural area loss to 19%, and average and medium patch sizes increase due to the loss of smaller, unprotected patches, leaving a smaller number of large core areas.

Table 5.4: Core, edge, and total natural (evergreen and deciduous forest systems) area (Mha)

Situation / scenario	Natural area				
	Core (Mha)	Edge (Mha)	Average core patch size (ha)	Median core patch size (ha)	Total (Mha)
2015	2.6	4.4	49394	1583	7.0
2040 - Hands-off	1.4	4.3	28513	980	5.7
2040 - Penalization	1.7	4.9	37375	1526	6.6
2040 - Proactive Granting	2.1	4.3	78542	4522	6.4

In 2015, there was sufficient core natural area for 956 tigers, spread over four potential areas. The Eastern Plains deciduous forest, which has been identified as the main candidate for tiger reintroduction (Launay et al., 2012), is the landscape with the highest tiger carrying capacity, supporting up to 481 tigers.

Our simulation results show that, while the total core natural area faces significant drops, the size of individual patches of core area declines even more rapidly, making many too small to be viable tiger landscapes (Figure 5.3; Table 5.5). In all scenarios, a few core natural areas remain able to support a tiger population. However, all scenarios have less suitable tiger habitat conditions then what is found in the year 2015, as a result of a net loss in natural land systems. The potential for reintroduction in the Eastern Plains disappears in the Hands-off scenario and significantly shrinks in the Penalization scenario, due to strong fragmentation (Figure 5.3).

Table 5.5: Tiger carrying capacity in potential tiger landscapes in 2015 and in 2040 under three alternative scenarios. Location of natural areas are given in .

Situation / scenarios	Tiger carrying capacity in core natural areas				
	Cardamom Forest	Prey Lang	Virachey Forest	Eastern Plains	Total
2015	265	95	115	481	956
2040 – Hands-off	203	0	107	0	310
2040 - Penalization	225	0	111	250	586
2040 - Proactive Granting	287	68	106	459	920

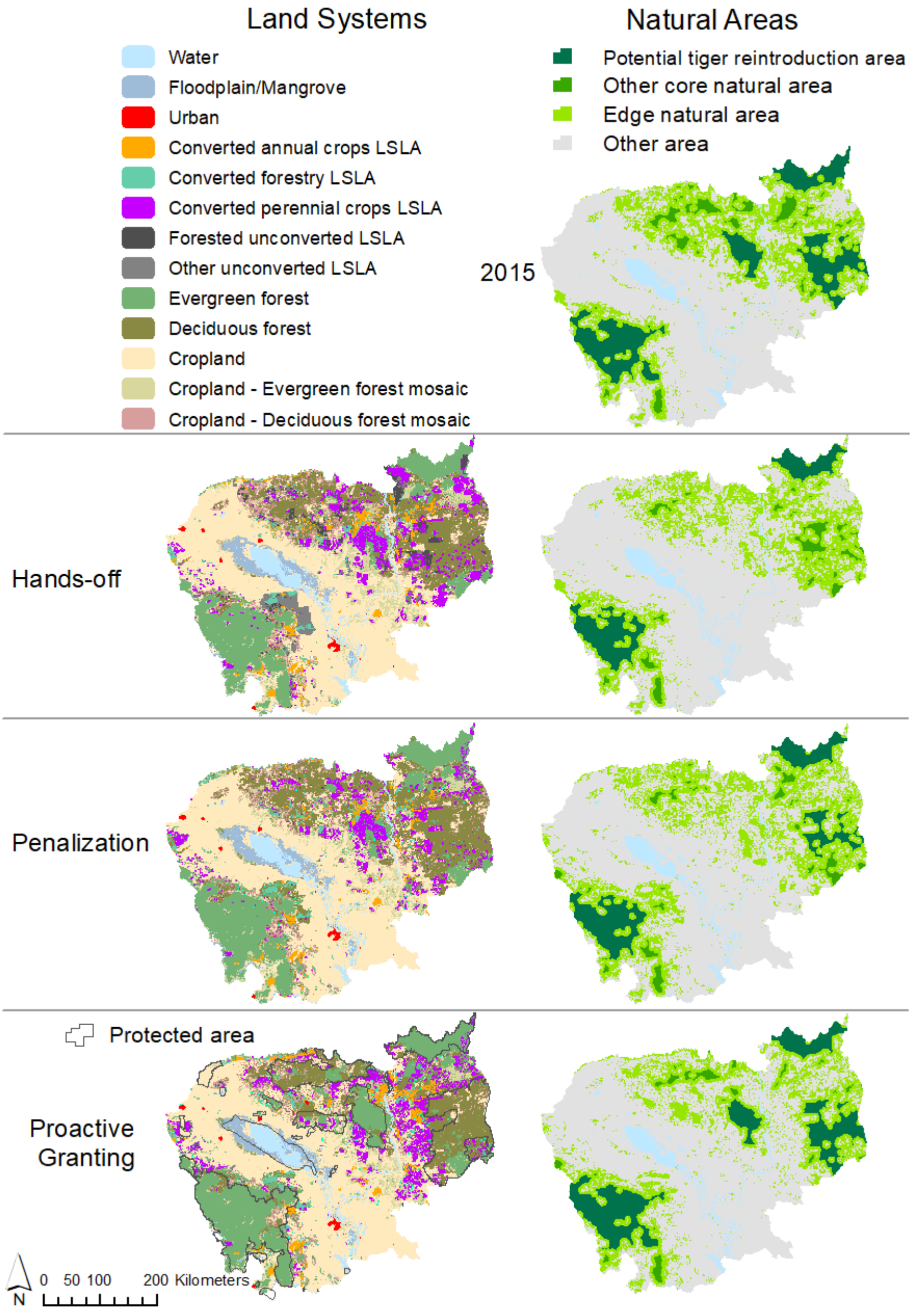

Figure 5.3: (left) Land system projections for 2040 in three scenarios. In the Proactive Granting scenario, the mapped protected areas are effective. (right) Impact on natural areas and tiger reintroduction candidate areas.

5.4. Discussion

5.4.1. Cambodian land systems in 2015

We present the first rigorous national-scale effort to estimate LSLA productive use. In 2015, 68% of mapped LSLA areas are not used productively. Üllenberg, (2009) reports 90% non-use in Cambodian land concessions in 2009, but no clarity is given on how this number was calculated. This underuse of LSLAs represents a major problem for Cambodian land governance. If the previous land users were small farmers it may mean that these farmers were evicted or live in a precarious land tenure situation. In other cases, LSLAs claim forested areas, which has been proven to form a high risk of deforestation even if they are not used productively (Davis et al., 2015). In 2015, 0.9 Mha of forest systems, 12% of all Cambodian forest areas, are therefore at higher risk of loss. Non-use is particularly problematic as it defeats the purpose of the Economic Land System policy, i.e. *"to use land more optimally"* (Oldenburg and Neef, 2014). If Cambodia anticipated positive economic effects to accrue from these investments, underuse may significantly scale back the expected benefits. The underuse problem is currently being addressed following the issuance of Order 01 in 2012, which, among others, aims to seize undeveloped parts of ELCs (Grimsditch and Schoenberger, 2015).

5.4.2. Scenarios of large-scale land governance

Our objective was to assess the potential conflict between Cambodian LSLA policies and its nature conservation ambitions, thereby confronting two disparate large-scale land claims. The policy options embedded in the presented scenarios do not constitute an exhaustive list of all policy interventions. Their storylines are designed to be contrasting in terms of policy approaches, thereby demarcating the option space for countries aiming to govern existing LSLAs and allocate new LSLAs. Each scenario is associated with several governance issues, which we briefly discuss here.

The policy option to neither penalize nor prevent LSLA underuse, captured in the Hands-off scenario, has been prevalent in many countries because it benefits elites and requires little state capacity. In a penalty-free playing field, land acquirers are inclined to clear-cut acquired land for valuable timber, or simply leave land vacant for its speculative future value (Grimsditch and Schoenberger, 2015). This often means that land acquirers can profit without investing in cultivation. However, a noninterventionist governance style may be hard to sustain as popular protest organizes and international pressure mounts. This is why many countries have had to curb the freedom with which LSLAs operate (Hall et al., 2015).

The Penalization scenario contains mechanisms to void contracts for the LSLA areas that have not been converted to productive use. This is indeed a policy on paper in many countries, including Cambodia since 2012 (Oldenburg and Neef, 2014). However, considerable difficulties can arise in the implementation of such a policy. Sunken costs and transaction costs are often too high. The state and judicial capacity to administer and judge disownments is frequently not in place (Burnod et al., 2013; Deininger and Byerlee, 2012). In Cambodia, as in many LSLA-targeted countries, domestic elites with a vested interest in maintaining a noninterventionist approach make a full-fledged interventionist LSLA governance unlikely (Beban and Gorman, 2015). Still, public protest, combined with oftentimes disappointing gains in e.g. employment and tax revenue from underused LSLAs can garner support for intervention and disownment on a case by case basis, as exemplified by Schoenberger, (2017).

The Proactive Granting scenario assumes that there is foreknowledge about future commodity demands. The implementation of Proactive Granting takes the form of sincere vetting of business plans prior to the allocation of land. Theoretically, Cambodia grants LSLAs using competitive solicited proposals which should guarantee that land is granted to the most capable investor. However, in reality this regulation may never have been applied (Oldenburg and Neef, 2014). Proactive Granting requires skilled state capacity, not hampered by conflicts of interest. Even if such capacity exists, the volatility of commodity markets will create uncertainties for the aspiring land owner as well as for the granting agency. The limitation imposed in the model, stating that only highly suitable land should be granted, will require agro-ecological knowledge. Furthermore, while our model assumes perfect protection of protected areas, the level of protection may range from ‘paper park’ to strict no-go zones (Ferraro et al., 2013). However, because of the rather low number of LSLAs, a ban of LSLAs in protected areas is likely relatively feasible by coordinating between responsible agencies. This step has been taken by the Cambodian government, as the Ministry of the Environment was ordered to cease granting LSLAs and is now coordinating with the Ministry of Agriculture to align their land policies (Souter et al., 2016).

In all scenarios, it is assumed that LSLAs will be present in the future, and new LSLAs will be granted (this is our point of departure). Scenario model results for Laos suggest that, if smallholders sufficiently diversify towards export commodity production, the country can meet both domestic and world market demands, making LSLAs superfluous (Debonne et al., 2018). This result is corroborated by historical analyses for Southeast Asia that situate LSLA as a trend-breaking phenomenon in a region characterized by a transition from plantations to smallholder systems since the end of the colonial times (Bissonnette and Koninck, 2017; Byerlee, 2014). Furthermore, the Penalization and Proactive Granting scenarios have redistributive mechanisms, as unconverted LSLAs are assumed to be reclaimed by either smallholder or natural land systems. However, LSLAs that have been converted to their intended use as a plantation are not assumed to be returned to smallholders or natural areas. Cancelling and redistributing all LSLAs is an interesting though experiment, but falls beyond our scope for a model-based approach.

