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Forest governance and its links with deforestation and forest recovery at the local scale in the tropics

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Abstract

Improved forest governance is considered a precondition for halting deforestation and promoting forest recovery in the tropics. Therefore, forest sector governance is currently being reformed in several tropical countries. Several analytical frameworks are also proposed to track the progress of forest governance. However, little is known yet about how forest governance specifically influences the forest transition (FT). Of particular interest is the potential to halt deforestation and promote forest recovery, considering the local socio-economic and biophysical conditions. Previous studies in this regard have mostly been conducted at the national scale and use rather general than forest-specific governance measures. Additionally, little is known yet about the performance of forest governance at the local scale, particularly in areas with overlapping formal and customary structures. Furthermore, although the Governance of Forests Initiatives (GFI) indicator framework is widely recommended for assessing forest governance, hardly has its applicability been tested at the local scale, where policy implementation occurs in practice (de facto).

This study examines the quality of forest governance in different governance arrangements that vary in terms of tenure and use rights and restrictions. It also examines the quality of forest governance in communities in provinces with different governance structures. Wilcoxon rank tests and cluster analysis are used for this purpose. The study further analyses the influence of de facto governance on deforestation, considering proximate drivers and other factors using stepwise regression. The study additionally examines the relationships between governance and socioeconomic factors and the FT dynamics at the local level, considering biophysical factors. Here, factor analysis is used as the basis for ordered logistic regression. Factor analysis is also used to test the applicability of the GFI framework at the local level.

To examine the quality of forest governance in different governance arrangements and communities and to test the applicability of the GFI framework, 238,296 ha of land were mapped within 24 communities spanning three provinces, Copperbelt, North-Western and Eastern, in the Zambian Miombo. To analyse the relationships between governance and socio-economic factors and FT dynamics, empirical data were collected from an extensive field study in 34 landscapes across different tropical contexts in Ecuador, Philippines, and Zambia covering approximately 500,000 ha.

With regards to governance quality, the results from the Wilcoxon rank test reveal that state actors do not necessarily lead to improved governance performance compared to individual and communal actors and vice versa. In fact, enforcement of rules and use restrictions, participatory land use planning and policy formulation processes, robust coordination mechanisms between customary and formal institutions and good institutional capacities per se condition improved governance. In addition, the results suggest that conflicts between customary and formal institutions may arise from unclear institutional mandates for customary forest management. This implies that customary and formal governance processes have to be better harmonized, otherwise implementation of the national and international forestry agenda including REDD+, Bonn challenge, and other climate change initiatives will not be feasible. The cluster analysis reveals that governance processes do not spatially depict the provincial/regional administrative structure. This underscores the need to align and streamline de facto and de jure governance factors across established administrative boundaries.

As regard to the influence of de facto governance on deforestation, the stepwise regression results show that the proximate drivers of charcoal production, cropland cultivation and road extension have stronger effects on deforestation than governance. Those drivers seem to be hardly affected by the in general very weak governance processes. This challenges the hypothesis that governance alone can considerably influence deforestation. On the other hand, scores of governance quality were low and showed little variation between the study sites. This suggests that governance may have been too weak to mitigate effects of the proximate drivers. Only the governance indicator 'local government capacity and effectiveness', although still weak, was significantly linked to low deforestation rates. The results suggest that governance can only affect deforestation drivers positively above certain thresholds. This needs to be further complemented by specific measures such as sustainable production systems, incentives and alternative livelihoods to regulate the proximate and other underlying drivers of deforestation.

Regarding the relationship between governance and socio-economic factors and FT dynamics, the ordered logistic regression results show that both governance factors (i.e., institutional capacities and effectiveness, and access to forest resources) and socio-economic factors (i.e., human population pressure and non-forest income) explain the FT dynamics of landscapes. This confirms that the previous findings at the national level are also valid for the local scale, considering completely different tropical contexts. Surprisingly, a high non-forest income is associated with the pre-transition phase, whereas a low non-forest income is associated with the early and late transition phases. Together with an increasing population, this could indicate a marginalization of the population during the deforestation process. Because deforestation-related processes obviously deprive small-holder farmers of their livelihood and push them further into forestlands, the challenge is to avoid the agriculture-dependent deforestation trap. The findings neither clearly confirm nor clearly refute the hypothesis that forest recovery and deforestation are distinct processes. Instead, the explanatory factors clearly distinguish the pre-transition phase from the rest of the phases. This may indicate that the course for the underlying development pathway is already set during the shift from the pre- to the early transition phase. This suggests that initiatives for reducing deforestation and forest degradation e.g., REDD+ and other conservation programs ought to establish alternatives to the usual agriculture-based development pathway already in the pre-transition phase. As a potential solution, alternative off-farm income opportunities and sustainable forest-based value chains should be promoted as substitutes for agriculture already in the pre-transition phase, under the condition that strict controls can be realized.

The factor analysis largely confirms that the GFI framework is appropriate for governance analysis at the local scale, as factors generally mirror the GFI indicators. In some cases, however, the de facto governance processes do not precisely reflect the thematic areas of the framework. Therefore, the use of single indicators to exclusively represent a thematic area should be done with caution. In addition, specific attention needs to be paid to customary rules and institutions, as these more clearly differentiated on the ground compared to the GFI framework.

Key words: Forest governance, forest transition, deforestation, forest recovery, local scale, tropics.

Zusammenfassung

Eine verbesserte Governance im Forstsektor wird häufig als Voraussetzung für die Verlangsamung der Entwaldung und für die Förderung der Wiederbewaldung in den Tropen betrachtet. Daher zielen viele internationale Anstrengungen in tropischen Ländern auf eine Reform der Governance des Forstsektors. Mehrere analytische Rahmenwerke sind verfügbar, um forstliche Governance zu erfassen. Es ist jedoch wenig darüber bekannt, wie forstliche Governance Entwaldungs- und Wiederbewaldungsprozesse, i.e. die ‚Forest. Transition' (FT), beeinflusst. Von besonderem Interesse ist dabei das Potential, unter Berücksichtigung von lokalen, sozio-ökonomischen und biophysikalische Bedingungen, Entwaldung zu stoppen und Wiederbewaldung zu fördern. Bisherige Studien hierzu wurden meist auf nationaler Ebene durchgeführt und berücksichtigen eher allgemeine als forstliche Governance-Maßnahmen. Darüber hinaus ist noch wenig über die Ausprägung der forstlichen Governance auf lokaler Ebene bekannt, insbesondere in Gebieten mit sich überschneidenden formalen und traditionellen Strukturen. Auch wenn die Indikatoren der ‚Governance of Forests Initiative' (GFI) weithin für die Erfassung von Governance empfohlen werden, wurde ihre Anwendbarkeit auf lokaler Ebene kaum getestet, wo die politische Umsetzung in der Praxis (de facto) stattfindet.

Diese Studie untersucht die Qualität der forstlichen Governance in verschiedenen Governance-Arrangements, die sich in Bezug auf Nutzungsrechte und -einschränkungen unterscheiden. Außerdem werden Gemeinden in Provinzen mit unterschiedlichen Verwaltungsstrukturen untersucht. Dazu werden Wilcoxon-Rangsummentests und Clusteranalysen durchgeführt. Die Studie analysiert darüber hinaus den Einfluss der de-facto-Governance auf Entwaldung, unter Berücksichtigung von unmittelbaren Treibern und anderen Faktoren mittels schrittweiser Regressionsanalyse. Die Studie untersucht ferner die Zusammenhänge zwischen Governance und sozioökonomischen Faktoren und der FT-Dynamik auf lokaler Ebene, unter Berücksichtigung biophysikalischer Faktoren. Dazu wird Faktorenanalyse als Grundlage für eine geordnete logistische Regression verwendet. Die Anwendbarkeit des GFI-Frameworks auf lokaler Ebene wird mittels Faktorenanalyse getestet. Um die Governance-Qualität in verschiedenen Governance-Arrangements und Gemeinden zu analysieren und um die Anwendbarkeit des GFI-Rahmenwerkes zu testen, wurde eine Fläche von 238.296 ha in 24 Gemeinden in drei Provinzen im sambischen Miombo, nämlich Copperbelt, North-Western und Eastern, kartiert. Um den zusammenhang zwischen Waldumwandlung und Governance und sozioökonomischen Faktoren zu analysieren, wurden im Rahmen einer umfangreichen Feldstudie empirische Daten in 34 Landschaften in verschiedenen tropischen Kontexten in Ecuador, den Philippinen und Sambia auf einer Fläche von etwa 500.000 ha erfasst.

In Bezug auf Governancequalität zeigen die Ergebnisse der Wilcoxon-Rangsummentests, dass staatliche Akteure im Vergleich zu individuellen und kommunalen Akteuren nicht unbedingt zu einer verbesserten Governance-Performance führen und umgekehrt. Tatsächlich bedingen die Durchsetzung von Regeln und Nutzungsbeschränkungen, partizipative Landnutzungsplanung und Politikformulierungsprozesse, robuste Koordinationsmechanismen zwischen traditionellen und formalen Institutionen sowie gute institutionelle Kapazitäten *per se* eine verbesserte Governance. Darüber hinaus legen die Ergebnisse nahe, dass sich Konflikte zwischen traditionellen und formalen Institutionen aus unklaren institutionellen Mandaten für die traditionelle Waldbewirtschaftung ergeben können. Dies impliziert, dass traditionelle und formale Governance-Prozesse besser aufeinander abgestimmt werden müssen, da sonst die Umsetzung der nationalen und internationalen forstpolitischen Agenda einschließlich REDD+, Bonn Challenge und anderer Klimaschutzinitiativen nicht realisierbar ist. Die Clusteranalyse zeigt, dass die lokalen Governance-Prozesse die provinzielle/regionale Verwaltungsstruktur nicht räumlich abbilden. Dies unterstreicht die Notwendigkeit, de facto und de jure Governance-Faktoren über die etablierten Verwaltungsgrenzen hinaus aufeinander abzustimmen und zu straffen.

In Bezug auf den Einfluss der de-facto-Governance auf die Entwaldung zeigen die Ergebnisse der schrittweisen Regression, dass die unmittelbaren Entwaldungstreiber Holzkohleproduktion, Ackerbau und Straßenausbau stärkere Auswirkungen auf die Entwaldung haben als Governance. Diese Treiber scheinen von den allgemein sehr schwachen Governance-Prozessen kaum betroffen zu sein. Dies stellt die Hypothese in Frage, wonach Entwaldungsprozesse duch Governance allein erheblich beeinflusst werden kann. Auf der anderen Seite ist die Governance-Qualität insgesamt niedrig und zeigt kaum Variation zwischen den Projektgebieten. Dies legt die Schlussfolgerung nahe, dass sie möglicherweise insgesamt zu schwach ist, um Auswirkungen auf unmittelbare Entwaldungstreiber zu zeigen. Lediglich der Governance-Indikator „Kapazität und Effektivität der lokalen Regierungen“ war signifikant in Bezug auf niedrige Entwaldungsraten, obwohl auch er insgesamt niedrig bewertet wurde. Die Ergebnisse legen nahe, dass Governance die Entwaldungstreiber erst ab bestimmten Schwellenwerten positiv beeinflussen kann. Dies muss durch spezifische

Maßnahmen wie nachhaltige Produktionssysteme, Anreize und alternative Lebensgrundlagen weiter ergänzt werden, um unmittelbare und andere Treiber der Entwaldung zu regulieren.

Hinsichtlich des Zusammenhangs zwischen Governance und sozioökonomischen Faktoren und der FT-Dynamik zeigen die Ergebnisse der geordneten logistischen Regression, dass sowohl Governance-Faktoren (d.h. institutionelle Kapazitäten und Effektivität und Zugang zu Waldressourcen) als auch sozioökonomische Faktoren (d.h. Bevölkerungsdruck und Nichtwaldeinkommen) die FT-Dynamik von Landschaften erklären. Dies bestätigt, dass bisherige nationale Ergebnisse auch auf lokaler Ebene gültig sind; und dies unter ganz unterschiedlichen tropischen Bedingungen. Überraschenderweise wurde ein hohes Nicht-Wald-Einkommen in der ‚pre transition' Phase beobachtet, während ein niedriges Nicht-Wald-Einkommen in der ‚early transition' und ‚late transition' Phase auftritt. Zusammen mit einer steigenden Bevölkerung könnte dies auf eine Marginalisierung der Bevölkerung während des Entwaldungsprozesses hindeuten. Die mit der Entwaldung zusammenhängenden Prozesse berauben die Kleinbauern offensichtlich ihrer Lebensgrundlage und drängen sie weiter in verbleibende Waldgebiete. Entwaldung kann wie eine Falle wirken, die die Bevölkerung in die Abhängigkeit von landwirtschaftlicher Produktion drängt. Die Herausforderung besteht darin, dies zu umgehen.

Die Ergebnisse bestätigen weder eindeutig noch widerlegen sie die Hypothese, dass Wiederbewaldung und Entwaldung unterschiedliche Prozesse sind. Stattdessen differenzieren die erklärenden Faktoren die ‚pre transition' Phase klar von den übrigen Phasen. Dies könnte darauf hinweisen, dass die Weichen für die Art der zukünftigen Entwicklung bereits beim Übergang zwischen der ‚pre transition' und ‚early transition' Phase gestellt werden, und es legt nahe, dass Initiativen zur Reduzierung von Entwaldung und Walddegradation, z. B. REDD+ und andere Naturschutzprogramme, bereits in der ‚pre transition' Phase Alternativen zur üblichen auf Landwirtschaft fokussierten Entwicklung etablieren sollten. Alternative nichtlandwirtschaftliche Einkommensmöglichkeiten und nachhaltige waldbasierte Wertschöpfungsketten bieten Lösungsansätze und sollten als Alternativen für die Landwirtschaft bereits in der ‚pre transition' Phase gefördert werden, allerdings unter der Bedingung, dass strenge Kontrollen realisiert werden können.

Die Faktoranalyse bestätigt weitgehend, dass das GFI-Rahmenwerk für die lokale Governance-Analyse geeignet ist, da die Faktoren im Allgemeinen die GFI-Indikatoren widerspiegeln. In einigen Fällen spiegeln die de facto Governance Prozesse allerdings die

thematischen Bereiche des GFI Rahmenwerkes nicht wieder. Einzelne Indikatoren können daher nur bedingt thematische Bereiche abdecken. Darüber hinaus muss traditionellen Regeln und Institutionen verstärkt Aufmerksamkeit gewidmet werden, da diese im Vergleich zum GFI-Rahmenwerk vor Ort deutlich stärker ausdifferenziert sind.

Schlagworte: Forstliche Governance, Waldumwandlung, Entwaldung, Wiederbewaldung, lokale Ebene, Tropen

Scientific publications

This cumulative thesis is based on the following publications:

I. Nansikombi, H., Fischer, R., Kabwe, G. & Günter, S. 2020a. Exploring patterns of forest governance quality: Insights from forest frontier communities in Zambia´ s Miombo ecoregion. *Land Use Policy,* 99**,** 104866. https://doi.org/10.1016/j.landusepol.2020.104866. (Appendix I, pages 109-124).

II. Nansikombi, H., Fischer, R., Velasco, R. F., Lippe, M., Kalaba, F. K., Kabwe, G. & Günter, S. 2020b. Can de facto governance influence deforestation drivers in the Zambian Miombo? *Forest Policy and Economics,* 128**,** 102309. https://doi.org/10.1016/j.forpol.2020.102309 (Appendix J, pages 125-142).

III. Nansikombi, H., Fischer, R., Velasco, R. F., Lippe, M., Zhunusova, E., Kazungu, M., Ojeda, T. & Günter, S. (Submitted). How are governance and socioeconomic factors linked to the forest transition dynamics at the local scale in the tropics? Empirical evidence from Ecuador, Philippines and Zambia. *Land use Policy* (Appendix K, pages 143-184).

The contribution of Hellen Nansikombi to the publications included in this thesis was as follows:

- Publication I (Nansikombi et al., 2020a): Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing original draft, Writing-reviewing and editing, Visualization.
- Publication II (Nansikombi et al., 2020b): Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing original draft, Writing-reviewing and editing, Visualization.
- Publication III (Nansikombi et al., submitted): Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing original draft, Writing-reviewing and editing, Visualization.

Contents

1 Introduction

Tropical forests host about 50% of the world's terrestrial species diversity (Phillips et al., 2017) and account for 50% of the world´s carbon stored in trees (Harris et al., 2021). In addition, approximately 40% of the world´s extreme rural poor directly rely on tropical forests products for their subsistence and cash income e.g. timber, fuelwood, mushrooms and medicine (FAO, 2018). Despite their value, tropical forests experience high rates of deforestation and forest degradation. According to FAO (2020) between 2015 and 2020, with about 9.28 million hectares of forests lost annually, tropical forests accounted for more than 90% of the global deforestation. Moreover, although net forest gain has been observed in some specific locations (Ashraf et al., 2017, Costa et al., 2017, Rudel et al., 2002), only 13 tropical countries had shifted from experiencing net loss to net gain in forest cover, a phenomenon referred to as forest transition, between 1990 and 2015 (Keenan et al., 2015). Tropical deforestation and forest degradation are known to have deleterious consequences for species diversity, carbon sequestration and the livelihood of forest dependent communities (Millennium Ecosystem Assessment, 2005, Sean et al., 2017). In contrast, tropical forest recovery is known to have positive consequences for the respective aspects (FAO, 2018).

The drivers of both tropical deforestation and forest recovery vary regionally and change over time (Hosonuma et al., 2012, Rudel et al., 2009). However, the two processes are posited as distinct and also, with differing drivers (Grainger, 1995, Barbier et al., 2010). The proximate (direct) drivers of tropical forest recovery comprise abandonment of agricultural lands that revert back to forests and forest products scarcity and declining forest ecosystem services that prompt governments and land managers to commence reforestation or afforestation (Rudel et al., 2002). The leading underlying (indirect) driver of tropical forest recovery is socioeconomic growth and the accompanying urbanization, industrialization and non-farm jobs that compel rural populations to migrate to urban areas and abandon marginal agricultural lands that revert to forests (Crk et al., 2009, Wolfersberger et al., 2015). Governance measures e.g. improved land tenure security, increased restrictions on the use of forest resource and incentivising farmers to plant trees are equally important underlying drivers of tropical forest recovery (de Jong et al., 2017).

The leading proximate driver of tropical deforestation and forest degradation is crop agriculture (Hosonuma et al., 2012). Timber logging, charcoal production, firewood extraction, infrastructure expansion and livestock grazing are also important proximate drivers of tropical forest loss (Geist and Lambin, 2001, Kissinger et al., 2012). The underlying drivers of deforestation and forest degradation in the tropics comprise weak governance, socioeconomic, technological, and demographic/population factors (Geist and Lambin, 2001, Kissinger et al., 2012). Amongst the underlying drivers mostly the socioeconomic factors are emphasized in the tropics e.g., Mena et al. (2006), Dimobe et al. (2015) and Xu et al. (2019). Studies show a significant proportion of tropical forest area to coincide geographically with a considerable number of forest dependant poor households (Buys, 2007). Additionally important in the tropics is population growth, because it is correlated with increasing demand for forest and agricultural products (Hermans-Neumann et al., 2016, Rademaekers et al., 2010).

An equally important reason for deforestation and forest degradation is that governance is often too weak to counteract the proximate drivers of deforestation (Barr et al., 2014, Geist and Lambin, 2001). Indicators of weak forest governance including insufficient law enforcement, inadequate land tenure security, weak institutions, unclear property rights, weak forest legislation and policies and absence of land use planning have been linked to the detected forest loss in 93% of the surveyed tropical countries in the REDD+ readiness preparation phase (Kissinger et al., 2012). Weak forest governance permits unsustainable anthropogenic forest use activities e.g. crop agriculture, charcoal production, fuel wood collection, timber extraction and infrastructure development (Kissinger et al., 2012, Hosonuma et al., 2012). Weak forest governance is also evidenced to foster inequitable socioeconomic growth, which frequently pushes disadvantaged farmers to migrate further into forestlands that they convert to agricultural lands (Buys, 2007, Riggs et al., 2018, Riggs et al., 2020).

Against this background, improved forest governance is proposed as a necessary precondition for slowing forest loss, facilitating forest recovery and protecting the world’s remaining tropical forests especially in the context of increasing anthropogenic pressure (Fischer et al., 2020, Wehkamp et al., 2018). Given the widespread agreement on the necessity for improved forest governance in the tropics, several countries have adopted policies and initiatives that take this into consideration. In Zambia for example, the forest sector has been decentralized to permit citizen participation in forest resource management (GRZ, 2002). Zambia also developed a national strategy for reducing emissions from deforestation and forest degradation (REDD+), which integrates strengthening forest governance in the preparatory phase (Matakala et al., 2015). However, hardly has the progress of forest governance been examined in Zambia like elsewhere in the tropics, particularly at the local scale, where policy implementation occurs in practise (de facto).

Several international frameworks have been developed to analyse the progress of forest governance. They include the "framework for assessing and monitoring forest governance" of the Food and Agriculture Organization (Kishor and Rosenbaum, 2012), the "natural resource governance framework assessment guide" of the International Union for Conservation of Nature (Campese et al., 2016), and the "governance of forest initiatives indicator framework" of the World Resource Institute (Davis et al., 2013). The governance of forest initiatives (GFI) indicator framework by the World Resource Institute is widely recommended for forest governance analysis given its comprehensive coverage, providing a series of indicators for analysing different dimensions of forest governance systems (Brito et al., 2009, Agung et al., 2014). However, barely has its applicability been tested at the local scale in the tropics.

The links of particular governance indicators to deforestation and forest recovery have also hardly established at the local scale in the tropics (Umemiya et al., 2010). Yet, the framework by Geist and Lambin (2001) on the divers of tropical deforestation and forest degradation and the forest transition (FT) theory by Mather (1992) provide a good basis for this. The framework by Geist and Lambin (2001) classifies the drivers of tropical deforestation and forest degradation into proximate, underlying and other factors. The FT theory on the hand, highlights the subsequent phases that countries or regions experience as they shift from a declining to an expanding forest cover: (1) an initial phase characterised by high forest cover and low deforestation rates, (2) a phase of forest cover loss at an increasingly rapid rate, (3) a phase of decelerating rate of deforestation from the small fraction of remnant forests, and finally (4) a phase, where the forest cover increases through reforestation (Angelsen and Rudel, 2013, Hosonuma et al., 2012, Angelsen, 2007). The theory additionally highlights the governance and socioeconomic factors that drive the change in the FT phase (Angelsen and Rudel, 2013, Hosonuma et al., 2012, Angelsen, 2007). However, those factors are only indicative of broad tendencies and not necessarily definitive to any particular phase (Buys, 2007).

1.1 Research gap

Although forest sector governance reforms are underway in several tropical developing countries e.g. Zambia, little is known yet about their implementation at the local scale in absence of reliable data (Secco et al., 2014). Previous studies in this regard have mostly been conducted at the national scale and capture the legal conditions (de jure) e.g. Kalaba et al. (2014) and Blaser (2010). However, the legal conditions at the national scale have been found to differ substantially from the actual implementation of policy and institutional reforms at the local scale (Ribot, 2003b, Kaufmann et al., 2007, Agarwala and Ginsberg, 2017). Thus, it is necessary to complement the exclusively national focus with local scale studies that capture the variations from differential implementation of policy and legislative reforms on the ground. The applicability of the widely recommended GFI indicator framework has also hardly been scientifically tested at the local scale, especially since very few scientific studies e.g. Agung et al. (2014) and Pettenella and Brotto (2012) have utilized it to quantitatively analyse forest governance performance. There is also still need for a better understanding of how specific aspects of forest governance affect deforestation at the local scale, accounting for socioeconomic, demographic and biophysical factors (Agrawal et al., 2008). Studies in this regard have mostly been conducted at the national scale and use rather general than forest-specific governance indicators such as corruption democracy, voice and accountability, political stability, violence and rule of law e.g. Umemiya et al. (2010) and Wehkamp et al. (2018). Although they provide valuable insights, general governance indicators may capture broader phenomena and mask the effects of forest-specific governance aspects on deforestation (Kishor and Belle, 2004, Wehkamp et al., 2018). Besides, different studies underscore differing actors i.e. communal (Rights and Initiative, 2018, Oldekop et al., 2019), private (Koyuncu and Yilmaz, 2013b, Koyuncu and Yilmaz, 2013a) and state (Dudley and Stolton, 2010, Wilshusen et al., 2002), as optimal policy options for curbing deforestation and forest degradation. The mixed results imply the necessity for further studies in this respect. The hypothesis that deforestation and forest recovery are two distinct processes of forest transition, which are shaped by differing socioeconomic and governance factors (Grainger, 1995, Barbier et al., 2010) has also hardly been substantiated at the local scale (He et al., 2014), across different tropical contexts, accounting for biophysical factors. This is mostly because reliable data are seldom available at the local scale (Secco et al., 2014). And even more, if they are available, they are hardly comparable due to different methodological approaches. In addition, FT dynamics are conceived for larger spatial scales i.e. national scale, where policy design occurs, or regional and global scales, owing to globalization effects (Meyfroidt et al., 2010, Ametepeh, 2019). However, the local scale drivers are known to have strong influence on national-level processes especially in the situations where macroeconomic adjustments do not play a significant role (Oliveira et al., 2017). Local level insights may moreover strengthen the efficiency and effectiveness of national and global policy and landscape interventions that aim to control deforestation and promote forest recovery (Riggs et al., 2018).