5.4.3. Impacts of LSLA policy scenarios

Scenario results suggest that, if not penalized or prevented, LSLAs will be left underused. The majority of unconverted land in the Hands-off scenario (87%) has been unconverted since the beginning of the simulation in 2015. This is because of the relatively low suitability of these lands for any plantation agriculture, and in retrospect these areas should likely never have been granted. Penalization measures, to some extent active under Order 01 since 2014 (Grimsditch and Schoenberger, 2015), manage to minimize LSLA underuse until 2040 in our scenarios. However, while penalization of existing, unconverted LSLAs may return land to the land market, avoiding underuse altogether is preferable as this can abate negative impacts of LSLAs. The Proactive Granting scenario shows that when LSLAs are only granted if there is demand for the commodities they intent to produce, underuse can be avoided. By granting smaller LSLAs with higher minimum requirements in terms of suitability, non-use is further avoided.

The impacts on tree cover indicate that Penalization measures perform best to limit tree cover loss, saving 0.4 Mha more tree area then under Hands-off policies. This is partly because, in this scenario, commodity demands are lowered in response to LSLA revocations, ultimately easing the pressure on land in Cambodia. However, because we assume this demand will leak to other countries, these leakage effects may cancel out the tree cover savings in Cambodia (Lambin et al., 2014), making the result uncertain on a larger scale. Overall, tree cover losses remain limited because the yield increases by smallholders instigate a land sparing effect (Phalan et al., 2011). Furthermore, the tree cover loss from natural areas is partly compensated by tree cover gain within agricultural mosaics. However, this assumes that these mosaics are appropriately managed. Importantly, the Hands-off scenario not only results in the lowest tree cover, but the share of tree cover residing in (unconverted) LSLA land systems is highest in both absolute and relative terms. Davis et al. (2015) have found that Cambodian LSLA areas are characterized by accelerated deforestation, making our estimates of tree cover optimistic.

Changes in natural areas differs more strongly between scenarios. While a Penalization scenario results in more natural areas, these areas are more fragmented compared to Proactive Granting. This indicates that, while the penalization measures are able to maximize natural areas, the integrity of natural areas can only be preserved by effective protection measures. We found that, currently, a tiger reintroduction is feasible in terms of habitat, as has also been found by Gray et al., (2017). In addition, while all scenarios yield a possibility to accommodate tigers in 2040, the number of tigers that can be sustained in core natural areas ranges from 310 in the Hands-off scenario to 920 in the Proactive Granting scenario. Hence LSLA policies considerably affect the potential size of the tiger population and the chance of a successful reintroduction. This assessment of reintroduction potential is modest by design, and only evaluates habitat size and integrity. The Virachey, Eastern Plains, and Cardamom natural areas extend across the border, and therefore may host more tigers than estimated here. Oppositely, because we only mapped known LSLAs and did not include plantations outside of official LSLA areas, the tiger estimates may be too high. These biases are consistent across scenarios, making comparisons between scenarios valid. More detailed assessment frameworks, relying on landscape genetics (Thatte et al., 2018) or population viability analysis (Tian et al., 2011), can serve to fine-tune this assessment.

Lastly, while we did not assess social impacts of our scenarios, we note that such impacts exist and are significant (Dell'Angelo et al., 2017a). Cambodian LSLAs have been associated with brutal evictions (Schoenberger, 2017). Furthermore, LSLA can intensify competition over land resources and instigate loss of commonly used land is (Dell'Angelo et al., 2017b; Friis et al., 2016). Such consequences might be more dire under the Proactive Granting scenario, because LSLAs move outside of protected areas and into smallholder agricultural areas. This is another leakage effect (Meyfroidt and Lambin, 2009) that intensifies competition between smallholder and LSLA systems. Whether and to what extent such competition leads to dispossession and other undesirable social effects is dependent on a large number of factors and processes in the livelihood context of the target population (Oberlack et al., 2016). Because of the range of potential socioeconomic consequences, as well as the myriad of contextual factors that moderate the relation between our land use scenarios and their socioeconomic impacts (Messerli et al., 2015), these could not be quantified with sufficient certainty. Therefore, we focused our analyses on the landscape impacts only while acknowledging the importance of establishing further insight in the socioeconomic impacts.

5.4.4. Implications for land use policies

The connection made here between two largely disparate areas of governance (forest and wildlife conservation versus LSLA) showcases that integrated land management is needed to reconcile multiple large-scale claims on land. The goal to reintroduce tigers in Cambodia is jeopardized by LSLA development. While the reintroduction plan is specifically aimed at the Eastern Plains deciduous forests, there are three other viable candidate areas (Cardamom forest, Prey Lang Wildlife Sanctuary, and Virachey National Park). In the absence of protection measures, our scenarios show that Prey Lang is almost fully converted to plantations, and the Eastern Plains deciduous forests fragments to the point that the sustenance of a tiger population is unlikely. The Cardamom forest and Virachey National Park show a remarkable stability in the absence of protection, because these areas are not very suitable for commodity production. This in turn is caused by their poor accessibility, rough terrain and/or poor soil drainage. For protecting the other areas the current capacity of responsible agencies to enforce protection has been too low to be effective in the past, and the additional funding that is necessary for capacity building is not on the agenda (Souter et al., 2016). This leads to two options: (budget for) protection capacity could be significantly increased, as is also suggested by Launay et al., (2012). Alternatively, the Cardamom Forest and Virachey National Park could be the target areas for reintroduction of tigers instead of the Eastern Plains. These areas are less suitable for reintroduction at face value, because they consist of evergreen tropical forests which have a lower tiger carrying capacity. However, as a consequence of their agricultural unsuitability, they are more stable reintroduction zones in the longer term.

Habitat availability is only one factor contributing to the potential for tiger reintroduction. A sufficiently large habitat will still require enough prey animals, and will have to be protected from poaching and other threats (Gray et al., 2017). These factors are not included in our assessment, making the reported tiger carrying capacities theoretical upper limits. Our assumption that only core natural areas are suitable habitat may be contested by reports that tigers are observed to roam in sparsely populated areas (Thatte et al., 2018). However, human-tiger conflict is likely in Cambodia (Gray et al., 2017), making the restriction to core areas necessary for social acceptability.

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6. Synthesis

The objective pursued in this thesis is to develop concepts and methods to integrate new actors and scales of agriculture into land system science. The different chapters represent progress in identifying and representing new actors and scales, in comprehending their relative agency in environmental and developmental questions, and in their potential as transformative powers. Land system science serves as an integrative platform throughout this thesis. I identify three major new actor constellations in agriculture: LSLAs, MSFs, and VCC. I then address knowledge gaps concerning each of these actors with the aim to make progress on systems, target and transformation knowledge. Specifically, questions addressed are:

RQ1: What are the land system characteristics related to new agricultural actors?

RQ2: How can new agricultural actors, and associated scales of land system change, be integrated in land system models?

RQ3: What are the objectives of new actors in agriculture and how do these objectives align or misalign with environmental or rural development objectives?

RQ4: How do new actors and arrangements in agriculture provide opportunities for environmental management and rural development?

Each chapter of this thesis acts as a standalone research endeavor with chapter-specific questions. The following paragraphs in this synthesis highlight how the findings of these chapters represent progress in systems, target, and transformation knowledge domains. I reflect on how the work presented in this thesis builds and relates to the state-of-the art in each domain, and envision future research.

6.1. Systems knowledge proceedings

Systems knowledge concerns insights in the state, dynamics, drivers, and impacts of a land system dynamic. This thesis addresses two challenges to improve systems understanding concerning new actors and scales of agriculture. The primary challenge is to conceptually link the multitude of ongoing processes of agricultural change. A second challenge is to represent new actors in sufficient detail and extent, thus pushing the limits of what current (spatial) data and models can deliver. Together, the systems knowledge proceedings presented here contribute to the first two research questions of this thesis: to characterize new actors and scales of agriculture as land systems, and to integrate them into land system change models.

Concerning the first challenge, the search for a common denominator for the actors, I provide conceptual foundations to existing work that links LSLAs with other dynamics. This existing work is mostly empirical and is situated in the wake of the research rush on LSLAs. It finds other, similarly rapid dynamics occurring in rural landscapes across the globe. The pioneering studies on MSFs (Anseeuw et al., 2016; Jayne et al., 2016; Sitko and Jayne, 2014) all explicitly relate MSF dynamics to LSLA dynamics, stating that the former may combine to a more widespread and important process compared to the latter. VCC is similarly dialectically discussed in relation to LSLA, and is hypothesized by some to be a preferable alternative to LSLA (Cramb et al., 2016; De Schutter, 2011). In contrast with this line of thought, Derek Hall (2011) positions the boom-and-bust variant of VCC as complementary, not alternative to LSLAs, and argues that VCC can be a way to instrumentalize smallholders in predatory land control acquisitions. The work by Ruth Hall et al. (2017) evaluates the performance of LSLAs, MSFs, and VCC (respectively plantations, medium-scale commercial farming, and contract farming in their study), for the first time bringing all three dynamics together, yet without conceptually linking them explicitly.

The second challenge, to represent new actors in sufficient detail, concerns both the representation of the state of new actors (in datasets or land system maps) as well as their land system dynamics (in land system models). For MSF and VCC, the only indications of their location and extent are given in census interpretations (Jayne et al., 2016) or estimates (Otsuka et al., 2016). For these two actors, major efforts are still needed to categorize and conceptualize them, i.e. by documenting them in field surveys (e.g. Hakizimana et al. 2017; Bellemare and Lim 2018). For LSLA, datasets are more developed (Anseeuw et al., 2013), especially for specific countries (e.g. Open Development Cambodia 2016). Still, LSLAs are most often represented without spatial information, or using only point data (Eckert et al., 2016). They are not represented as land systems, which would imply a characterization of their land use/cover, socio-economic qualities, technology use, and more. Furthermore, despite their global significance as a force of land system change, most land system models do not account for them (Rounsevell et al., 2012; Verburg et al., 2019a) or do so at a local scale only (Hailegiorgis and Cioffi-Revilla, 2018).

Building on the state of the art, briefly outlined above, I address the first challenge by conceptually linking the processes of LSLA, MSF, and VCC. In Chapter 2, I propose that the concepts of agency and agency shifts tie together these processes.

Through this lens, we gain a more holistic view of agricultural dynamics. The chapter introduces this concept, and finds that LSLAs, MSFs, and VCC all represent, to varying extents, a relinquishment of agency from individual land managers and states to value chain actors. This agency shift is nearly complete in the case of LSLAs, where land control is almost fully transferred to the acquiring party leaving almost no agency for states or individuals. In the case of VCC, the extent of the agency shift depends on the type of contract, and in the case of MSFs, a narrow empirical basis provides mixed lessons.