1.2 Conceptual framework

The conceptual framework (Figure 1) provides a guide for analysing forest governance quality and its links with deforestation and forest recovery. Further, the framework provides a guide for testing the applicability of the GFI framework at the local scale, where policy implementation occurs in practise.

The contemporary governance concept recognizes that forest governance is not restricted to the domains of governments but covers many actors in society including civil society, communities and the private sector (Agrawal et al., 2008, Arts, 2014, Mwangi and Wardell, 2012). Forest governance “comprises a) all formal and informal, public and private regulatory structures, i.e. institutions consisting of rules, norms, principles, decision procedures, concerning forests, their utilization and their conservation, b) the interactions between public and private actors therein and c) the effects of either on forests”(Giessen and Buttoud, 2014). Considering this contemporary definition, governance in this study is conceptualized as being based on (A) multiple actors/institutions and (B) formal and informal rules of forest-related decisions and their implementation (Figure 1). In addition to these two components, the (C) interactions amongst actors and (D) interactions between actors and rules and (E and F) their effects on forests are considered to compose a comprehensive governance framework. Because it is difficult to cover all these aspects within the methodology of one study, while simultaneously maintaining scientific rigour, it is recommended to focus on certain aspects (Giessen and Buttoud, 2014). This study comprises three smaller studies, each focusing on a different aspect. The first study (Publication I) assesses the quality of rules, actors/institutions and their interactions. The second study (Publication II) examines the effects of institutions, rules and their interactions on deforestation. The third study (Publication III) examines the linkages between institutions, rules and their interactions and the FT dynamics in form of deforestation and forest recovery.

To assess the quality of rules, and institutions and their interactions, a set of indicators (Section 3.2.3.2) from the Governance of Forests Initiative (GFI) framework of the World Resource Institute by Davis et al. (2013) was used. Like in other governance assessment frameworks (Graaf et al., 2017, Kishor and Rosenbaum, 2012, Worldbank, 2006), these indicators reflect compilations of operational aspects that were found to be relevant for forest governance. The GFI framework groups the relevant issues into six thematic areas: 1) forest tenure, 2) land use planning, 3) forest management, 4) forest revenues, 5) crosscutting institutions and 6) crosscutting issues (Davis et al., 2013). The indicators are clustered according to these thematic areas. The indicators capture the different components of the above described theory-based governance concept (Davis et al., 2013). The ability of the GFI framework to differentiate between the distinct governance aspects at the local scale is also tested in this study.

Governance arrangements (Section 3.2.3.1) are included as specific expressions and combinations of the basic governance components, which constitute key spatial units of assessment in governance studies. The arrangements, which in this study are categorised based on the concept of property rights regimes by Schlager and Ostrom (1992) clarify the institutions with the responsibility to control forests (state, community and private/individual), tenure (customary and state) and the restrictions/rules on forest access and use (restricted and non-restricted).

To assesses the effects of governance (institutions, rules and their interactions) on deforestation, additional reference is made to the framework on the drivers of tropical deforestation and forest degradation by Geist and Lambin (2001). According to Geist and Lambin (2001), weak forest governance is an underlying driver i.e. a fundamental force that underpins the proximate drivers of deforestation and forest degradation. Thus, the role of proximate drivers of deforestation is incorporated (Figure 1). Proximate drivers are human activities that directly affect the forest (Geist and Lambin, 2001, Hosonuma et al., 2012). They include agricultural expansion, wood extraction and infrastructure extension (Vinya et al., 2011, Armenteras et al., 2017, Geist and Lambin, 2001). Other factors that work as catalytic attributes, leading to changes in human-environment conditions i.e. biophysical factors such as slope and size of the forest are also considered. Additionally considered are other important underlying drivers of deforestation and forest degradation in the tropics i.e.

demographic/population density (Mayaux et al., 2013), economic and socio-cultural drivers (Kissinger et al., 2012).

To assess the linkages of governance (institutions, rules and their interactions) to the FT dynamics in the form of deforestation and forest recovery, further reference is made to the concept of the four FT phases, based on the FT theory as described by Angelsen and Rudel (2013), Hosonuma et al. (2012) and Angelsen (2007). According to this concept, deforestation and forest degradation characterise the first three FT phases i.e. (i) pre-transition (ii) early transition and (iii) late transitions. The fourth phase (post-transition) is characterised by forest recovery (Hosonuma et al., 2012).

The first phase (pre-transition) describes core forest areas, where deforestation rates are low, and the forests are relatively undisturbed. Poor infrastructure and market access, low population density, low demand for agriculture and forest products, high poverty, low non-farm opportunities and low opportunity costs of avoided deforestation represent the socioeconomic conditions. Because these forests are often remote, outside the reach of state or governments, government agencies have limited capacity to enforce and monitor regulations/restrictions and implement other management measures. Accordingly, formal forest governance is often weak, with customary/traditional structures existing in some areas. Formally, insecure land tenure predominates most of those areas especially since the cost of defending property rights rises with distance from towns (Hosonuma et al., 2012, Culas, 2012, Angelsen and Rudel, 2013, Angelsen, 2007, Buys, 2007).

The second phase (early transition) refers to the areas within forest frontiers, where deforestation rates are high. Medium infrastructure and market access, mixed poverty, low to medium population density, low non-farm opportunities, low to medium demand for agriculture and forest products and medium to high opportunity costs for avoided deforestation often characterise the socioeconomic conditions. Forest governance is weak, and the land tenure is insecure in those areas (Hosonuma et al., 2012, Culas, 2012, Angelsen and Rudel, 2013, Angelsen, 2007, Buys, 2007).

The third phase (late transition) refers to areas within forest/agricultural mosaics with low levels of forest loss. High infrastructure and market access, medium to low poverty and medium to high population density, increasing non-farm income opportunities, and high avoided deforestation characterize the socioeconomic conditions. Forest governance and forest management are both well-established (stable) and the land tenure is also reasonably secure (Hosonuma et al., 2012, Culas, 2012, Angelsen and Rudel, 2013, Angelsen, 2007, Buys, 2007).

The fourth phase (post-transition) comprises the areas with forest restorations and reforestations through plantations, and agrarian mosaics. Improved infrastructure and reasonable market access, medium to low poverty levels, medium to high population density, high non-farm income opportunities, high farm labour costs, scarcity of forest products, high opportunity costs for avoided deforestation and abandonment of agriculture on marginal lands e.g., steep slopes and further from markets, characterize the socioeconomic environment. Because such areas are easily accessible by government institutions to enforce regulations, forest governance is well-established and stable. Moreover, given that forest scarcity is likely to increase the demand and value of forest products, there is increased incentive for protecting remnant forests e.g., through establishment of national parks and measures to restrict human access to environmentally valuable areas (Angelsen, 2010). The land tenure is considered secure, mainly among larger landowners.

However, the aforementioned variations in socioeconomic and governance factors across the FT phases are only indicative of broad tendencies and not necessarily definitive to any particular phase (Buys, 2007). The link between specific governance factors and the FT phases is also still unclear (Angelsen and Rudel, 2013). This underscores the necessity to explore the linkages between governance and socioeconomic factors and the FT phases. Moreover, deforestation and forest recovery are theorised as two distinct processes with potentially different predictors (Grainger, 1995).

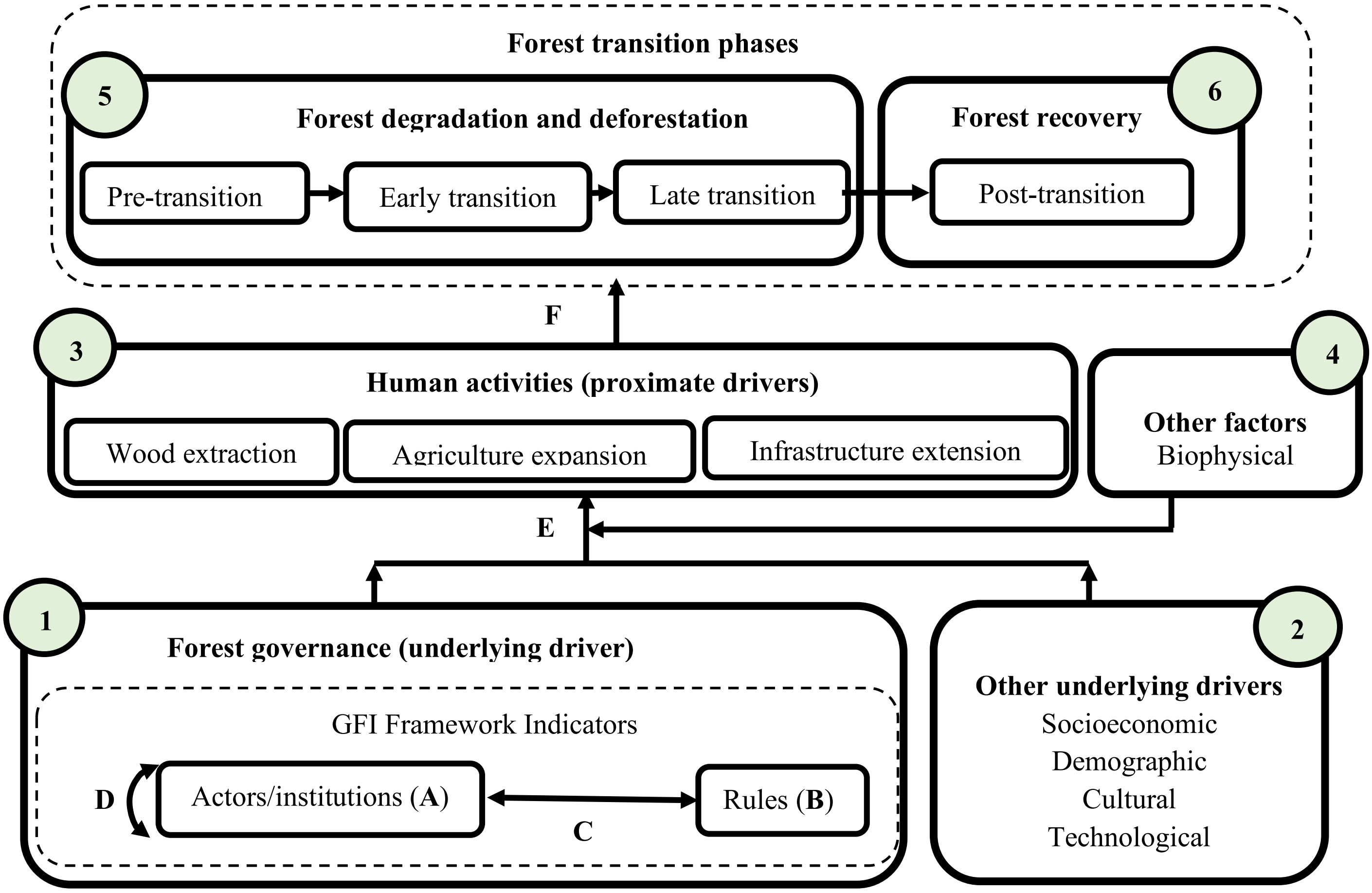

Figure 1 Conceptual framework for analysing forest governance quality and its links to the FT dynamics (deforestation and forest recovery) and as well testing the applicability of the GFI framework. A implies the governance component on actors/institutions; B, Rules; C, interactions between rules and actors; D, interactions amongst actors. Box 1 illustrates forest governance, Box 2, other underlying drivers; Box 3, proximate drivers/ human activities; Box 4, other factors; Box 5, deforestation; Box 6, forest recovery. Arrow E illustrates the governance effects on proximate drivers, accounting for other underlying drivers and factors. Arrow F illustrates the governance effects on deforestation and/ forest recovery through its effects on proximate drivers accounting for other underlying drivers and factors. The indicators for governance components A, B, C and D are taken from the GFI framework. Adapted from Geist and Lambin (2001), Davis et al. (2013) and Hosonuma et al. (2012).

1.3 Research aim and objectives

Given the gaps in knowledge, this study examines the quality of forest governance and its links to the FT dynamics in the form of deforestation and forest recovery at the local scale in the tropics. The study additionally tests the applicability of the GFI framework at the local scale based on the perception of the local population. The study aims to contribute to a more robust understanding of governance structures and assessment tools and as well identify the specifics of forest governance with potential to curb deforestation and forest degradation and facilitate forest recovery in the tropics. This is relevant for global initiatives e.g. REDD+, Bonn challenge and other conservation programs that propose improved forest governance to curb deforestation and promote forest recovery (Korhonen-Kurki et al., 2014, Angelsen and Rudel, 2013, Messinger and DeWitt, 2015). Methodologically, the study aims to conclude on the suitability of the widely recommended GFI framework for governance assessment at the local scale, where policy implementation occurs in practise.

The specific objectives of the study are:

I. To determine if the GFI framework differentiates distinct aspects of forest governance based on the perception of the local population.
II. To determine if the quality of forest governance varies across governance arrangements with differing tenure and use restrictions and communities in provinces with differing local government administration in the tropics.
III. To examine the influence of forest governance on deforestation at the local scale in the tropics.
IV. To examine the linkages between governance and socioeconomic factors and the FT dynamics at the local scale in the tropics.

Objectives I and II are addressed in Publication I (Annex I). They are covered in Box 1, representing forest governance in the conceptual framework (Figure 1). Objective III is addressed in Publication II (Annex J). It is focused on understanding the effects of forest governance on deforestation, represented by letters E and F in the conceptual framework. Objective IV is addressed in Publication III (Annex K). Like objective III, objective IV is also focused on understanding the effects of forest governance on deforestation, represented by letters E and F in the conceptual framework. However, in addition to deforestation, illustrated by Box 5 in the framework, objective IV integrates forest recovery, illustrated by Box 6 in the framework. In both objectives III and IV, the role of other underlying drivers (socioeconomic, demographic cultural and technological), illustrated by Box 2 in the framework, and other factors (biophysical), illustrated by Box 3 in the framework, is additionally considered.

2 State-of-the-art

This chapter comprises recent literature on forest governance quality and its assessment frameworks. The chapter additionally presents information on the linkages between forest governance and the forest transition in the form of deforestation and forest recovery.

2.1 Forest governance assessment frameworks

Forest governance is operationalized by several indicator frameworks. They include the "framework for assessing and monitoring forest governance" of the Food and Agriculture Organization (Kishor and Rosenbaum, 2012), the "natural resource governance framework assessment guide" of the International Union for Conservation of Nature (Campese et al., 2016), and the "governance of forest initiatives indicator framework" of the World Resource Institute (Davis et al., 2013).

The Governance of Forest Initiative (GFI) indicator framework is widely recommended for forest governance assessments given its comprehensive coverage, providing a series of indicators for analysing different dimensions of forest governance systems (Agung et al., 2014, Brito et al., 2009). Moreover, the aspects focused by the GFI framework largely reflect the different components of the theory-based concept of forest governance by Giessen and Buttoud (2014). Unlike previous models that underscore either actors (Hardin, 2009) or rules/institutions (Goodin, 1996, Ostrom, 1990) as the theoretical basis, the GFI framework, is able to integrate both aspects (Arts, 2014) as, based on theoretical foundations of the governance concept, it includes agency and structure components (Fischer et al., 2020). It allows to capture the diversity of actors, the links between formal and informal practises and the rules that shape governance (Davis et al., 2013).

A few scientific studies have utilized the GFI framework to quantitatively analyse progress towards proposed governance improvements: Agung et al. (2014) and Pettenella and Brotto (2012) analyse the impact of REDD+ readiness on forest governance in Indonesia and the successful features for REDD+ project organizations, respectively. Moreover, those studies have been conducted at the national scale. The applicability of the proposed GFI indicators has hardly been scientifically tested at the local scale using community perceptions. Yet community perceptions can indicate the extent to which governance structures are legitimated by community members (DeCaro and Stokes, 2013). Community perceptions have also been found to correlate with local compliance with rules for common pool resource management

(Jenny et al., 2007). Community perceptions may as well capture the de facto reality that exists on the ground, which has been found to differ substantially from the fact-based de jure notions of laws (Kaufmann et al., 2011).

On the other hand, the GFI is primarily a process-oriented governance assessment framework (Davis et al., 2013). Yet, the definition of forest governance by Giessen and Buttoud (2014) as well includes the effects of forests. This implies the necessity to complement the GFI framework with analytical frameworks that emphasize the effects of governance on forests for a more comprehensive study. For example, the framework by Geist and Lambin (2001), which emphasizes the effects of governance on deforestation and forest degradation and the concept of the FT phases, based on the FT theory as described by Angelsen and Rudel (2013) and Hosonuma et al. (2012), which emphasizes the effects of governance on the FT dynamics in the form of deforestation and forest recovery.

2.2 The quality of forest governance

The quality of forest governance has commonly only been judged based on the ecological and socioeconomic effects of particular governance arrangements e.g. Porter-Bolland et al. (2012) and Bray et al. (2008). This effect/outcome-oriented approach of governance assessment is appealing to policy actors because it assumes systemic change in a clear way that permits distinguishing between policy options that may either influence the driver, alleviate direct pressure, or impact on society (Giupponi, 2007). The challenge with this approach, however, is the uncertainty to establish a clear explanatory link between a specific governance process and the consequences that occur in the system being governed (Conley and Moote, 2003). This has nurtured the rising interest to assess governance processes in addition to the effects. Insights about the processes are expected to improve and correct our judgement of the effects. Insights about the process may also permit ascertaining whether the processes have been adapted to the social and political specificities of a given setting. This is likely to improve the quality of decision-making and implementation (Rauschmayer et al., 2009, Fukuyama, 2013).

Scholars (Kishor and Rosenbaum, 2012, Davis et al., 2013) propose to assess forest governance processes in accordance with the normative concept of good governance. Studies e.g. Agung et al. (2014), Brito et al. (2009) and Kishor and Rosenbaum (2012) assess forest governance quality in this manner. Most of those studies, however, focus on the legal (de jure) condition at the national scale, where policy design occurs. There are hardly any studies in this regard at the local scale, where policy implementation occurs, de facto (Secco et al., 2014).

Moreover, with to the emergence of new arrangements of governing that are not restricted to the domains of the state alone, but embrace the private and communal actors (Arts, 2014, Agrawal et al., 2008), there are increased scholarly studies into the actors that are likely to foster improved forest governance conditions. However, the conclusions are still contradictory. Dudley and Stolton (2010) and Hardin (2009) emphasize state actors, Agrawal (1996), Ostrom (1990) and Woldie and Tadesse (2019), community actors, and Koyuncu and Yilmaz (2013b) and Koyuncu and Yilmaz (2013a) private actors.

Besides, given the co-existence of customary and formal governance systems operating in parallel in several African countries (Martin, 2011), there is incessant demand for scientific studies that aim to understand how interrelationships amongst these distinct structures of authority shape forest governance outcomes. This is particularly significant because scholars e.g. Anderson et al. (1998) hypothesize a high likelihood for conflicts between the two overlapping systems of governance.

Additionally, although decentralized forest governance has been widely adopted in several tropical developing countries, Zambia inclusive (Agrawal, 2001, Ribot, 2003a, GRZ, 2002), hardly has its implication on forest governance quality/ performance been explored across regions. Yet, this is relevant for prioritizing governance solutions for each region in the tropics (Charron et al., 2014). The few studies in this regard have been conducted in the temperate developed countries, e.g., Charron et al. (2012) and Charron et al. (2014). The respective studies moreover, use rather general than forest-specific governance measures.

2.3 Linkages between forest governance and deforestation

Understanding governance-deforestation relationships has become a priority topic in the global discussions on forests e.g. New York Declaration on Forests (United Nations Climate Summit, 2014). The subject has as well received growing attention in the recent global environmental change research (Umemiya et al., 2010, Wehkamp et al., 2018, Bhattarai and Hammig, 2004, Li et al., 2005, Abman, 2018). However, the respective studies use rather general than forest-specific governance indicators such as corruption, democracy, voice and accountability, political stability, violence, and rule of law. Although they provide valuable insights, general governance indicators may capture broader phenomena and mask the effects of forest-specific governance aspects on deforestation (Kishor and Belle, 2004, Wehkamp et al., 2018)

The forest-specific governance attributes that have been linked to forest conservation are tenure security (Robinson et al., 2014), land use planning (Nolte et al., 2017), participatory policy processes (Wright et al., 2016), law enforcement (Nugroho et al., 2018, Tacconi et al., 2019) and governmental, non-governmental and customary institutions (Banana et al., 2001, Ostrom, 2009). Equally, included are the diverse arrangements that specify the fundamental governance features on tenure (Holland et al., 2014, Robinson et al., 2014), access and use restrictions (Pfaff et al., 2014), and the institutions with the responsibility for forest management (Lund et al., 2009). However, governance attributes are only part of the underlying drivers of deforestation (Geist and Lambin, 2001). Thus, the role of other underlying and proximate drivers and factors ought to be considered in the governance-deforestation relationships.

2.4 Linkages between forest governance and forest transition (FT) dynamics

Classical FT theory posits socioeconomic factors as the key determinants of the changes in the FT phases (Rudel, 1998, Rudel et al., 2005, Wolfersberger et al., 2015). Even so, long-term trends indicate that socioeconomic factors can only influence forest cover positively if there are supportive governance structures i.e. institutions, rules and their implementation (Liu et al., 2017). This implies that governance is an important factor, which influences the socioeconomic effects on FTs (Bhattarai and Hammig, 2004). This is also, reinforced by the theory on the tragedy of the commons, which predicts that private interests will lead to destruction of public goods including forests, if there are no governance structures to regulate the economic activities of agents. Improved forest governance, by limiting illegal activities, permits efficient, sustainable and equitable use of forest resources, which in turn induces inclusive socioeconomic growth and an accompanied decrease in natural resource dependence (PROFOR, 2011, Davis et al., 2013, van Bodegom et al., 2012, Wolfersberger et al., 2015). Conversely, evidence suggests that poor forest governance fosters inequitable socioeconomic growth, which frequently pushes disadvantaged farmers to migrate further into forestlands that they convert to agricultural lands (Riggs et al., 2018, Riggs et al., 2020, Buys, 2007). Moreover, because forest governance involves restrictions on human exploitation of forest resources, it may have substantial impacts on FTs even where the economic preconditions for turning point are unmet (Barbier and Tesfaw, 2015, Bebber and Butt, 2017).

Recent studies have contributed to an understanding of the governance features that are likely to affect the forest transition, i.e. constrain deforestation and facilitate forest recovery. They include robust legal frameworks (Riggs et al., 2018, Wolfersberger et al., 2015) and credible and strong institutions (Paudel et al., 2014, Ametepeh, 2019, Bhattarai and Hammig, 2004) that effectively enforce good quality forest policy and support sustainable forest management (Barbier and Tesfaw, 2015). Similarly included are the governance arrangements that provide for participatory planning (Buys, 2007) and forest management (Ametepeh, 2019) and those that recognise and protect individual and communal rights to forest resources (Youn et al., 2017, Porter-Bolland et al., 2012). Those arrangements foster tenure security and local legitimacy of forest rules and minimise land use conflicts (Buys, 2007, Mather, 2007). Other governance arrangements that are associated with the FT i.e. lower deforestation and higher forest recovery are the intervention that incentivise landowners to retain or increase forests (Angelsen and Rudel, 2013) and those that restrict the clearing of forest even in weak economic settings e.g. protected areas (Gizachew et al., 2020, Buys, 2007, Singh et al., 2017).

However, most deductions on the governance effects on forest transitions are mainly generated through national scale analyses, with hardly any local scale based inferences in this regard (He et al., 2014). Yet, implementation of forest legislation and institutional reforms mainly occur at the local scale (Secco et al., 2014). The socioeconomic processes of household decision-making, which are highly diverse and crucial to understand forest cover dynamics also transpire at the local scale (Perz and Walker, 2002). Accordingly, it is necessary to complement the exclusively national focus with studies of FT that emphasize governance effects at the local scale (Ametepeh, 2019, Angelsen and Rudel, 2013).

3 Materials and methods

This chapter gives an overview of the study area as well as data sources and analytical approaches used in publication I (Nansikombi et al., 2020a), addressing objectives I and II, publication II (Nansikombi et al., 2020b), addressing objective III, and publication III (Nansikombi et al., submitted), addressing objective IV. Because this thesis was embedded in a wider interdisciplinary research project entitled Landscape Forestry in the Tropics, LaForeT (www.la-foret.org), different governance, socioeconomic, biophysical and forest cover data from project partners were available for the research. For purposes of transparency, project partners who provided data are acknowledged in the citations.

3.1 Study site selection

The empirical evidence for addressing objectives: (I) on determining if the GFI framework differentiates distinct aspects of forest governance based on the perception of the local population, (II) on determining if the quality of forest governance varies across governance arrangements with differing tenure and use restrictions and communities in provinces with differing local government administration in the tropics and, (III) on examining the influence of forest governance on deforestation at the local scale in the tropics was generated from 24 communities in Zambia. Zambia presents a highly relevant context for analysing forest governance quality and its effects on deforestation and testing the applicability of the widely recommended GFI framework because of its alarmingly high deforestation rates, i.e about 0.63% annual forest loss between 2000 and 2018 (Hansen et al., 2013b, Global Forest Watch, 2018), despite its policy reforms and initiatives that consider forest governance improvements, e.g. decentralization and REDD+. Zambia also comprises diverse forest governance arrangements, which reflect the variations in the fundamental governance aspects on tenure (i.e. customary and state), institutions or actors with the responsibility for forest management (i.e. private, communal and state) and restrictions to forest access and use (i.e. restricted and non-restricted). The arrangements range from (i) hierarchical command and control systems in state-owned National Forest Reserves and National Parks to (ii) participatory arrangements with restrictions of forest use and management in state-owned Local Forest Reserves, and Game Management Areas, to (iii) inclusion of communities, customary institutions and private entities into forest conservation initiatives in customary and private forests (GRZ, 2015a, GRZ, 2015b).