Chapter 3 aims to broaden the empirical base for MSFs, and finds that these farms are indeed more likely to engage in non-local value chains, although this is not unique to this farm scale category, nor did I detect a particularly recent emergence of commercially-oriented MSFs. Chapter 4 represents LSLAs and smallholders as two possible policy pathways for Laos, both able to deliver goods to world markets but with very different direct and indirect land system consequences. This chapter builds on the idea of LSLAs and VCC as connected and, to a large extent, interchangeable strategies to engage with global markets. By pitting these two pathways against each other in a spatial model using scenarios, the environmental and societal trade-offs of specific policy pathways are made explicit.

To improve the representation of new actors and scales of land system maps and models (i.e. the second systems knowledge challenge), this thesis contains steps forward for each actor according to the knowledge gaps they face. For LSLAs, this implies a more nuanced representation of these mega-farms as land systems and a major effort to include their dynamics in national-scale land system models. For MSFs, I provide much-needed empirical data, and for both MSF and VCC, I scope the existing literature to find spatial patterns.

In Chapter 4, I innovate land systems modeling so that it can account for scale-differentiated land system dynamics. In this way, the non-incremental nature of LSLAs can be represented and simulated, alongside and in interaction with general incremental dynamics. It also inquires whether, for example, a rubber plantation system is characterized by the same spatial drivers as a rubber smallholder system, and finds this to be only partly so. In chapter 5, I innovate the representation of LSLAs as land systems by adding thematic cartographic detail. LSLAs are often represented primarily by their size, which disregards the fact that large areas incorporated in land deals remain unconverted (Deininger et al., 2011). By mapping converted and unconverted areas within land deals for Cambodia, we gain insight in the land use/cover within LSLAs. By embedding this newly-acquired knowledge in a land system model, I highlight that, if LSLAs are already detrimental to smallholders and the environment on a national scale (as Chapter 4 finds), a failure to mitigate non-conversion adds another issue to the problematic: an inefficient land use distribution which undermines biological conservation targets. Sophisticated remote sensing findings have since echoed these conclusions for Cambodia (Magliocca et al., 2019).

For MSFs, I contribute to the ongoing effort to broaden the empirical knowledge base (Chapter 3), but unlike previous case study work, I not only profile MSFs, but also contrast their characteristics with those of a representative sample of small farms and a panel of large farms. Chapter 3 corroborates findings of previous case study work in Sub-Saharan Africa to some extent, but also reveals that there is a wide variety of MSFs (and SSFs) which should not be overlooked. In Chapter 2, I aim to generalize the MSF dynamics, studied uniquely in Sub-Saharan Africa, with similar processes occurring worldwide, by scoping a wider range of literature on agricultural change. While each continent, and arguably each country and region, has its own peculiarities, I argue that land concentration in Latin America and farm scale enlargement in Europe have similar features.

For VCC, I address the general lack of a global overview of its occurrence by mapping the current state of literature on contract farming in Chapter 2. This exercise reveals the global nature of contract farming, and invites further inquiry into the diversity, drivers and impacts of contract farming and VCC.

The research into these agricultural changes is far from finished, and major gaps remain, particularly concerning MSFs and VCC. Both processes still suffer from definitional vagueness, calling for further reinforcements of conceptual fundamentals. My thesis calls into question the usefulness of MSF as a conceptual boundary object, noting that farm scale is a poor proxy for the entrepreneurial qualities often attached to the farm category. This does not mean that processes of commercialization, elite land capture or other non-incremental rural change do not occur outside of LSLAs. Indeed, such processes are well-described for Sub-Saharan Africa without reference to MSFs (e.g. "emergent farmers"; Sitko and Jayne 2014; "new customary tenure"; Chimhowu 2018). As future research builds more rigorous conceptualizations, I foresee that land system science will continue to play a valuable role in tracking and benchmarking these processes, to then assess drivers and impacts.

For VCC, I note that recent research has made progress to link the actions across value chains to damages to the environment (Laroche et al., 2020; Paitan and Verburg, 2019), and that our understanding of how land systems environmentally deteriorate once value chain actors engage with it has improved (Ornetsmüller et al., 2019). However, as my thesis touches upon, there are examples to be found of value chain actors improving land system sustainability. The contexts in which these positive impacts are manifested remain poorly understood.

For LSLAs, ever-increasing coverage of databases may allow for land system change studies similar to those presented here to be conducted in other countries and continents. Recent research is indeed combining findings from Cambodia, a particularly data-rich country with which my thesis engages, with similar empirical work in Ethiopia, Peru, and Liberia (Liao et al., 2020).

6.2. Target knowledge proceedings

Target knowledge concerns the agency, decision-making processes, and the distribution of benefits and negative consequences related to land systems. As stated above, agency shifts are what conceptually bind LSLA, MSF and VCC together (i.e. they all potentially represent a shift towards more value chain actor agency). The chapters of this thesis examine how this agency shift results in the emergence of new configurations in decision-making. This thesis addresses target knowledge in two ways: by modeling how LSLA policies counteract and undermine other land use policies, and by reflecting on the implications of agency shifts towards value chain actors for environmental policy making. These target knowledge proceedings address the third research question of this thesis: What are the objectives of new actors in agriculture and how do these objectives align or misalign with environmental or rural development objectives?

Concerning LSLAs, a major target knowledge gap identified at the onset of this thesis is the poor understanding of land governance conflicts at the national level. The sheer size of even an individual LSLA is large enough to make conflicts with other land use policy domains highly likely, but this is rarely acknowledged or prevented by host governments (Rudel and Meyfroidt, 2014), even though these governments are not powerless bystanders but rather active participants in most LSLA deals (Cotula, 2012; Wolford et al., 2013). This is especially remarkable given that a targeted land governance that allots LSLAs only to "unused", "idle" or "available" land has been a major justifying narrative in favor of LSLAs, used by land acquirers and host governments (Deininger et al., 2011). As suggested by Messerli et al. (2013), identifying who has the power to define what constitutes "idle" land, and how such decisions are made, is a key target knowledge question, with which this thesis engages.

Concerning the general agency shift instigated by the combined effects of LSLA, MSF and VCC, this thesis builds on work by, among others, Sikor et al. (2013), who describes how land governance is shifting from a territorial, governmental affair to a globalized value chain affair. I also root my contributions in research on corporate environmental sustainability (Dauvergne and Lister, 2012; Rueda et al., 2017). In Chapter 2, I argue that value chain actors increasingly make direct land management decisions. For VCC agreements, this power to decide is manifested in, for example, the prerequisites for entry into contracts, and the provision of agricultural inputs to farmers. LSLAs command a far larger power by exerting full control over land management, often unrestrained by effective regulations (The World Bank, 2014). To what extent this applies to MSFs as well remains unclear.

Chapter 5 shows the use of land system modeling to make key trade-offs in land governance pertaining to LSLAs tangible and spatially explicit. The chapter opposes two high-profile, large-scale land governance projects in a land system model for Cambodia: pro-LSLA policies and nature conservation policies (specifically to reintroduce tigers). Relative to Chapter 4, this model enhances target knowledge representation by adding the decision-making of LSLA managers. LSLA managers often decide not to fully convert their concession areas into plantations. The model in Chapter 5 captures this dynamic from the manager's perspective (responding to market demands and land suitability) and the governmental response to this issue (using scenarios of regulation).

I conclude that, as value chain actors gain importance in the direct decision-making concerning land management, this implies that land can increasingly be managed through agricultural value chains rather than through governmental policy making. This presents a number of threats, foremost the misalignment between value chain priorities and environmental or societal priorities. If left unmitigated, as is arguably the case in many LSLA instances, this raises a host of issues of environmental and social unsustainability (see Chapters 2, 4 and 5). On the other hand, value chain actors act globally, and, as Chapter 2 highlights, they have a uniquely powerful position to catalyze policies at a large scale. Environmental policy making should innovate to engage with these actors, by nurturing existing business cases for private environmental action and triggering motivators for such action. At the same time, private land governance, where value chain actors self-regulate, cannot suffice to enact sufficiently strong environmental policies. The case of Land Degradation Neutrality shows that, even if value chain actors are committed to environmental stewardship and use tools to avoid and reduce land degradation, they do not sufficiently possess the necessary tools to reverse land degradation. This implies that state actors should not be complacent towards the general trend of agency shifting, and may need to reassert their role as land policy enactors if they wish to pursue large-scale, ambitious environmental targets. These findings align with similar conclusions for the case of international climate change policy making, where Hickmann et al. (2019) similarly conclude that an increased engagement by international organizations with non-state actors is beneficial to the effectiveness of policy brokering.

Considering the importance of land systems to the attainment of many Sustainable Development Goals (Metternicht, 2018; Roe et al., 2018), a deeper understanding of the objectives and agency of all actors, and specifically value chain actors, will only become more important. Next steps in this line of work include more groundwork to gauge the objectives of value chain actors. Land system scientists have mostly projected objectives of actors based on their measurable actions, not on their expressed intentions. Research that considers the heterogeneous profiles, intentions, priorities and capabilities of new actors in more detail is still scarce (but see e.g. Schönweger and Messerli (2015) for coffee land acquisitions in Laos, or Neven et al. (2009) for Kenyan supermarkets). As we continue to paint a sharper picture of the objectives of new actors, these insights can be confronted with societal and environmental targets to find synergies and conflicts. A final outstanding issue is the practical implementation of the high-level policy recommendation in my thesis. Chapter 2 ends with the recommendation for international organizations such as the UNCCD to collaborate more closely with value chain actors. Research into environmental policy making can articulate how this can be done in practice in an effective way, without allowing for an overly privatized land governance. Similarly, where Chapter 5 reveals land use policy conflicts involving LSLAs and suggests governance options to better align conservation with LSLA in Cambodia. I acknowledge that such stylized scenarios may have an exploratory and normative role, but fail to do justice to the inherent complexity of policy making. Here, again, land system science can contribute by, among others, participatory modeling (Bourgoin et al., 2012), to make synergies and conflicts tangible and negotiable.

6.3. Transformation knowledge proceedings

Transformation knowledge concerns the identification of alternative pathways of land system change, and the search for leverage points to steer developments towards such alternative pathways. The transformation knowledge proceedings presented in this thesis aim to answer the last research question: How do new actors and arrangements in agriculture provide opportunities for environmentally management and rural development?

Land system science is increasingly engaging with transformations towards sustainability (Filatova et al., 2016; Meyfroidt et al., 2018; Müller et al., 2014), studying transformations either in retrospect or as scenarios (Ramankutty and Coomes, 2016).