The empirical evidence for addressing objective IV on examining the linkages between governance and socioeconomic factors to the FT dynamics was generated from Ecuador, Philippines and Zambia (Figure 2). Those three countries present a diverse array of tropical forest cover and deforestation dynamics that permit capturing the different FT phases also at the local scale. The countries also provide a variant but methodologically comparable set of socioeconomic and governance conditions across the geographical regions. The countries as such represent different FT phases according to Köthke et al. (2014).

3.1.1 Zambia

Zambia is a landlocked country located between Southern and Central Africa. As shown in Table 1, at the start of our study in 2016, the country had a high forest cover (65.2%) and a moderate deforestation rate i.e. about -0.3% yr^{-1}(FAO, 2015). The population density (22 persons/km^2) and GDP per capita, purchasing power parity (3467.87 USD) were relatively low (World Bank Group, 2016b). The globalization index, which reflects the effect of globalization on the economic growth was quite low in Zambia as compared to Ecuador and Philippines (Gygli et al., 2019). Although varying across regions, the main driver of deforestation in Zambia like the Philippines is shifting agriculture (Vinya et al., 2011). According to the same source, another important reason for deforestation and forest degradation is that governance is often too weak to counteract the direct drivers of deforestation. Timber logging, infrastructure extension, charcoal production, firewood collection, and livestock grazing are also important drivers of deforestation in Zambia (Vinya et al., 2011).

In Zambia, the study was conducted in in the Miombo woodlands. Characterized by the dominance of *Brachystegia*, *Julbernadia* and *Isoberlinia* species, the Miombo is the most extensive forest type in Zambia, covering 45% of the total land area (Matakala et al., 2015). The Miombo is also one of the five global biodiversity hotspots (Mittermeier et al., 2003), harboring about 8,500 higher plant species (Frost, 1996), 54% of which are endemic (Rodgers et al., 1996). Additionally, on average the woodland sequesters between 0.5 and 0.9 tons of carbon per hectare annually (Chidumayo, 2014, Williams et al., 2008), contributing to global climate change mitigation. Further, over 100 million rural people directly rely on Miombo´s timber and non-timber forest products for income (Gumbo et al., 2018, Bradley and Dewees, 1993). Despite its importance, deforestation and forest degradation persist in the Miombo (Vinya et al., 2011, Chomba et al., 2012, Kalinda et al., 2008, Campbell et al., 2007), weakening its ability to provide forest ecosystems goods and services (Millennium Ecosystem Assessment, 2005).

In the Miombo the study was conducted in three provinces, Copperbelt, North-western and Eastern. These were selected to represent different socioeconomic and demographic conditions as well as different forest cover and deforestation contexts (Table 1). North-Western is characterized by a low population density, estimated at 8 persons/km^2 in 2017 (Worldpop, 2018), high forest cover (71%) with a tree cover larger than 30% in 2010 (Global Forest Watch, 2019), and unsustainable timber extraction as the main driver of deforestation (Shakacite et al., 2016). Medium to low deforestation rates have been observed, with an annual average tree cover loss of 0.30% between 2013 and 2017 (Global Forest Watch, 2019). According to the same sources, Eastern province has a medium population density, estimated at 38 persons/km^2 in 2017, low tree cover (14%) and a relatively low rate of tree cover loss (0.40% annually) between 2013 and 2017, mostly from small-scale crop agriculture. Copperbelt is characterized by a very high population density, estimated at 76 persons/km^2 in 2017, medium to high tree cover (60%), and high rate of tree cover loss (1.16% annually) between 2013 and 2017, mostly from unsustainable charcoal production.

Table 1: Description of the demographic, economic, socio-cultural, forest cover and deforestation attributes of the study provinces in Zambia. Sources: Forest cover and deforestation rates (Global Forest Watch, 2019), Population density estimates (Worldpop, 2018), Main drivers of deforestation (Shakacite et al., 2016). Poverty incidence (Central Statistical Office, 2018). Dominant ethnicity and share of urbanized population (Central Statistical Office, 2016).

Attributes	**Zambia**	**Copperbelt**	**North-Western**	**Eastern**
Forest cover (2010) (Tree cover >30%)	30%	60%	71%	14%
Deforestation rates	High	High	Medium-Low	Medium-Low
(Mean annual tree cover >30% loss 2013-17)	-0.52%	-1.16%	-0.30%	-0.40%
Population density 2017 (people/km^2)	22	76	8	38
Poverty incidence (%)	-	30.80	66.40	70.00
Urban share of the population (%)	41.80	83.00	27.20	12.20
Dominant ethnicity	-	Bemba	Luvale	Chewa
Main driver of deforestation	-	Charcoal production	Timber extraction	Shifting agriculture

3.1.2 Ecuador

Ecuador is located at the Pacific side of North-Western South America. The country is a mega-biodiversity hot spot that covers the Andes and Amazon basin. In 2016, Ecuador had reduced its forest cover to 50.2% and the deforestation rate was still relatively high i.e. -0.6% yr^{-1} (FAO, 2015). Ecuador had more than twice the population density of Zambia i.e. 66 persons/km^2, with a share of 63.99 % of the urban population and a high GDP per capita, purchasing power parity i.e. 11551.62 USD (World Bank Group, 2016b). The main driver of deforestation in Ecuador is shifting agriculture. Small-scale ranching and more locally, commodity production e.g. palm oil are also important drivers of deforestation in Ecuador (Piotrowski, 2019).

In Ecuador, the study was conducted in the lowland rainforest frontiers of the Central Amazon (Napo, Pastaza, and Orellana provinces) and the Chocó-Darién (Esmeraldas province) (Figure 2). According to Marchese (2015) and Barthlott et al. (2007), the two regions are biodiversity hotspots holding about 6.3 M ha of forests, and accounting for 68% of the legally harvestable timber volume of suitable quality in Ecuador. Despite their biological significance, Central Amazon and the Chocó-Darién regions are highly prone to deforestation.

3.1.3 Philippines

The Philippines is an archipelago country of Southeast Asia in the western Pacific Ocean. Philippines recorded a net forest cover increase of 0.8%, annually between 1990 and 2015, with less than 30% of the forest cover left in 2015 (FAO, 2015). In 2016 the Philippines were densely populated i.e., 348 persons/km^2, exhibited the highest road density among the three countries and had 41.72% of its land under agricultural production (FAO, 2015). At 0.00, on a scale ranging from -2.5 to +2.5, Philippines had better-quality regulations than Zambia at -0.48 and Ecuador at -1.02 in 2016 (World Bank Group, 2016a). Forest cover loss in the Philippines is mainly attributed to commodity-driven agriculture expansion (Curtis et al., 2018). Forestry practices and urbanization also play a more significant role in the Philippines as compared to Zambia and Ecuador (Curtis et al., 2018).

In the Philippines, the study was conducted in three provinces, Leyte, North Cagayan Valley and South Cagayan Valley (Figure 2).

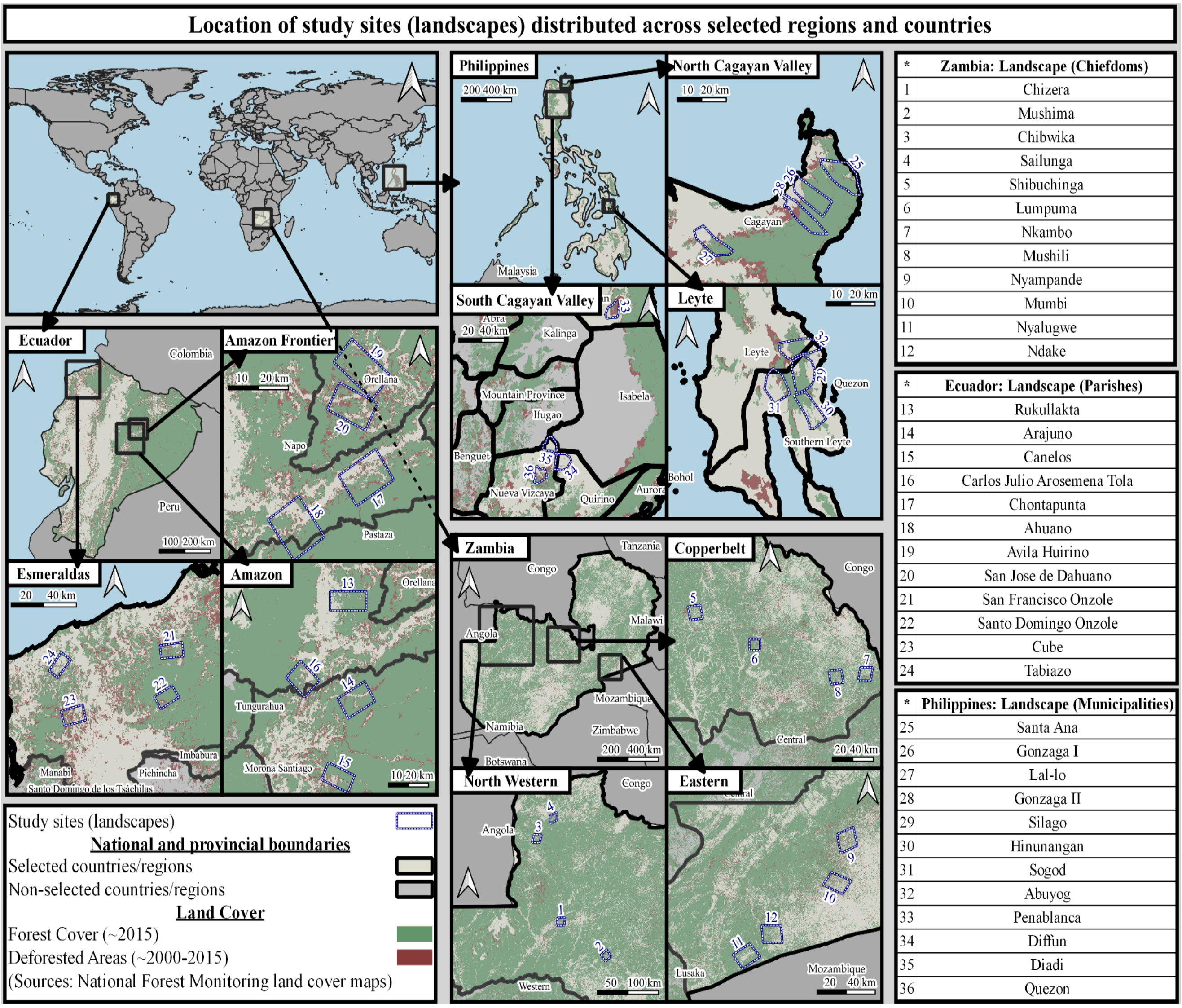

Figure 2: A map showing the location of selected countries and landscape. Illustrated by the author.

Within each country, three regions were selected to capture the different FT phases, totalling to nine regions. Within each of the nine regions, four landscapes each of approximately 100-150 km^2 were selected, thus resulting in 36 landscapes (Figure 2). The 36 landscapes correspond to distinct country-specific administration units, i.e., chiefdoms, parroquias and municipalities in Zambia, Ecuador and Philippines, respectively, which were selected to ensure homogenous formal administration across landscapes. The landscapes were selected to represent typical land-use, socioeconomic, demographic, and biophysical attributes of their respective regions. Each landscape constituted about 2-5 communities, each with one or more governance arrangements. The different arrangements reflect important variations in tenure, rules and actors/ institutions in forest management. The arrangements constituted the unit of observation for the governance and biophysical assessments. For the socioeconomic assessment, a household constituted the unit of observation.

To address objectives I, II III, the governance arrangements were used as the unit of analysis (Figure 3). Governance arrangement are specific expressions and combinations of the basic governance components, i.e institutions/actors, rules and their interactions, and constitute key spatial units of assessment in governance studies. To address objective II, a community was additionally used as a unit of analysis. In Zambia, the country used as the case for addressing objective II, a community, constitutes a group of people living together who share natural resources and are tied together by local traditions, rules and values under the leadership of a section head/sub-chief (Twumasi and Freund, 1985, Madzudzo et al., 2013). To address objective IV, the landscape was used as the unit of analysis (Figure 3). The landscape permits simultaneous framing of social and ecological aspects (Sayer, 2009, Sayer et al., 2013).

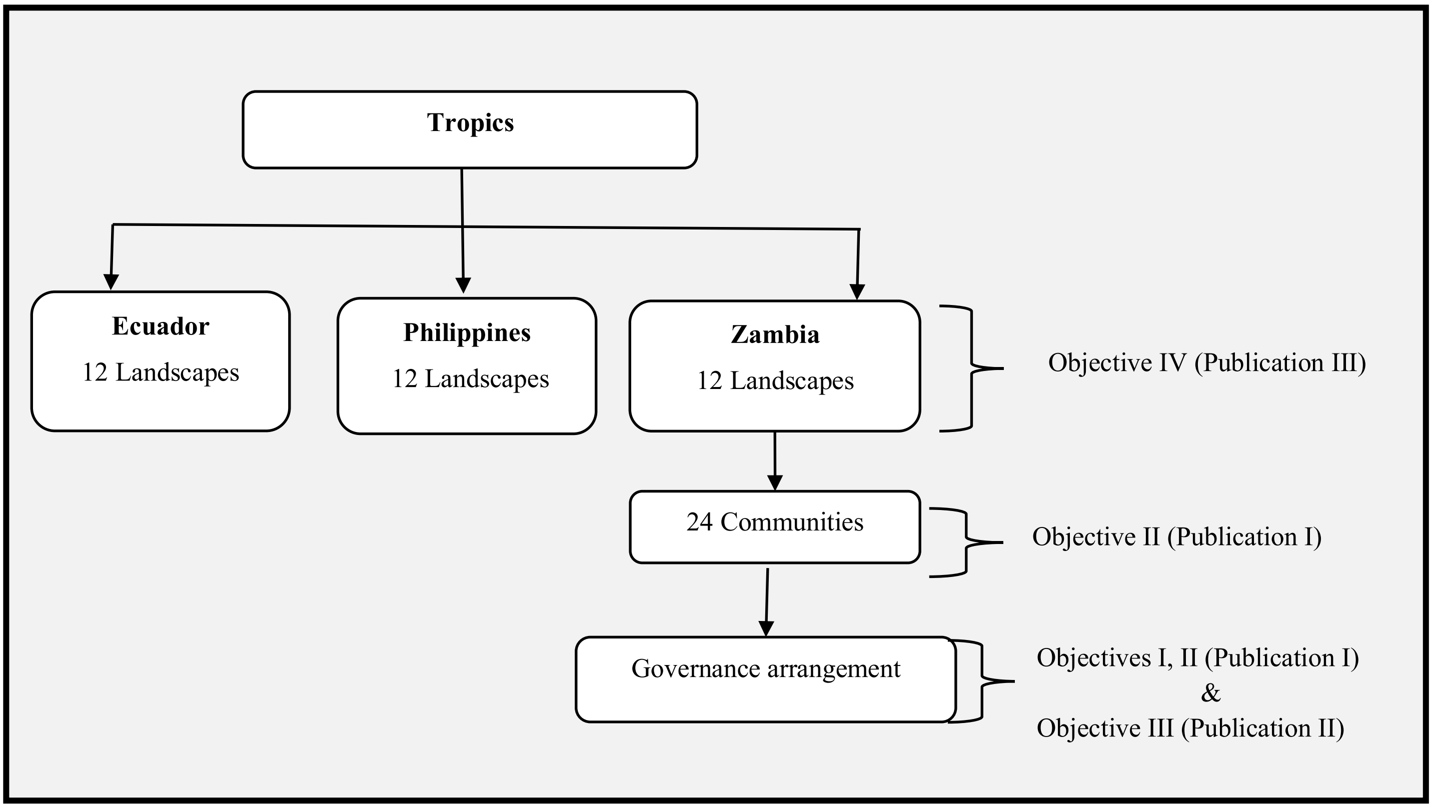

Figure 3: A figure showing the level of analysis for each research objective. Illustrated by the author.

3.2 Data sources and processing

To address objectives: (I) on determining if the GFI framework differentiates distinct aspects of forest governance based on the perception of the local population and, (II) on determining if the quality of forest governance varies across governance arrangements with differing tenure and use restrictions and communities in provinces with deferring local government administration in the tropics, the study exclusively uses governance data (Table 2). To address objective III on examining the influence of de facto forest governance on deforestation a combination of governance data and data on deforestation rates and proximate and other underlying drivers and factors is used. To address objective IV on examining the linkages between governance and socioeconomic factors and the FT dynamics in tropical landscapes, the study combines governance data, data on FT phases and socioeconomic and biophysical data (Table 2).

The landscapes are categorised into FT phases using Geographical Information systems (GIS) Governance data were obtained through focus group discussions (FGDs) and participatory mapping. Data on deforestation rates were obtained through GIS. Data on proximate and other underlying drivers and factors were obtained through a combination of GIS, particpatory mapping and FGDs. Data on socioeconomic factors were obtained through a household survey. Data on the biopysical factors were obtained through GIS (Table 2). The data collection and processing methods are presented in detail below.

Table 2: Different types of data used for addressing the different objectives in the study. FGDs, Focus group discussions, GIS, geographical information systems. Illustrated by the author

Objective	Variable category	Data type	Data collection method
I	Dependent	Governance indicators	FGDs
II	Dependent	Governance indicators	FGDs
	Independent	Governance arrangements	Participatory mapping
III	Dependent	Deforestation rates	Extrapolation from satellite data using GIS
	Independent	Governance indicators	FGDs
		Governance arrangements	Particpatory mapping
	Control	Proximate drivers	FGDs, GIS, participatory mapping
		Other underlying drivers and factors	Extrapolation from satellite data using GIS
IV	Dependent	Categories of FT phases	Extrapolation from satellite data using GIS

Independent	Governance indicators	FGDs, participatory mapping
	Restricted governance arrangements	Particpatory mapping
	Socio-economic factors	Household Survey, GIS
Control	Biophysical factors	Extrapolation from satellite data using GIS

3.2.1 Categorization of study landscapes

The FT phases constituted the outcome (dependent) variable in the analysis to address objective IV (Table 2). Following the methodology described by Hosonuma et al. (2012) and Da Fonseca et al. (2007), the 36 landscapes were grouped into four FT phases i.e. pre-transition, early transition, late transition and post-transition, based on two factors: percentage forest cover and rate of forest area change. A decision tree (Figure 4) was developed for categorizing the 36 landscapes into four FT phases and is based on the most recently available data sets for forest cover per country (Table 3). The percentage forest cover of 2016 was used for Zambia and Ecuador while that of 2015 was used for Philippines, contingent on data availability (see data sources in Table 3). Forest cover change rates were calculated based on the amount of annual forest change relative to forest cover in 2000 for Zambia and Ecuador and 2003 for Philippines for two time periods using national level map information derived from government authorities or related project archives (Table 3). An annual forest area loss rate of -0.35% was used to separate between pre-and early transition landscapes. A forest cover of 60% was used as the minimum thresholds for high forest cover and 25% as the maximum thresholds for low forest cover. A forest area change rate of 0% was selected as an additional threshold (Figure 4). The limitation of this approach is that the FT phase of landscapes can change depending on the thresholds of forest cover and forest cover loss.

Table 3: The two periods used to calculate the amount of annual rate of forest area change for the landscapes in each country: Source (NAMRIA, 2013, ESA, 2017, MAE, 2015, RCMRD, 2010). Illustrated by the author

Landscape country of location	**Annual forest area change**			
	Period 1	**Source**	**Period 2**	**Source**
Zambia	2000-2010	RCMRD Maps	2010-2016	ESA maps
Ecuador	2000-2008	MAE Maps	2008-2016	MAE Maps
Philippines	2003-2010	NAMRIA Maps	2010-2015	NAMRIA Maps

Of the 36 tropical landscapes, 11 were in the pre-transition phase, 14 in early transition, 4 in late transition and 7 in post-transition.

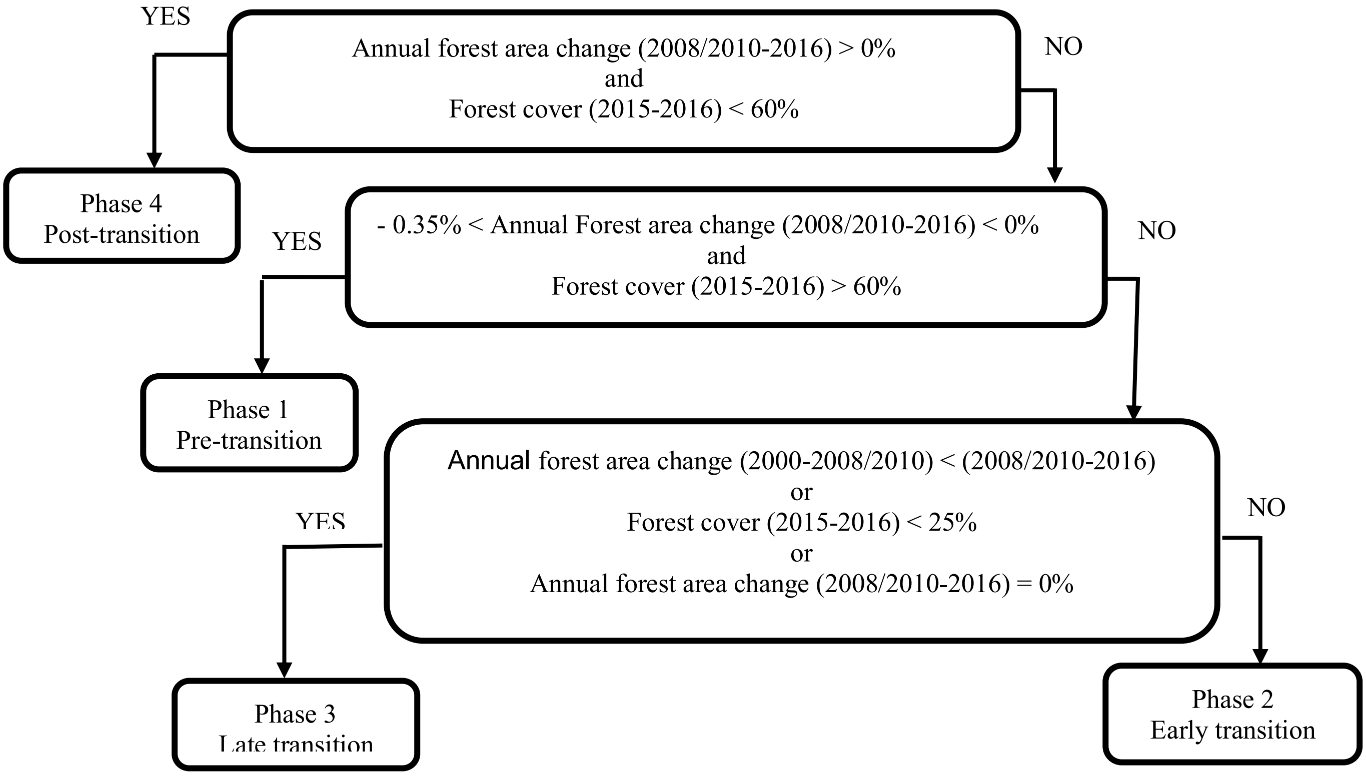

Figure 4: Decision tree for FT categorization. Adapted from Hosonuma et al. (2012).

3.2.2 Scoping visits

Scoping visits were conducted in each of the 36 landscapes as a preliminary step. In these visits, it was ensured that the landscapes and communities fitted within the objectives of the study and the willingness of the communities to participate and cooperate with the research project was confirmed. The visits also enabled the identification of relevant de jure governance arrangements, representing different tenure and restrictions to forest access and use within each landscape. Contacts to representatives from all communities and major stakeholder groups within each landscape were also established during these visits.

3.2.3 Governance data

Focus group discussions (FGDs) (O. Nyumba et al., 2018) were carried out to conduct governance assessment and participatory mapping exercises aiming to identify the locally perceived, de facto, governance arrangements and land use patterns. Focus group discussions were carried out in all 36 landscapes, each with about 15-20 key stakeholder representatives including community leaders, customary leaders and forest committee representatives. Participants comprised men and women, including young persons from 18-30 years and adults from the communities in the landscape. This enabled broad representation of decision makers and social groups in the landscape. Despite the fact that FGDs are perception-based methods, they capture the reality that exists on the ground, which differs from the fact-based notions of laws (Kaufmann et al., 2011). Participatory mapping (Martin et al., 2012) was essential to create awareness on the focus governance arrangements and to ensure that subsequent governance assessment was done in a spatially consistent manner. The participatory mapping exercises were carried out between August 2016 and October 2018 using recent colour print outs of high-resolution Google Earth satellite images of approximately 80*120 cm (Fischer, 2020, Nansikombi et al., 2020a [Publication I]).

3.2.3.1 Classification and delineation of governance arrangements

Governance arrangements constitute a key independent variable in the analyses to address objectives II, III and IV (Table 2). In the participatory mapping exercise, while referring to the de jure categories of governance arrangements in each country, participants were asked to distinguish and delineate the de facto arrangements within the different communities in the landscape using the satellite image print outs. The de facto arrangements were differentiated based on tenure, ownership status and access and use restrictions in the respective countries. The local categories were assigned to general categories using a coding system to permit comparable analysis of categories across countries (Fischer, 2020, Nansikombi et al., 2020a). Between 3 to 7 major categories of de facto governance arrangements per country were identified by local stakeholders, depending on the country and region of context as summarised in Table 5. The polygons of the mapped governance arrangements within each landscape were digitized using QGIS. Overall, 91 arrangement polygons were digitised in Zambia, 80 in Ecuador and 22 in the Philippines (Table 5).