This thesis provides two lines of research concerning transformation knowledge: first, I reflect on possibilities to leverage increased value chain agency over land management decision-making towards sustainability (Chapter 2). The chapter shows the various tools that value chain actors are able to deploy with their increasing agency, categorized as either carrots (incentives towards adherence), sticks (punishments for non-adherence) and sermons (building capacity, raising awareness, etc.). While I provide examples of the use of these tools to avoid, reduce, and reverse land degradation, I note the lack of demonstrable impact quantification, as is also remarked by Defries et al. (2017). Furthermore, I note that the effectiveness of value chain actors to act in the interest of sustainability hinges heavily on their motivation (financially or intrinsically) to do so. Transformative change driven by value chain actors will depend on the weight of sustainability in corporate decision-making, and the possibility to act without undermining a company's competitive position. While specific companies are found to pioneer in this regard, it should be noted that, in the case of LSLAs specifically, I find that, even if their proliferation implies more agency for value chain actors, this power is not combined with a broad-scale interest to take up environmental responsibilities, as short-term interest appear to consistently trump notions of stewardship (see also The World Bank 2014). I conclude that, going forward, a sustainability transformation may be achieved by value chain actors operating in tandem with re-empowered governmental actors (similarly stated by Lambin et al. 2014).

Second, I represent the specific transformative power of LSLAs in the scenarios developed for land system change models. Both Chapter 4 and 5 demonstrate that, because of their sheer size, policies concerning LSLAs have far-reaching, transformational consequences. The model for Laos finds that a moratorium on new LSLAs going forward could result in a smallholder transition to cash crops and rubber. This corroborates the hypothesis that, at national-to-global scales, LSLAs foreclose smallholder transitions and could reinforce a lock-in effect of subsistence agriculture (Jayne et al., 2014b). This model is the first to explore this hypothesis with spatiotemporally explicit simulations. Chapter 5 goes further by presenting innovative scenarios. LSLAs have been justified and even branded as being of limited harm, because they would target idle land without competing with other land-based demands. The model scenarios in Chapter 5 make clear how proactive and interventionist a government needs to be to transform LSLAs to the least-damage pathway they presented themselves to be. In order to accommodate tiger sanctuaries and preserve tree cover, the Cambodia government would need to actively regulate LSLAs and proactively balance land concessions with commodity demands, while maintaining a zero-tolerance policy on encroachment into protected areas. Even this would still risk the foreclosure effect identified in Chapter 4. By highlighting these policy challenges, chapters 4 and 5 question the possibility of an LSLA pathway to yield environmentally and developmentally sustainable benefits, and substantiate the claim by De Schutter (2011) that LSLAs are unlikely to be an optimal pathway compared to smallholder-driven development. The scenarios and their outcomes are not intended as predictive estimates of land system change, but rather as a concretization of normative imaginations of transformation. Normative perspectives in land system science are increasingly call for (Nielsen et al., 2019; Rounsevell et al., 2012), and by confronting relatively extreme policy scenarios, the potential for transformation towards sustainability is made tangible.

6.4. Concluding remarks

Land system science is an evolving field, and covers a wide range of methodological (Verburg et al., 2015) and conceptual (Meyfroidt et al., 2018) approaches. This thesis uses several of these tools to approach new actors and scales: methodologically, I use field surveys, remote sensing, meta-analysis, scenario-building and modeling to gain a better understanding of new actors and scales. Conceptually, I bring together perspectives from the fields of, among others, land use change, nature conservation, sustainable land management, and livelihood sustainability. This use of land system science as an integrative, multi-method platform runs like a thread throughout the thesis and constitutes its main academic contribution. By containing inquiries at the global, national, and local scale, and by approaching new actors and scales with a wide range of perspectives and methodologies, I have contributed to integrate new actors and scales of agriculture into land system science, thus presenting a step forward towards the objective of this thesis. The insights, datasets and modeling tools that are the product of this work can feed into future land system science research in a myriad of ways: The framing of new actors and agency shifts can give conceptual foundations to future research, data produced in this thesis, such as survey data and land system maps, can be taken up for further analysis, and the scale-differentiated land system models are certain to find applications in other domains of land system modeling.

While the objective of this thesis lends itself primarily to academic applications, the thesis can present some modest but important societal relevance and usefulness as well. The understanding that land management, as a decision-making process, is increasingly being dominated by value chain actors, is of particular use to policy makers aiming to enact sustainable land management or leverage land management in the fight against climate change. Insights from this thesis concerning the threats and opportunities of the agency shift have been integrated in the IPCC Special Report on Land and especially in the UNCCD Science-Policy Interface report on land governance, to which I contributed (Arneth et al., 2019; Verburg et al., 2019b). Furthermore, while the land system models of Chapters 4 and 5 are not a suitable standalone communication or planning tool for policy makers, their use in moderated workshops in Laos and Cambodia demonstrated their potential as an integrative land use planning tool for groups of experts. Beyond their technical use, these models and the insights they produce confront society with the finite nature of land, and therefore the finite option space in land use planning. In a rapidly changing world where demands on land and the stakeholders involved are increasingly diverse, my thesis invites contemplation on the land futures we desire.

7. References

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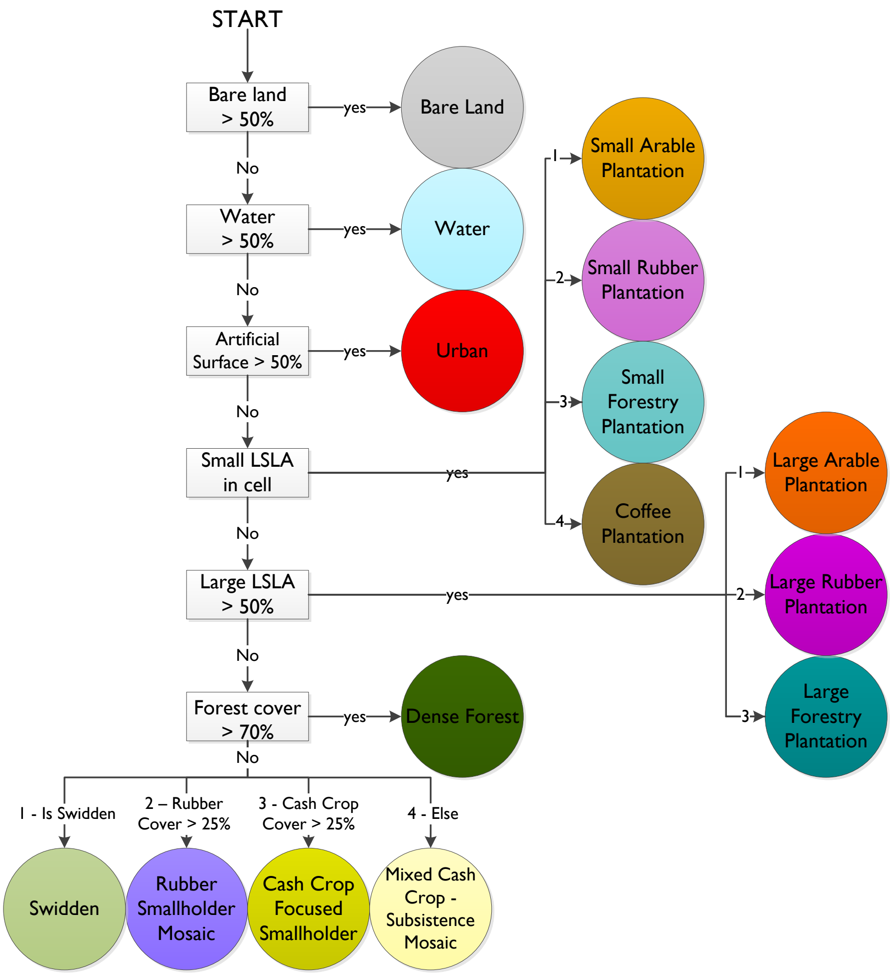
Appendix A

Appendix A-1: Land system classification input data sources

Parameter	Source	Spatial resolution	Time
Land Cover – Bare land, Water, Urban, Tree Cover	)	Polygons	2010 / 2002
Large-scale land acquisitions	)	Points / polygons	Updated until 2015
Upland Rice Ratio	Agricultural census 2010/11	Village	2011
Rubber area fractions	Agricultural census 2010/11	Village	2011
Cash crops area fractions	Agricultural census 2010/11	Village	2011

Appendix A-2: Land system classification decision tree. Numbers indicate priorities (e.g. a cell is first checked for swidden, then for rubber smallholder mosaic, etc.)



Appendix A-3: Smallholder agriculture classification

In the land system classification decision tree, a cash crop focused smallholder system is defined as a cell where the fraction of the area that is covered by cash crops is larger than 25%. For this purpose, the sum of area fractions as reported in the Lao Agricultural Census 2010 for the following crops is calculated.

Coffee	Banana	Mango	Cassava
Tea	Cashew	Pineapple	Sugar cane
Cabbage	Durian	Plum	"Other fruits"
Cucumber	Lemon	Tamarind	
Avocado	Longan	Sweet corn	

Similarly, smallholder areas where rubber covers over 25% of the area are classified as rubber – permanent smallholder mosaic. For swidden, we reclassified the land system map by . This map represents a number of swidden systems with differing intensities and forest cover, which we reclassified to a single swidden system.

Appendix A-4: Land system service calculations

For all 15 land systems, the provision of each of five land system services (wood, rubber, cash crops, subsistence crops and urban area) was quantified. These services remain constant in all scenarios, whereas the LSLA service is scenario-dependent. Exception to this is the wood service in the Moratorium scenario which is kept constant, because smallholders cannot substitute as a supplier in our application.

In a first step, area breakdowns of land covers per land system were empirically established. In the cases of urban, water, dense forest and bare land, it was assumed that these land systems are covered 100% by their respective land covers. The same assumption was used for all large plantation systems. For small plantation systems (including coffee plantations), overlay analysis using the actual polygons of the plantation and the plantation land system cells was performed to determine the average area percentage of LSLAs within LSLA land system cells. Similarly, the area dedicated to cash crops by smallholders was quantified by overlaying the agricultural census (GoL, 2011) with the land system raster. The same operation was used to calculate average tree cover of land systems, using the national land cover map (GoL 2010). Subsistence crops were calculated as the remainder area for each land system.

For LSLA in Laos, it is known that the granted area (the polygons used in this study) is often much larger than the allocated area, which is again larger than the developed area. An inventory for two Lao provinces indicates that current LSLAs use only 49%

(Luang Prabang) and 12% (Xiengkhouang) of their granted area (Hett 2015). Expansion beyond the granted area also occurs but is much more rare. As there are no nationwide statistics, we quantified productive use for LSLAs by overlaying a forest map (GoL, 2010) with arable plantation polygons. This way we established that, for small arable plantations, on average 18% of the granted area is covered with trees and therefore not used productively. For large arable plantations, 45% is similarly not used productively. As the same method cannot be used for rubber, coffee or wood plantations, as the land cover map records these land uses as tree cover, we used the same number for all small and large plantations respectively, where coffee plantations are considered small plantations.

Next, typical yields were used calculate the average services output per land system. These yields are assumed to be constant across all cells belonging to the same system.

Service	Quantity	Provided by	Source and procedure
Cash crops	4.31 ton.ha^{-1}yr^{-1} (smallholders) 5.75 ton.ha^{-1}yr^{-1} (plantations)	All smallholder systems, Arable plantations, Coffee plantations	Area-weighted average for the main cash crops: permanent crops (excl. rubber), maize, sugar cane, cassava and paddy rice. Paddy rice weight adapted to count only 20% as cash crop. Yield figures obtained from (FAO 2017). Lower yield for smallholder reflect presumed lower access to inputs and technology.
Rubber	1100 kg.ha^{-1}.yr^{-1} (smallholders) 1300 kg.ha^{-1}.yr^{-1} (plantations)	Rubber plantations, Rubber permanent smallholder mosaic	Typical values from Manivong & Cramb (2008). Higher yields for LSLAs reflect presumed better technology.
Wood	5 m^3.ha^{-1}.yr^{-1}	Forestry plantations	Typical mean annual increment yield value for Laos for eucalyptus from (FAO 2016)
Sub-sistence crops	2.6 ton.ha^{-1}.yr^{-1}	All smallholder systems, All small plantations, Coffee plantations	Weighted average of 1.7 ton.ha^{-1}yr^{-1} (typical for low-input upland rice, Saito et al., 2006) and 3.59 ton.ha^{-1}yr^{-1} (paddy rice, FAO 2017)
Urban	400 ha per cell	Urban	Cell is fully used for urban

Appendix A-5: Logistic regression

Num	Variable	Abb-reviation	Original resolution	Source	Procedure
1	Elevation (m)	Elev.	90 m	SRTM#	Aggregated to 2000m
2	Slope (Degrees)	Slope	90 m	*Own processing*	Calculated from Elevation Aggregated to 2000m
3	Terrain Ruggedness Index (m/m)	TRI	90 m	*Own processing*	Calculated using GDAL from Elevation Aggregated to 2000m
4	Annual Precipitation (mm)	P_{annual}	30 arcsec	worldclim.org*	Aggregated to 2000m
5	Mean temperature	T_{annual}	30 arcsec	worldclim.org*	Aggregated to 2000m
6	Precipitation in the driest month	$P_{DriestMonth}$	30 arcsec	worldclim.org*	Aggregated to 2000m
7	Minimum temperature in the coldest month	$T_{ColdestMonth}$	30 arcsec	worldclim.org*	Aggregated to 2000m
8	Maximum temperature in the warmest month	$T_{WarmestMonth}$	30 arcsec	worldclim.org*	Aggregated to 2000m
9	Available water storage capacity (mm/m)	AWC	Region-dependent	Harmonized World Soil Database†	Resampled to 2000m
10	Soil drainage (5 classes)	/	Region-dependent	Harmonized World Soil Database†	Resampled to 2000m
11	Topsoil gravel content (%)	Topsoil gravel	Region-dependent	Harmonized World Harmonized World Soil Database†	Resampled to 2000m
12	Topsoil sand content (%)	Topsoil sand	Region-dependent	Harmonized World Soil Database†	Resampled to 2000m
13	Topsoil silt content (%)	Topsoil silt	Region-dependent	Harmonized World Soil Database†	Resampled to 2000m
14	Topsoil clay content (%)	Topsoil clay	Region-dependent	Harmonized World Soil Database†	Resampled to 2000m
15	Subsoil gravel content (%)	Subsoil gravel	Region-dependent	Harmonized World Soil Database†	Resampled to 2000m
16	Subsoil sand content (%)	Subsoil sand	Region-dependent	Harmonized World Soil Database†	Resampled to 2000m

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17	Subsoil silt content (%)	Subsoil silt	Region-dependent	Harmonized World Soil Database†	Resampled to 2000m
18	Subsoil clay content (%)	Subsoil clay	Region-dependent	Harmonized World Soil Database†	Resampled to 2000m
19	Ethno-linguistic family (4 families)	/	Village	Population census 2005 (GoL 2005)	Resampled to 2000m
20	General accessibility (travel time to village centers, hours)	Gen. Accessibility	50m	Centre for Development and Environment, Bern	Aggregated to 2000m
21	Domestic market accessibility (travel time to district capitals, hours)	Dom. Accessibility	50m	Centre for Development and Environment, Bern	Aggregated to 2000m
22	International market accessibility (travel time to district border crossings, airports, province capital, hours)	Int. Accessibility	50m	Centre for Development and Environment, Bern	Aggregated to 2000m
23	Population density	PopDens	Village	Population census 2005 (GoL 2005)	Resampled to 2000m
24	Distance to the Chinese border (km)	Dist. to China	2000m	*Own processing*	
25	Distance to the Lao country border	Dist. to border	2000m	*Own processing*	
26	River flood hazard (cm of flood with 100 year return interval)	/	1000m	Global Risk Data Platform (UNEP, 2016)	Aggregated to 2000m
27	High landslide hazard	/	0.5 arcmin	Global Risk Data Platform (UNEP, 2016)	
28	US bomb dropping density	US Bomb	Point data	US Department of Defense records‡	Heath map at 2000m resolution

USGS (2004)

*Fick and Hijmans (2017)

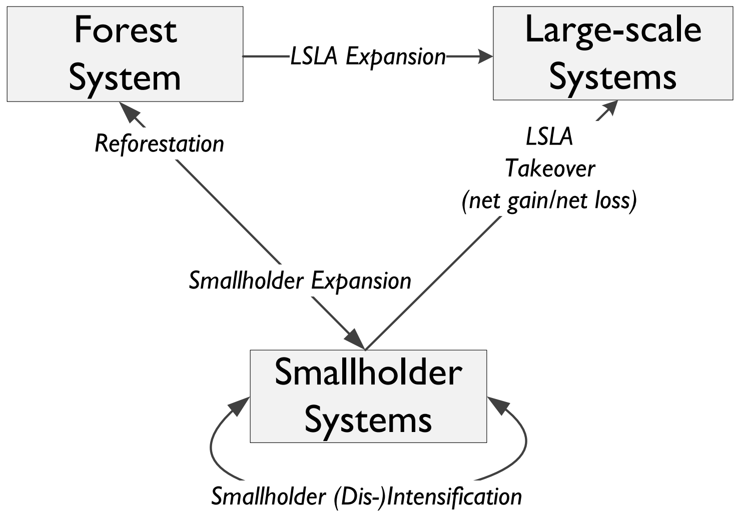
†Nachtergaele et al. (2009)

‡Available at https://mangomap.com/blog/delving-into-us-bombing-data-1965-1975/

Land System	Contributing factors	AUC
Urban	Gen. Access (+)	0.993
Small Arable Plantation	Dom. Access (+); P_{annual} (+); River flood hazard (-)	0.839
Small Rubber Plantation	Dom. Access (+); T_{annual} (+); $P_{DriestMonth}$ (+); Dist. to	0.839
Small Forestry Plantation	Dom. Access (+); Topsoil gravel (+); Dist. to border	0.829
Large Arable Plantation	River flood hazard* (-); Slope* (-)	0.963
Large Rubber Plantation	Int. Access* (+); AWC* (+); Lao-Tai* (-);	0.811
Large Forestry Plantation	Int. Access* (+); T_{Annual}* (+); P_{Annual}* (+); Poorly	0.749
Dense Forest	Gen. Access (-); PopDens (-); Lao-Tai (+)	0.704
Swidden	Gen. Access (+); P_{Annual} (-); Lao-Tai (-); Slope (+);	0.752
Rubber Smallholder Mosaic	Dom. Access (+); P_{Annual} (+); Dist. to China (-)	0.900
Cash Crop -Focused	Gen. Access (+); T_{Annual} (-); P_{Annual} (+); Topsoil clay	0.730
Mixed Cash Crop -	Gen. Access (+); Lao-Tai (+); Population Density	0.686

*Average of 3x3 cell neighborhood

Appendix A-6: Model parameters: Processes through which changes in demand for cash crops or rubber are resolved in the CLUMondo application. Arrows indicate processes that are allowed in the application, while other processes being restricted in our model. See main text for a description of each of these processes.



The Allowed land systems changes matrix sets which land system changes are allowed (indicated by a Boolean 0 or1). The 102 in the reforestation column indicates that this change is allowed after at least 2 years. More information can be found in CLUMondo documentations at www.environmentalgeography.nl.

FROM \ TO	Water	Urban land	Small Arable Plantation	Small Rubber Plantation	Small Wood Plantation	Large Arable Plantation	Large Rubber Plantation	Large Wood Plantation	Coffee Plantation	Dense Forest	swidden	Rubber Permanent Smallholder Mosaic	Cash Crop-Focussed Smallholder	Mixed Cash Crop - Subsistence Mosaic	Bare Land
Water	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urban land	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Arable Plantation	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Small Rubber Plantation	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Small Forestry Plantation	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Large Arable Plantation	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Large Rubber Plantation	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Large Forestry Plantation	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Coffee Plantation	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Dense Forest	0	1	1	1	1	1	1	1	0	1	1	1	1	1	0
Swidden	0	1	1	1	1	1	1	1	0	102	1	1	1	1	0
Rubber Permanent Smallholder	0	1	1	1	0	1	1	0	0	102	0	1	1	1	0
Cash Crop-Focussed Smallholder	0	1	1	1	0	1	1	0	0	102	0	1	1	1	0
Mixed Cash Crop - Subsistence	0	1	1	1	0	1	1	0	0	102	0	1	1	1	0
Bare Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

The Conversion order matrix. indicates the relative competitive advantages of land systems to provide land system services. Increasing numbers indicate higher competitive advantage. A 01 indicates that the land system is not considered when increasing or decreasing total supply to meet demands. The LSLA service is not used in the Moratorium scenario.

Land system	**Export Wood**	**Export Arable**	**Rubber**	**Subsistence Crops**	**Urban Land**	**LSLA**
Water	-1	-1	-1	-1	-1	-1
Urban land	-1	-1	-1	-1	1	-1
Small Arable Plantation	-1	1	-1	-1	-1	1
Small Rubber Plantation	-1	-1	1	-1	-1	1
Small Forestry Plantation	1	-1	-1	-1	-1	1
Large Arable Plantation	-1	2	-1	-1	-1	1
Large Rubber Plantation	-1	-1	2	-1	-1	1
Large Forestry Plantation	2	-1	-1	-1	-1	1
Coffee Plantation	-1	-1	-1	-1	-1	-1
Dense Forest	0	0	0	0	0	0
Swidden	0	0	0	2	0	0
Rubber Smallholder Mosaic	0	0	2	0	0	0
Cash Crop Focussed Smallholder	0	2	0	0	0	0
Mixed Cash Crop - Subsistence Mosaic	0	1	0	1	0	0
Bare Land	-1	-1	-1	-1	-1	-1

The Conversion resistance table indicates the resistance a land system has to changing into a different land system.