Table 5: Categories and coding system for de facto forest governance arrangements generated from the participatory mapping exercises within each country. No implies number of cases within each country. CADT- Certificate of Ancestral Domain Title, CBFM- Community Based Forest Management Agreement, IPR-Individual Property Rights, ISF - Integrated Social Forestry, PACBRMA - Protected Area Community Based Resource Management Agreement and PANE - Heritage of Natural Areas (Patrimonio de Áreas Naturales del Estado). Obs implies number of observations. Each category of governance

arrangement within a given community in a landscape constitutes an observation. Adapted from Fischer (2020), Nansikombi et al. (2020a) and Nansikombi et al. (2020b).

General code	Philippines	Obs	Ecuador	Obs	Zambia	Obs
1. Communal						
1.1 Communal with no title						
1.1.1 Individually managed			Communal	2	Individual customary	24
1.1.2. Jointly managed					Communal customary	22
1.1.3. Customary restricted					Culturally restricted	8
1.1.4. Formally restricted						
1.2. Communal with title	PACBRMA CADT, CBFM	9				
1.2.1 Individually managed			Communal	29	Individual customary	2
1.2.2. Jointly managed						
1.2.3. Customary restricted			Indigenous reserves	7		
1.2.4. Formally restricted			Socio Bosque	6		
2. Private		3				
2.1 Private with no title	ISF, IPR	3				
2.1.1. Managed non-restricted			Individual	7		
2.1.2. Restricted						
2.2. Private with title					Private	8
2.2.1. Managed non-restricted land			Individual	26		
2.2.2. Restricted land						
3. State						
3.0.1. Restricted	State forest with logging ban	10	PANE	3	State restricted reserves	6
3.0.2. Non-restricted						
4. Unclarified tenure					Overlapping claims	21
Total number of observations		**22**		**80**		**91**

3.2.3.2 Governance indicator assessment

Governance indicators constituted key dependent variables in the analyses to address objectives I and II and, key independent variables in the analyses to address objectives III and IV (Table 2). The study relies on the Governance of Forests Initiatives framework (GFI) of the World Resource Institute (Davis et al., 2013) to generate information the indicators of forest governance. The GFI framework provides a comprehensive diagnostic tool that covers six core governance issues in forestry referred to as thematic areas (see details in section 1.3). The framework assesses these governance areas through a set of detailed indicators. The GFI framework recommends that the indicators should be adapted based on contextual factors such as scale of assessment, type of forest biome, or ownership regime from the large multitude of governance aspects covered (Davis et al., 2013).

Initially, we selected only the indicators that are relevant for the local scale. These were refined to capture at least one indicator from each of the thematic areas, choosing those that reflect pertinent issues of forest governance in our three study countries (Zambia, Ecuador and Philippines). We finally selected 21 quantitative governance indicators covering all thematic areas. They include

• Thematic area “forest tenure”: (1) recognition and protection of tenure rights
• Thematic area “land use”: (2) formal land use planning.
• Thematic area “forest management”: (3) implementation of land use strategies and plans, administration of licences for (4) timber, (5) charcoal and, (6) non-timber forest products, implementation of (7) reforestation, (8) National Greening Program (NGP) (9) forest protection and conservation, (10) protection and logging moratorium (11) payment for ecosystem services, (12) sustainable, forest-based livelihood programs and enforcement of (13) formal and (14) customary forest laws.
• Thematic area “revenues”: (15) forest revenue distribution and, (16) implementation of benefit sharing mechanisms.
• Thematic area “cross-cutting institutions”: capacities and efficiencies of (17) central, (18) local government, (19) non-government organizations and (20) customary institutions
• Thematic area “cross-cutting issues”: (21) public participation in policymaking.

Within each country, the 21 indicators were adapted to suit the local context after pre-test workshops (Table 2). Each selected indicator was specified by five elements of quality, rated on a scale of pre-coded statements, ranging from low to high governance performance (Appendix A). In the FGD, participants were asked to discuss (based on their experiences) and agree on scores for governance performance that was assigned as a Likert score (Likert, 1932) on a scale from 0 (not present), 1 (very low) to 5 (very high) to each element of quality (Annex A) per governance arrangement. Likert scales transform qualitative data to quantitative data (Flynn et al., 1990). This permits the integration of information across observations or cases (Kirk et al., 1986). The Likert scores of all five elements of quality per indicator were aggregated as the arithmetic mean to derive indicator scores for each of the governance arrangements. All qualitative comments made for the governance scores were also noted. It was not possible to establish contacts to private landowners to a meaningful extent; thus, we could not score governance on private forests. Accordingly, the private arrangements were excluded from the later analysis where governance indicators were needed.

To address objectives I, II and III, only 19 governance indicators that were present in Zambia were considered (Table 6). But only 9 of those were used in the analysis as the rest were not present in all study sites. Of the nine recurrent indicators, only eight were present in all governance arrangements. These are (1) recognition and protection of tenure rights; (2) formal land use planning, (3) formal law enforcement, (4) customary law enforcement, (5) central government, (6) local government, (7) customary institutions and (8) public participation in policymaking. The ninth indicator was "forest conservation and use restrictions" that considered one of the following three original indicators depending on the main management objective of the respective governance arrangement, namely i) timber and ii) charcoal licences and iii) forest protection and conservation.

To address objective IV, only 4 indicators that were present in all study sites in the three countries were considered (highlighted in green Table 6). The analyses with indicators that are applicable in all sites enabled better comparison across all study landscapes. The indicators on customary and formal law enforcement (highlighted in orange in Table 6) both from the "thematic area forest management" were only applicable in specific governance arrangements. However, since at least one of the indicators could be measured for each arrangement and all these represent procedures for enforcing forest laws, they were grouped into one indicator, forest law enforcement. This constituted the fifth governance indicator in the cross-country analyses. This was also the case with the indicators on administration of timber and charcoal licence, protection and conservation and implementation of PES program (highlighted in grey in Table 6) from the thematic area "forest management", which were grouped into one indicator, forest management. Forest management constituted the sixth indicator in the cross-country analyses. Local government and customary institutional capacities and effectiveness (highlighted in blue in Table 6) from the "thematic area crosscutting institutions" were also grouped into one indicator, local institutional capacities and effectiveness, which constituted the seventh indicator in the cross-country analyses. The percentage of restricted area was also included as a potential factor associated with FTs (Yackulic et al., 2011). In Ecuador, Socio Bosque, state protection areas (PANE) and indigenous reserves constituted the restricted arrangements. In the Philippines and Zambia the state forest reserves constituted the restricted forests. This summed up to 8 governance variables in the cross-country analyses.

To address objectives I, II and III, the indicator score for each governance arrangement was used. To address objective IV, the area under each governance arrangement was calculated as a proportion of the landscape. Based on governance assessments per arrangements mean governance values per landscape were calculated as means weighted by the area of the governance arrangement.

Table 6: Description of the governance indicators and the elements of quality by thematic areas of the GFI framework. ✓ implies applicable in the country, - implies non-applicable. Indicators highlighted in grey are grouped into the indicator on forest management in the cross-country analysis. Indicators highlighted in blue are grouped into the indicator on local institutional capacities and effectiveness in the cross-country analysis. Indicators highlighted in orange are grouped into the indicator on law enforcement in the cross-country analysis. Indicators highlighted in green constitute the 4 original indicators in cross-country analysis. Component *Inst* predominantly captures institutions, *R*, rules and *I*, interactions amongst actors or between actors and rules. Adapted from Davis et al. (2013).

Thematic area	Indicator	Component	Philippines	Ecuador	Zambia
Forest tenure	1 Tenure recognition and protection	*I*	✓	✓	✓
Land use	2 Land use planning/decision making	*I*	✓	-	✓
Forest management	3 Implementation of strategies and plans	*I*	✓	-	✓
	4 Timber licences and permits	*R*	✓	✓	✓
	5 Charcoal licences and permits	*R*	-	-	✓
	6 Non-timber forest products licences and permits	*R*	✓	-	✓
	7 Implementation Reforestation programs (Not NGP)	*I*	✓	-	✓
	8 Implementation of National Greening programs (NGP)	*I*	✓	-	-
	9 Protection and conservation	*R*	✓	✓	✓
	10 Protection of natural forests (logging moratorium)	*R*	✓	-	-
	11 Implementation of Payment for Ecosystem Services programs	*I*	✓	✓	✓
	12 Implementation of forest-base livelihood programs	*I*	✓	-	✓
	13 Formal law enforcement	*R*	✓	✓	✓
	14 Customary law enforcement	*R*	-	-	✓
Revenues	15 Revenues	*I*	-	-	✓
	16 Benefit-sharing mechanisms	*I*	-	-	✓
Cross-cutting Institutions	17 Central government capacity and effectiveness	*Inst*	-	-	✓
	18 Local government capacity and effectiveness	*Inst*	✓	✓	✓
	19 Customary institutions capacity and effectiveness	*Inst*	✓	✓	✓
	20 Non-government organizations capacity and effectiveness	*Inst*	✓	✓	✓

Cross-cutting issues	21 Public policy participation	*I*	✓	✓	✓
Number of indicators assessed			**16**	**9**	**19**

3.2.4 Deforestation

Deforestation was used as the dependent variable in the statistical analysis to address objective III (Table 2). The average annual rate of tree cover loss was used as a proxy for the annual rate of deforestation relying on data from Hansen et al. (2013b) as provided by Global Forest Watch (Global Forest Watch, 2018). Similar to related studies in Africa (Potapov et al., 2012, Zabala, 2018, Venter et al., 2018), Hansen et al. (2013a) provide tree cover and change estimates for the study period. The data consists of 30 m ground resolution tree cover maps, based on Landsat's satellite imagery for the entire globe, and allows calculating extent and change of tree cover globally. The average annual rate of tree cover loss (%) using a 30% tree cover threshold was calculated for each individual governance arrangement within 24 communities in Zambia for a five-year period before the fieldwork (2013-2017). Visual validation using Google Earth and Bing Maps suggested 30% as a reasonable threshold to estimate forest cover in our landscapes. Tree cover does not necessarily correspond to forest cover and can be also related to plantations or trees outside forest.

3.2.5 Classification and delineation of main land use types

FGD participants were asked to delineate land use patterns in their community using a classification based on Di Gregorio (2005) as a reference, also taking into account the local conditions. Overall, 11 main land use classes (Appendix B) could be distinguished and spatially delineated during the participatory mapping exercises in Zambia. These were also digitized using QGIS.

3.2.6 Proximate drivers

The proximate drivers were included as control variables in the statistical analysis to address objective III (Table 2). Eight variables represented potential proximate drivers: i) timber, ii) charcoal, iii) pole and iv) firewood use indicated wood extraction; v) livestock grazing and vi) percentage of area under crop agriculture characterized agricultural pressure; vii) distance to the road and viii) percentage of build-up area denoted infrastructure expansion.

Data on extraction of charcoal, firewood, timber and poles and livestock grazing were obtained through the same focus group discussions as already described in Section 3.2.3.

First, participants were asked to discuss and distribute 100 pebbles between benefits based on their importance to the community. Subsequently, they were tasked to locate the land use classes (generated in section 3.2.5) from which each benefit is gained on the map. For each governance arrangement, the degree of extraction/use per benefit was computed as a ratio of the community's assigned pebble score, compared to the size (hectares) of the land use polygon that offers the benefit, expressed as a proportion of the size (hectares) of governance arrangement in which the land use polygon is located. Forest use by people other than community members is mainly captured in the arrangements with overlapping community claims.

Distances to roads were computed from the nearest point of a delineated and digitized governance polygon using open street map data extracts. Percentages of crop and built-up area were computed from the ESA CCI land cover map 2016.

3.2.7 Socioeconomic variables

Socioeconomic variables constituted key predictors in the analysis to address objective IV and control variables in the analysis to address objective III (Table 2).

Six socioeconomic variables were considered to address objective iv: (i) population density, (ii) road density, (iii) crop income, (iv) livestock income, (v) non-farm income and (vi) forest income. Population density reflects the demand for forest and agricultural products (Rademaekers et al., 2010). Road density reveals the level of urbanization (Zhao et al., 2017) and market access (Ulimwengu et al., 2009). Crop income indicates the smallholder households` dependence on crop farming for consumption and commercial purposes. Livestock income reveals smallholder households` dependence on livestock farming for consumption and commercial purposes. Non-farm income represents the presence of alternative opportunities to agriculture and as well the opportunity cost of farm labour (Vedeld et al., 2007, Angelsen et al., 2011). Forest income represents smallholder households` dependence on forest extraction for consumption and commercial purposes.