Land System	Conversion resistance
Water	1
Urban land	1
Small Arable Plantation	0.8
Small Rubber Plantation	0.8
Small Wood Plantation	0.8
Large Arable Plantation	0.9
Large Rubber Plantation	0.9
Large Wood Plantation	0.9
Coffee Plantation	1
Dense Forest	0.4
Swidden	0.3
Rubber Smallholder Mosaic	0.7
Cash crop-Focussed Smallholder	0.7
Mixed Cash Crop - Subsistence Mosaic	0.5
Bare Land	1

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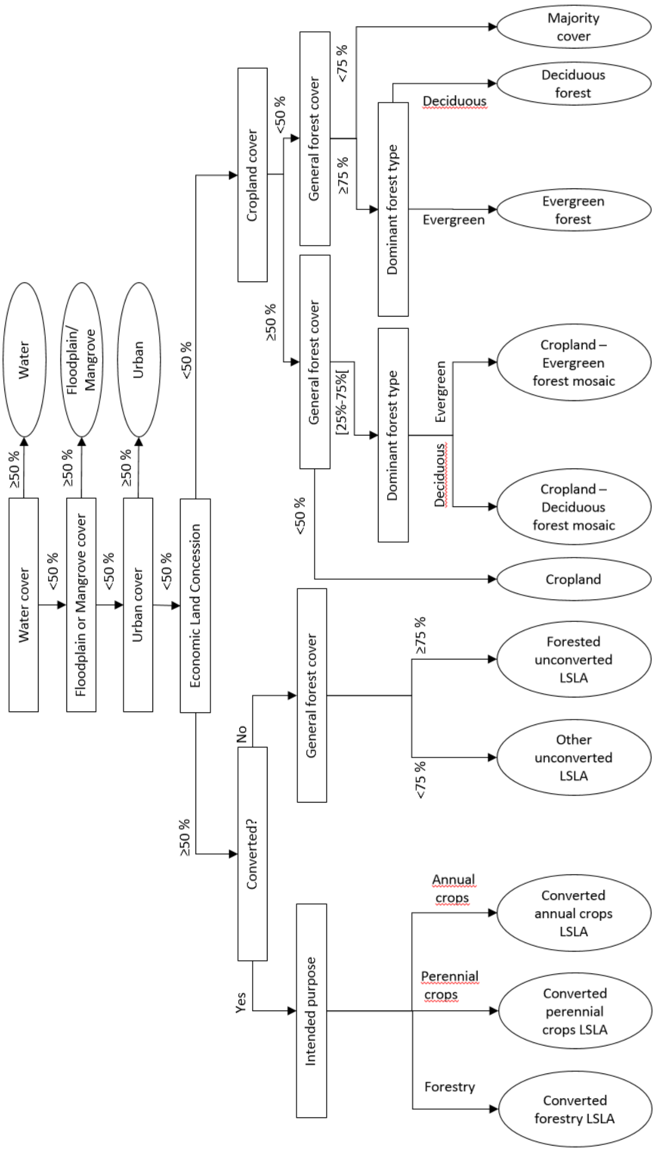
Appendix B

Appendix B-1: Decision tree for land Cambodia land systems classification



Appendix B-2: Land system classification procedure

The input data for the land system classification are as follows:

Input data	Source	Format
Water	(Open Development Cambodia, 2016a)	Landsat land cover classification for 2014 at 30m resolution
Floodplain/Mangrove cover Urban Forest cover* Cropland cover**	(Miettinen et al., 2016)	Land cover classification at 250m resolution
Economic land concession: granted area	(Open Development Cambodia, 2016b)	Polygon delineations of Economic Land Concessions
Economic Land Concession: used area	Author's own mapping based on interpretation of Landsat time series and Google Earth imagery. See SI-1C	Polygon delineations of ELCs in use as plantations

* General forest cover calculated following tree cover densities in various forest types reported in Miettinen et al., (2016), as follows:

```
General Forest Cover = Lowland Evergreen + Lower Montane Evergreen + Upper Montane Evergreen + 0.6 x Regrowth + 0.25 x Lowland Mosaic + 0.25 x Montane Mosaic + Lowland Deciduous + Lower Montane Deciduous
```

** Cropland cover calculated following cropland fractions reported in Miettinen et al., (2016), as follows:

```
0.92 x Lowland open + 0.77 x Lowland mosaic + 0.40 x Regrowth + 0.64 x Montane mosaic + 0.73 x Montane open
```

First, all inputs are represented in a raster with a resolution of 1000m, using resampling and rasterization operations. These rasters represent the fraction within each cell that is covered with the land cover/use it represents (e.g. the water raster represent fraction water cover in each 100ha cell.

Then, the decision tree is implemented using a series of conditionals on each raster cell.

Appendix B-3: Modelling future land system changes

Land systems produce a defined quantity of land system commodities, services, and effects. We assume land system productivity is equal in all cells of the same land system (e.g. all cropland – evergreen mosaic cells produce the same amounts of commodities). The commodities produced by a pixel of a specific type depend on the land cover composition. We combined these compositions with typical yields for the specific commodities, derived from World Bank (2015). We assume that used LSLA areas are monocultures and therefore only produce their intended crop type. The resulting productivity numbers are given below.

Cambodian farmers have a large potential to increase yields, so our model assumes yields to increase yearly in smallholder systems. The extent to which yields are assumed to increase are quantified using expert estimates. This procedure is detailed below. We furthermore assume that used LSLA systems have already closed these yield gaps, given their access to capital and technology (Deininger and Byerlee, 2012).

The projection of future demand for commodities and services builds on existing projections by the World Bank and the United Nations, and is detailed below. We project continued growth in demand for commodities and a high urbanization rate.

Land system production of goods and services:

Nr.	land system	Annual cash crops (units)	Timber (units)	Perennial crops (units)	Rice (tons)	Urban (ha)	LSLA
0	Water	0	0	0	0	0	0
1	Floodplain / Mangrove	0	0	0	0	0	0
2	Urban	0	0	0	0	100	0
3	Converted annual crops LSLA	158	0	0	0	0	0
4	Converted forestry LSLA	0	100	0	0	0	0
5	Converted perennial crops LSLA	0	0	114	0	0	0
6	New forested LSLA	0	0	0	0	0	1
7	New Other LSLA	0	0	0	0	0	1
8	Forested unconverted LSLA	0	0	0	0	0	0
9	Other unconverted LSLA	0	0	0	0	0	0
10	Evergreen Forest	0	0	0	0	0	0
11	Decidious forest	0	0	0	0	0	0
12	Cropland	10	1	6	153	0	0
13	Cropland - evergreen forest mosaic	5	1	3	75	0	0
14	Cropland - deciduous forest mosaic	6	1	4	100	0	0

Projection of future yields by smallholders:

Projection of smallholder yield. We assume yields of smallholders will increase linearly every year, thus partially closing existing yield gaps. The following assumptions are operational:

Commodity	Yield increase 2015 – 2040	Source and assumption
Rice	30%	Estimation by the World Bank (2015) based on comparison with comparable rice varieties in neighboring countries
Annual cash crops	58%	Closure to 75% of the attainable yield of sugar cane, soy, cassava, and maize according to (Mueller et al., 2012).
Perennial cash crops	14%	Rubber yield increase from 1137 ton/ha (World Bank, 2015) to 1300 ton/ha (Manivong and Cramb, 2008)
Timber	0%	Assumption

Projection of future demand for land system commodities and services:

The following assumptions are operational concerning future demand for commodities and services. Demands for annual cash crops, perennial cash crops and timber can deviate in scenario 2 (Penalization), where the cancellation of non-used LSLA areas results in a decrease of commodity demand due to leakage effects.

Commodity	Demand increase 2015 – 2040	Source and assumption
Rice	41%	we combined growth figures from the OECD-FAO Rice Projection (OECD/FAO, 2017) between 2015 and 2026, and Alexandratos and Bruinsma (2012), between 2031 and 2040. We interpolated the gap period between 2026 and 2031, which is not covered by these projections.
Annual cash crops	100%	Extrapolation of a 2013-2030 World Bank projection of cassava, maize, and vegetables to 2040 (World Bank, 2015)
Perennial cash crops	152%	Linear extrapolation of 2002-2015 rubber production figures (World Bank, 2015). Rubber production has boomed in the past decade (Ahrends et al., 2015), making any projection highly speculative. However, given the high amount of immature rubber plantations (World Bank, 2015) and the high potential for palm oil expansion (Colchester et al., 2011), we believe that linear extrapolation of the high past growth trends is a justifiable estimation.
Timber	100%	Assumption
Urban	97%	Projections made by the United Nations Department of Economic and Social Affairs (2014).
LSLA	Scenario-dependent	

Conversion resistance of land systems:

The conversion resistance parameter quantifies the difficulty to change an existing land system cell into another land system.

Nr.	Land System	resistance
0	Water	1
1	Floodplain	1
2	Urban	1
3	Used annual crops LSLA	0.9
4	Used forestry LSLA	0.9
5	Used perennial crops LSLA	0.9
6	New forestedLSLA	0
7	New other LSLA	0
8	Forested unconverted LSLA	0.4
9	Other unconverted LSLA	0.4
10	Evergreen forest	0.5
11	Decidious forest	0.5
12	Cropland	0.7
13	Cropland - Evergreen forest mosaic	0.7
14	Cropland - Deciduous forest mosaic	0.7

Allowed conversions:

Allowed land system conversions are indicated with “1”. Non-allowed conversions are indicated with “0”. “-10x” indicates that a land system may only exist for x years. “10x” indicates that the conversion is allowed only if the land system has been present for x years.

	Hands-off	0 Water	1 Floodplain	2 Urban	3 Converted annual crops LSLA	4 Converted forestry LSLA	5 Converted perennial crops LSLA	6 New forested LSLA	7 New other LSLA	8 Forested unconverted LSLA	9 Other unconverted LSLA	10 Evergreen forest	11 Decidious forest	12 Cropland	13 Cropland - Evergreen forest	14 Cropland - Deciduous forest
	0 Water	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1 Floodplain	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	2 Urban	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	3 Converted annual crops LSLA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	4 Converted forestry LSLA	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	5 Converted perennial crops LSLA	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	6 New forested LSLA	0	0	0	1	1	1	-101	0	1	0	0	0	0	0	0
FROM	7 New other LSLA	0	0	0	1	1	1	0	-101	0	1	0	0	0	0	0
	8 Forested unconverted LSLA	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0
	9 Other unconverted LSLA	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0
	10 Evergreen forest	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0
	11 Decidious forest	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1
	12 Cropland	0	0	1	0	0	0	0	1	0	0	102	102	1	1	1
	13 Cropland - Evergreen forest mosaic	0	0	1	0	0	0	0	1	0	0	102	0	1	1	0
	14 Cropland - Deciduous forest mosaic	0	0	1	0	0	0	0	1	0	0	0	102	1	0	1

Hands-off

	Penalization	0 Water	1 Floodplain	2 Urban	3 Converted annual crops LSLA	4 Converted forestry LSLA	5 Converted perennial crops LSLA	6 New forested LSLA	7 New other LSLA	8 Forested unconverted LSLA	9 Other unconverted LSLA	10 Evergreen forest	11 Decidious forest	12 Cropland	13 Cropland - Evergreen forest mosaic	14 Cropland - Deciduous forest mosaic
	0 Water	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1 Floodplain	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	2 Urban	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	3 Converted annual crops LSLA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	4 Converted forestry LSLA	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	5 Converted perennial crops LSLA	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
FROM	6 New forested LSLA	0	0	0	1	1	1	-101	0	1	0	52	53	1	52	53
	7 New other LSLA	0	0	0	1	1	1	0	-101	0	1	102	102	1	52	53
	8 Forested unconverted LSLA	0	0	0	1	1	1	0	0	-103	0	52	53	1	52	53
	9 Other unconverted LSLA	0	0	0	1	1	1	0	0	0	-103	102	102	1	52	53
	10 Evergreen forest	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0
	11 Decidious forest	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1
	12 Cropland	0	0	1	0	0	0	0	1	0	0	102	102	1	1	1
	13 Cropland - Evergreen forest mosaic	0	0	1	0	0	0	0	1	0	0	102	0	1	1	0
	14 Cropland - Deciduous forest mosaic	0	0	1	0	0	0	0	1	0	0	0	102	1	0	1

Penalization and Proactive Granting

Neighborhood Effects:

We use the CLUMondo neighborhood effects algorithm to make the transition potential of certain land systems higher or lower when they are in the vicinity of certain influencing land systems. Specifically:

- New urban areas are more likely in the vicinity of existing urban areas
- New used ELCs are more likely in the vicinity of existing used ELCs of the same commodity type.

Appendix B-4: Core area and potential tiger area delineation

Core areas are delineated by converting the land system maps to polygons. These polygons are classified as 'natural area' (evergreen and deciduous forest, as well as unconverted forested LSLAs) and non-natural area (all other land systems). Very small patches (< 300 ha) of non-natural area within a larger natural area are filtered out and merged with the larger natural area polygon that surrounds it.

Using these natural area polygons, we use buffer operations to distinguish core and edge natural areas, where core natural areas are natural areas situated at least 5km from non-natural areas. To deal with natural areas adjacent to country borders, we assumed that the natural area extends across the border using a mirroring algorithm.

The procedure relies on a Python (arcpy) script, which will be shared with interested readers on request.

Tiger areas are those core natural areas that are larger than 2000 km^2.

Appendix B-5: Logistic regression

Accessibility calculations:

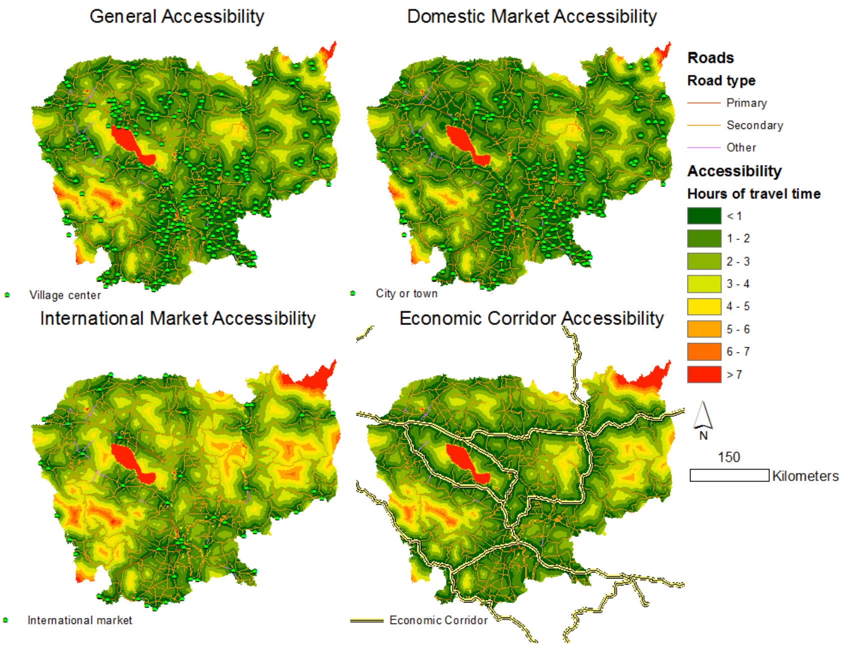
We calculate accessibility as travel time to source points. We use four sets of source points:

1) Village centers (MapCruzin, 2018) to calculate general accessibility
2) Major cities and towns, a sub-selection of villages, to calculate domestic market accessibility
3) International markets: all provincial capitals, ports, airports, and border crossings, to calculate international accessibility
4) Economic corridors: A cross-border infrastructure project to interconnect the Mekong (GMS, 2018), including extensive road constructions, to calculate economic corridor accessibility.

To calculate travel time, we first create a friction surface. This friction surface is calculated using travel speeds:

- Water (Miettinen et al., 2016): 0.25 km/h
- Roads
    - Primary: 70 km/h
    - Secondary: 30 km/h
    - Other: 10 km/h
- Off-road:
    - Smooth terrain (<4 degrees): 8 km/h
    - Rugged terrain (4 – 25 degrees): 5 km/h
    - Very rugged terrain (>25 degrees): 2 km/h

Using this friction surface in combination with the source points, we use the ESRI Cost Distance algorithm to produce accessibility maps.



Parameters considered in logistic regressions:

Variable	Original resolution	Source	Procedure
Domestic market accessibility	1000 m	*Own processing*	See Appendix
General accessibility	1000 m	*Own processing*	See Appendix
International market accessibility	1000 m	*Own processing*	See Appendix
Economic corridor accessibility	1000 m	*Own processing*	See Appendix
Available water storage capacity (mm/m)	Region-dependent	Harmonized World Soil Database†	Resampled to 1000 m
Elevation	90 m	SRTM#	Aggregated to 1000 m
Slope (Degrees)	90 m	*Own processing*	Calculated from Elevation Aggregated to 1000 m
Soil drainage (4 classes)	Region-dependent	Harmonized World Soil Database†	Resampled to 1000 m
Minimum temperature in the coldest month	30 arcsec	worldclim.org*	Aggregated to 1000 m
Maximum temperature in the warmest month	30 arcsec	worldclim.org*	Aggregated to 1000 m
Average Precipitation	30 arcsec	worldclim.org*	Aggregated to 1000 m
Precipitation in the driest month	30 arcsec	worldclim.org*	Aggregated to 1000 m
Topsoil gravel content (%)	Region-dependent	Harmonized World Harmonized World Soil Database†	Resampled to 1000 m
Topsoil sand content (%)	Region-dependent	Harmonized World Soil Database†	Resampled to 1000 m
Topsoil silt content (%)	Region-dependent	Harmonized World Soil Database†	Resampled to 1000 m
Topsoil clay content (%)	Region-dependent	Harmonized World Soil Database†	Resampled to 1000 m
Subsoil gravel content (%)	Region-dependent	Harmonized World Soil Database†	Resampled to 1000 m
Subsoil sand content (%)	Region-dependent	Harmonized World Soil Database†	Resampled to 1000 m
Subsoil silt content (%)	Region-dependent	Harmonized World Soil Database†	Resampled to 1000 m
Subsoil clay content (%)	Region-dependent	Harmonized World Soil Database†	Resampled to 1000 m

USGS (2004)

*Fick and Hijmans (2017)

†Nachtergaele et al. (2009)

Resulting logistic regression models:

We use logistic regressions to relate current (2015) land system distribution to the explanatory factors detailed in above. All factors are significant (P < 0.05). Area Under the Curve (AUC) values indicate reasonably good to excellent fits.

Land System	Contributing factors	AUC
Urban	Dom. Access (+)	0.993
Converted arable crops LSLA	Slope (-); Econ-cor. Access (+); AWC (-); P_{Annual} (+)	0.756
Converted forestry LSLA	Econ-cor. Access (+); Slope (-); Topsoil gravel (+);	0.660
Converted perennial crops	Dom. Access (+); P_{Annual} (+); Topsoil gravel (-);	0.717
Unconverted LSLA	Int. Access* (+); T_{annual}* (-); Slope* (-); Drainage* (-)	0.630
Evergreen forest	Slope (+); P_{Annual} (+)	0.886
Deciduous forest	T_{Annual} (-); Slope (-)	0.763
Cropland	Gen. Access (+); Slope (-); AWC (+); Topsoil gravel	0.842
Cropland – Evergreen forest	Gen. Access (+); P_{Annual} (+); Topsoil sand (-); Elev	0.612
Cropland – Deciduous forest	Gen. Access (+); Elev. (-); Topsoil clay (-)	0.597

*Average of 5x5 cell (2500 ha) neighborhood window

Appendix B-6: Functionalities of the CLUMondo model

CLUMondo is a forward looking land system change model. Land system changes are assumed to occur in response to exogenously defined demands (in this application: annual crops, timber, perennial crops, rice, urban area, and large-scale land acquisitions). A land system can deliver one or more of these demands, or none, and each demand can be fulfilled by one or more land systems.

Using logistic regressions, suitability surfaces are generated for each land system. In this, it is assumed that the current locations of a land system are suitable for that land system. By describing these locations using socio-economic and biophysical factors, and by establishing statistically significant quantitative relations between the occurrence of a land system and these factors, a suitability surface can be created.

The model assumes there is a competition between land systems. Specifically, when a given set of demands can be fulfilled by many combinations of land systems, CLUMondo iteratively calculates the optimal spatial combination to meet all demands. In the first iteration step, CLUMondo allocates on each raster cell the land system that has the highest transition potential, equal to the suitability. The resulting allocated land systems may overproduce or underproduce certain demands. CLUMondo then increases the transition potential for land systems producing underproduced demands, and vice versa. Using this altered transition potential, CLUMondo again allocates on each raster cell the land system that has the highest transition potential. This is repeated until all demands are met within a 5% margin, and the overall average deviation from the stated demand is less than 1%.

The basic functionality of CLUMondo is expanded in a number of ways. Firstly, a conversion matrix defines which land system conversions are allowed. We can for example restrict the conversion from water to any other land system, as this is unlikely. In this application, the conversion from a used LSLA to any other land system is restricted because it is assumed to be unlikely within the simulated time frame. The conversion matrix can also be used to define that a conversion can only occur after a land system has been present for a given number of years, or that a land system can only exist for a given number of years. The latter is used in this application to limit the existence of unconverted LSLAs for up to three years in the Penalization and Proactive Granting scenarios. Second, conversion resistance can be used to quantify the difficulty of converting a land system to something else. For example, because urban land systems are generally difficult to convert, they are given a high conversion resistance, while forests may be more easily converted. Third, neighborhood effects can be added to the transition potential. For example, new urban land systems are more likely to appear close to existing urban areas. We use these effects to increase the transition potential of used LSLAs in the vicinity of same-kind used LSLAs. Lastly, the multi-cell allocation algorithm allows for the allocation of multiple contiguous cells of the same land system. This functionality is useful when certain land systems typically convert larger areas than others. In this application, LSLAs are allocated using this algorithm. Refer to Debonne et al (2018) for more information.

A full description of the model functionality can be found in van Asselen and Verburg (2013). The model is available at www.environmentalgeography.nl.

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8. About the author

Niels was born in Bruges, Belgium, on December 13, 1991. He studied at the KU Leuven, where he obtained his Bachelor's degree in Geography (Cum Laude) in 2013, and his Master's degree (Magna Cum Laude) two years later. He spent three months in Guraferda, Southwest Ethiopia, where he conducted a field survey for his Master's thesis on the forest frontier dynamics in the area, under the supervision of prof. Anton Van Rompaey.

After a brief appointment as research assistant at the KU Leuven, where he was involved in the development of an agent-based spatial urban change model, Niels joined the Environmental Geography research group led by prof. Peter Verburg in January 2016. He was part of the GLOLAND research project (European Research Council) which had the broad goal of enhancing spatial land system change models by explicitly accounting for decision-making.

The Environmental Geography group later merged with the Institute for Environmental Studies (IVM), where Niels found a home among risk scientists, policy analysists, and environmental economists.

Niels was involved as a consultant for the UNCCD Science-Policy Interface, where he co-produced a policy brief which was presented at the Conference of the Parties in New Delhi. Additionally, he contributed to the IPCC special report on climate change and land. For his research on Kenyan medium-scale farms, Niels spent three months in Nakuru, Kenya. He continues to work as an assistant professor at the IVM to this day, and shifted his focus to sustainable intensification of European agriculture.

9. List of publications

Publications on which this thesis is based

Debonne, N., van Vliet, J., Heinimann, A., & Verburg, P. H. (2018). Representing large-scale land acquisitions in land use change scenarios for the Lao PDR. *Regional Environmental Change* , *18*, 1857–1869.

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Other publications

Arneth, A., Denton, F., Agus, F., Elbehri, A., Erb, K.-H., Osman Elasha, B., … Valentini, R. (2019). Framing and context. In P. R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H. O. Pörtner, D. C. Roberts, … J. Malley (Eds.), Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (1st ed., pp. 77–129). *(Contributing author)*

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Acknowledgements

Now follows what is arguably the strangest of all academic texts: the acknowledgements. For one, it is the only part of this booklet that has not been reviewed by anyone. No reviewer 1 or 2 to squeeze the soul out of this writing, no promotor with constructive comments to come to terms with, no learned opponent, not even a diagonal spell-check by my girlfriend. Still, it is well-known that these words are likely going to be the most-read of this book.

Yet how to proceed? Do I take the classical approach, thanking my promotors first (they certainly deserve that), after which friends, family, committee, funders and colleagues follow in short succession? Surely that would do the trick, but such a bullet-point approach does not do justice to the journey that has led me to this point. This achievement is the result of hard work, great people, lucky circumstances, and coffee. I believe a chronological order will be most suitable.

1. The road towards starting a PhD

I wouldn't go so far as to say that I always wanted to be a scientist, but my favorite characters in any cartoon I read as a child were always the savant inventor-scientists who knew everything about everything. Growing up brings the realization that being well-versed in every field from engineering to anthropology is not possible (for me), but becoming a discipline-combining geographer is as close as I could get to this aspiration. My parents have been a constant gentle push for me, although I cannot pinpoint one specific upbringing trick they applied on me. It's a combination: it was instilled into me that whatever I do, I should do it with a passion. Family dinners often became lively debates where we were encouraged to participate from a young age. But setting aside such anecdotes that sound logical with the benefit of hindsight, the overarching point is that my mother and father have been, and are, my examples, my enablers, and while they never set out a course for me, they kept me on it. I had the added benefit of having two great stepmoms, Roos and Saara who have been there for me along the way. Saara is the designer of the beautiful cover of the book you are reading.

My siblings have inspired me, driven me, and supported me. As an organizer for society's most vulnerable people and as a doctor, my brother and sister are both firmly rooted in "the real world", and I look up to them a lot. This rootedness led them to rebuke my often somewhat high-minded arguments on sustainability, they kept my thinking in check (or at least tried). Apart from pushing me off my ivory tower once in a while, Elise and Laurens were simply there whenever I needed them. This is true for my little sister Lenke in equal measure, who has been a joy in my life. Add two stepbrothers, Aaron and Joshua, in the mix, and my family became the perfect nursery to fully develop myself.

I met my girlfriend, Marthe, when I was 17. This tends to surprise people, because we continued to study the same bachelor's and master's degrees in Leuven, and are now direct colleagues at the IVM. She is probably the one person without whom I would not have started, let alone finished, a PhD. She gave me the courage to go for it, and kept me going when the going got tough. A geographer herself, she has been a sparring partner, a critical reviewer, and a sounding board.

It is interesting to see that, like me, my brother and sister both managed to find their true love at age 17-ish. This gave me a long acquaintance with Delphine and Bram, whom I have grown to see as equal parts sibling and friend. Thanks for being there. Bram, I wish you were here.

While I cannot thank my family and girlfriend enough, it should be mentioned that nothing comes for free. My education so far has been costly, yet neither I nor my family have paid the majority of that cost. Flemish tax payers have funded most of my education, and European tax payers have kindly funded my PhD. While I cannot be mistaken for a patriot, this is one thing that Belgium gets right: high-quality education is practically accessible to all with no differentiation based on wealth or social class. It is my firm belief that this should be the case everywhere.

Continuing this chronology, a key character in this story is prof. Anton Van Rompaey, who supervised my MSc thesis. While enjoying a beer in the darkness of a blacked-out brothel in Southwest Ethiopia (there are more stories here), he was the first to casually mention that a PhD could be something for me. Some months later, we were drafting funding proposals, no less than four of them. I

often ponder how things would have been if one of these proposals would have been successful, but failing that, I ended up in Amsterdam.

2. The PhD

I have had the honor to pursue my PhD in what is by all standards a leading research group, led by Peter. I continue to be amazed by the sharpness of Peter's mind. Meetings consistently provided new ideas, better clarity, creative framings, and a lot of to-do's. Yet besides that, I appreciate him most for his genuine care as a leader towards his employees. When my PhD almost came to a crashing halt due to mental health issues, Peter was exactly the kind of boss I needed him to be. When the pandemic pushed all of us to our limits, he went over and beyond to keep us healthy and sane in our work.

Jasper took on the role of day-to-day supervisor. Our weekly meetings were always great, and mostly ended severely off-topic as we discussed books, politics, and more. Such conversations, while arguably not strictly productive, were formative to me. I was encouraged to pursue my specific interests, and Jasper was always there with advice and encouragement. Jasper has also been great at finding and arranging amazing opportunities for me. It was in large part due to his brokerage that I found myself in workshops in Vientiane and Phnom Penh, and that I was able to go on field work in Kenya.

It cannot be understated how much I have appreciated my colleagues. There is simply too much to say here, too many stories and anecdotes. I want to thank , in no particular order, Ziga, Joona, Astrid, Christine, Harun, Marthe, Samantha, David, Koen, Katharina, Cecilia, Jonas, Sarah, Franzi, Adenew, Karina, Jonas, Claudia, Vita, Yue, Verena, Jac, Sean, Emma, Christian, Leen, Kina, Perrine, Bep, Rebecca, Job, Mengmeng, Floris, Rosa, Anna, Nynke, Brian, Reinhard, Willem, Marleen, Jens, Timothy, Eric, Anais, Toon, Ted, Hanna, Mark, Hans, Marije, and so many more, for the many afternoon ice creams, pizza Fridays, nighttime city explorations, directing me home when I got lost during such explorations (shout-out to Reinhard), book club dinner parties, and movie nights. For showing me that I am still among the worst soccer players alive, but still letting me play. For the amazing trips to Slovenia, Vienna, and Terschelling. For the great bouldering sessions. For every coffee break that lasted too long, and for all the lunchtime discussions that have shaped my thinking more than anything else. For being there and asking me how I'm doing. Truly, this paragraph could become a thesis on its own.

During the first one-and-a-half year of my PhD, I lived on a farm. I developed a fond relation with my landlords, Heleen, Matthijs, and Elvira, who became a sort of surrogate family. They gave me invaluable insight in the day-to-day reality of farming. And they serve the best andijvie-stamppot.

The academic work I did could only be done because of the excellent support by an army of support staff. A specifically important person is the secretary, and I have enjoyed three great ones, Barbara, Marjolijn, and Corrie. Thanks for running the place the way you did/do! Beyond that, the cleaning staff, the maintenance workers, the IT support, and the range of administrative workers that are needed to keep a university going have been a great contribution to this thesis. A special shout-out goes to Rabi, wo makes the best pizzas.

3. The PhD defence

In the final stretch of this PhD, I sincerely thank my reading committee. It is an honour to have an eminent group of scholars critically read my work and meet me with their remarks. As I write this, I'm already looking forward to it.

I'm curious how this will go, but I need not fear because I will have two great paranymphs by my side: Bep and Katharina. With a team like that, I'm rather confident that things will work out.

SENSE

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Socio-Economic and Natural Sciences of the Environment

D I P L O M A

for specialised PhD training

The Netherlands research school for the
Socio-Economic and Natural Sciences of the Environment
(SENSE) declares that

Niels Debonne

born on 13 December 1991 in Brugge, Belgium

has successfully fulfilled all requirements of the
educational PhD programme of SENSE.

Amsterdam, 5 February 2021

Chair of the SENSE board

Prof. dr. Martin Wassen

The SENSE Director

Prof. Philipp Pattberg

The SENSE Research School has been accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW)

K O N I N K L I J K E N E D E R L A N D S E
A K A D E M I E V A N W E T E N S C H A P P E N

The SENSE Research School declares that **Niels Debonne** has successfully fulfilled all requirements of the educational PhD programme of SENSE with a work load of 41.9 EC, including the following activities:

PhD and Advanced MSc Courses

- Research Integrity for PhD's, VU Amsterdam (2016)
- PhD Success and personal efficacy, VU Amsterdam (2016)
- Companion Modelling training, ETH Zürich (2016)
- Scientific Writing, VU Amsterdam (2016)

Science and society

- Contributor, and co-author of the UNCCD-Science-policy interface technical report 'Creating an enabling environment for land degradation neutrality and its potential contribution to enhancing well-being, livelihoods and the environment (2019)
- Contributing author to IPCC special report on land (2019)

Management and Didactic Skills Training

- Organiser of a workshop on Programming in Python (2016)
- Organiser of Workshop on Mental health in academia (2018)
- Organiser of Colloquium on Advocacy and communication with laypeople in times of environmental crises (2019)
- Supervising two MSc students with thesis entitled 'The distribution of medium-scale farms in 11 countries in Africa' (2018) and 'The relationship between farm size and pesticide application within Europe' (2020)
- Teaching assistant in the BSc course 'Methods and techniques for physical geography research (2016-2020)
- Guest lecturer in the MSc course 'Advanced Spatial Analysis' (2017)

Oral Presentations

- *The scale of change: Modelling land system dynamics from the smallholder to the plantation.* KOSMOS Conference: Navigating the Sustainability Transformation in the 21st Century, 28-30 August 2019, Berlin, Germany

SENSE coordinator PhD education

Dr. ir. Peter Vermeulen