Data on population density and road density were obtained through GIS. The population density in 2016 was calculated using data from worldpop.org by Sorichetta et al. (2015) for Ecuador, Linard et al. (2012), for Zambia and Gaughan et al. (2013) for the Philippines. Data on road density were obtained from OpenStreetMap. Data on the different income categories were obtained through a household survey. The data set relies on a transnationally harmonized survey of 1123 households in Zambia (Kazungu et al., 2020), 1294 households in Ecuador (Ojeda Luna et al., 2020) and 1005 households in the Philippines (Wiebe, Submitted). Household income categorization and computation methods are based on Angelsen et al. (2011) and Vedeld et al. (2007). For inter-household income comparisons we used adult equivalent units (AEU), precisely the OECD-modified scale (Chanfreau and Burchardt, 2008). We compared national currency values using purchasing power parity (PPP) rates (OECD and EUROSTAT, 2012); thus all income figures are reported as PPP adjusted US $ per AEU. For each country, PPP conversion factors were calculated using the average values for the field work period i.e. 2016-2018 for the Philippines and Ecuador and 2017- 2019 for Zambia. To derive the landscape level value, for each socioeconomic variable, we computed the average value of all the sampled households in the landscape. Country dummy variables were also included in our analysis to account for the possibility that unobserved factors within a particular country affect the outcome independently of the primary variables of interest.

To address objective III, the population density was considered because it is one of the underlying drivers that is strongly linked to deforestation in sub-Saharan Africa (Mayaux et al., 2013, Rudel, 2013, DeFries et al., 2010). However, the population estimates from Worldpop (2018) for the study period are mostly accurate at larger spatial scales and disaggregation would give biased results. For the rough estimation of its influence, the total population in 2017 per governance arrangement was estimated and its correlation with the selected infrastructure variables was established using the Spearman's correlation coefficient (Appendix C). The Spearman's correlation coefficient is a suitable measure of correlation for non-parametric cases (Dytham, 2011). Like (Burgess et al., 2007, Shoshany and Goldshleger, 2002, Stamber et al., 2016), population was strongly correlated with distance to roads and percentage of build-up area. Those variables were included in the model. Economic and socio-cultural drivers e.g. poverty incidence, level of urbanization and ethnicity were also considered and accounted for in the differences across the Zambian provinces (Table 1). Accordingly, dummies for the provinces were integrated in the analysis. Provincial boundaries were computed from the Zambia boundary map for Africa 2007.

3.2.8 Biophysical variables

The biophysical factors constituted control variables in the analyses to address objectives III and IV (Table 2). To address objective IV, five biophysical factors that are posited to influence the FT (Yackulic et al., 2011, Bennett and Barton, 2018) were included: slope, elevation, soil nutrient availability, precipitation, and temperature. To address objective III, slope (Jarvis et al., 2008) and area of governance arrangement represented the biophysical factors.

Data on slope and elevation were derived from the SRTM 90m Digital Elevation Database v4.1(Jarvis et al., 2008). Soil nutrient value data were computed from the harmonised world soil databases and precipitation and temperature data from climatologies at high resolution for the earth's land surface areas (Karger et al., 2017). To address objective iv, all biophysical variables were computed as a mean value for the landscape.

3.3 Statistical analyses

Different statistical analyses were conducted depending on the objective as summarised in Table 7.

Table 7: Summary of the statistical analyses and software used to address the different objectives. Illustrated by the author

Objective	Method used for statistical analysis	Statistical software
I	Factor analysis	JMP 15 (SAS Institute Inc, 2017)
II	Wilcoxon rank test	JMP 15 (SAS Institute Inc, 2017)
	Cluster analysis	JMP 15 (SAS Institute Inc, 2017)
	Principal component analysis	JMP 15 (SAS Institute Inc, 2017)
III	Multiple regression models	JMP 15 (SAS Institute Inc, 2017)
IV	Ordinal generalized linear models	STATA 16 (StataCorp, 2009)

3.3.1 Factor analysis

To address objective I, factor analysis (FA) using principal component factoring and varimax rotation methods was applied to examine the relationships between the elements of quality, indicators and thematic areas of the GFI framework. FA analysis entails the reduction of a large set of correlated predictor variables to a smaller less correlated set called factors, that still contains most of the information in the larger set (Perez, 2017). FA tests whether hypothesized constructs are represented by the measured variables by identifying variables that are correlated with each other (Byrne, 2013). The aim here was to examine whether the factors reproduce the hypothesised relationships between the different elements of quality, indicators and thematic areas of the GFI. The eigenvalue criterion (>1) was used to determine the number of factors. Based on recommendations from Comrey and Lee (2013), only those variables with loadings of 0.5 or greater were considered significant items, and thus belonging to a factor. To determine whether the correlated variables formed a reliable scale that effectively measured the factors, Cronbach's reliability analysis was conducted. Coefficients (α) range from 0 to 1, with values over 0.7 indicating a reliable measure of the underlying concept (Nunnally and Bernstein, 1967, Kline, 2013). Only when indicators belonging to the same GFI thematic area were loaded on the same factor was it concluded that these indicators actually reflect the thematic areas of the GFI framework.

3.3.2 Wilcoxon rank test

To address objective II, a Wilcoxon rank test was applied to determine whether governance quality differed between the restricted state, non-restricted communal customary, non-restricted individual customary and culturally restricted communal customary arrangements in Zambia. This test is recommended for comparing mean ranks when the assumption of data normality is violated (Bridge and Sawilowsky, 1999). Since the data remained skewed, even when a log transformation was performed, this test was applied.

3.3.3 Cluster analysis

To address objective II, a hierarchical cluster analysis based on the factor scores from the factor analysis (Section 3.3.1) was additionally used to identify patterns in governance performance of communities. Hierarchical clustering, unlike other clustering procedures, does not require a pre-specified number of clusters (Kaushik and Mathur, 2014). Accordingly, it was appropriate for this study, which was aimed at exploring the likelihood for the emergence of clusters. Moreover, by using the factor scores, we wanted to avoid any potential multicollinearity, which could result in an overrepresentation of single variables (Sarstedt and Mooi, 2014). In particular, the Ward criterion with Euclidean distances, which is often recommended as the best method for detecting group structures in data was ran (Lassar and Kerr, 1996). Communities falling within the same cluster were interpreted as reflecting similar governance conditions. As data on factor scores were not distributed normally, a Wilcoxon rank test was used for the comparison of clusters. Conversely, the data on mean factor scores were distributed normally so that the student´s t test was used for the comparison of clusters.

3.3.4 Principal component analysis

To address objective II, a principal component analysis (PCA) was also performed to determine whether community clusters reflect the provincial governance structure. PCA results were visualised using a score plot showing the distribution of community clusters along the two principal components that constituted the largest variations. The closer the communities were together on the score plot, the more similar their performance was related to the two principal components. Additionally, when all the communities from one province were grouped exclusively in the same cluster, it was inferred that provincial administrative structures determine patterns of community clusters, thus forest governance performance, and vice versa.

3.3.5 Multiple regressions

To address objective III, multiple regression models were run to analyse linkages between deforestation, governance attributes, proximate and other drivers. The multiple regression model had the form:

$$Y = B_0 + B_1X_1 + B_2X_2 + \cdots + B_kX_k + \varepsilon$$

Here, *Y* is the dependent variable, average annual rate deforestation between 2013 and 2017; X_1, X_2….X_k predictors; B´s, the parameters estimates or regression coefficients and ε, error.

The error, ε is assumed to follow a normal distribution with zero mean and variance σ^2 for any values of predictors.

The backward elimination method was used to determine the set of optimal predictors. Backward elimination is appropriate for selecting those factors that contribute most strongly to the regression model when the number of variables is high (Hocking, 1976), as was the case in this analysis. Akaike Information Criteria (AIC) was used to judge the importance of variables (Motulsky and Christopoulos, 2004). A variation inflation factor set limit < 2.5 was used to confirm the absence of multicollinearity between the predictors in the model (Craney and Surles, 2002).

Two models were specified in the analysis, both using the average annual rate of deforestation between 2013 and 2017 as the dependent variable. The models differed in the initial variables that constituted the predictors. In the first model, only the proximate and other drivers constituted the predictors. The second model added governance attributes (governance indicators and arrangements) to the predictors of the first model.

Although nineteen governance indicators were selected initially in Zambia, only nine were used in the second model, as the rest were not available in all study sites and communities (see details in Section 3.2.3.2). The regression model with indicators that are available in all sites enabled better comparison across all study sites and communities. Of the nine recurrent indicators, only eight were present in all governance arrangements.

Due to the absence of governance data for the private (10) and overlapping arrangements with private claims (1), only 80 of the 91 observations were included in the regression analyses (see Table 5 for details on number of observations per category of governance arrangement).

The dependent variable, average annual rate of deforestation was found positively skewed via a Shapiro-Wilk test with a p-value <.0001. It was thus transformed with a square root function to ensure normal distribution (Freeman and Tukey, 1950, Thacker and Bromiley, 2001). To ensure comparability of units all observations for the predictors were standardised (Dytham, 2011).

Shapiro-Wilk tests were applied to the residuals generated by the models to verify conformity to the assumptions of normality (Dytham, 2011). To verify whether the multiple regression models conform to the assumption of homoscedasticity (Hayes and Cai, 2007), we applied Bartlett´s test for homogeneity of variances by comparing the residuals across two categories of predicted values, generated by a median split (Bartlett, 1937).

3.3.6 Ordinal generalized linear models

To address objective IV, ordinal generalized linear models (oglm) were run to analyse the linkages between governance and socioeconomic factors and the FT phases. Because the outcome variable, the categories of FT phases, have a natural sequential order i.e. (i) pre-transition followed by (ii) early transition, (iii) late transition and finally, (iv) post-transition, the ordinal generalized linear models provides a good theoretical fit for the data (Agresti, 2010). The model moreover relaxes the proportional odds assumption for all explanatory variables (Fu, 1998), which was required for the data.

Two models were estimated to distinguish the factors which are relevant for deforestation and forest recovery. In both models governance, socioeconomic and biophysical factors constituted the explanatory variables. Only the categories of the outcome variable differed between the models to understand the implication of segregating deforestation and forest recovery in FT analysis. The categories of the outcome variable in the first model constituted all the four FT phases to reflect deforestation and forest recovery. In the second model, the categories of the outcome variable comprised only the three phases of deforestation. According to Long and Long (1997), for an ordered variable y with m categories, the probability of being in the FT phase j is written as:

$$\Pr(y_i > j) = g(x_i\beta') = \frac{\exp(x_i\beta' - \tau_j)}{1 + \exp(x_i\beta' - \tau_j)}, j = 1, \ldots. m - 1$$

Where x_i is a (k x 1) vector of observed non-random explanatory variables, β' is (k x 1) vector of unknown parameters to be estimated. The parameters of the model (β') and the cut-points (τ_1 and τ_2) are estimated by the method of maximum likelihood (Long and Long, 1997). In the model, β is not fixed across equations and the parallel-lines constraint is relaxed for all variables.

Prior to each regression analysis, factor analyses using principal component method were conducted for each category of explanatory variables i.e. governance, socioeconomic and biophysical variables separately, to reduce the likelihood of multicollinearity within each category.

The first factor analysis reduced the 8 governance variables into 2 principal factors that together explained 68.8 % of the variations in governance conditions for the three-phase model and 68.5 % for the four-phase model (Appendix D). For both models, the first governance factor was positively correlated with the capacities and efficiencies of (i) government, (ii) non-government organizations and (iii) local institutions and (iv) public policy participation and (v) formal law enforcement. It was interpreted as representing institutional capacities and effectiveness (Appendix D). The second factor was positively correlated with (i) tenure rights recognition and protection, (ii) forest law enforcement and (iii) forest management and negatively correlated with (iv) percentage of restricted area. The second factor was interpreted as representing access to forest resources.

The second factor analysis reduced the 6 socioeconomic variables into 3 principal factors that together explained 86.2% of the variations in socioeconomic conditions for the three-phase model and 87.2% for the four-phase model (Appendix E). For both models, the first socioeconomic factor, was positively correlated with (i) crop income (ii) livestock income and (iii) non-farm income (Appendix E). It was interpreted as representing non-forest income. The second factor was positively correlated with (i) population density and (ii) road density (Appendix E). It was interpreted as representing human population pressure. The third factor was strongly correlated with forest income and thus, interpreted as representing forest income.

The third factor analysis reduced the 5 biophysical factors into 2 principal factors that together explained 84.8% of the total variations in biophysical conditions for the three-phase model and 85.0% for the four-phase model (Appendix F). For both models, the first biophysical factor was positively correlated with (i) temperature (ii) slope and (iii) precipitation and negatively correlated with elevation (Appendix F). It was interpreted as mostly representing elevation. The second factor was positively correlated with (i) soil nutrients and (ii) precipitation (Appendix F). It was interpreted as representing soil fertility.

After the factor analysis, correlation analyses were conducted between the resultant principal factors that were to be included in each model. Correlation statistics (Appendices G and H) indicate that multicollinearity is less likely to be a significant constraint in the subsequent regression analyses. The correlation coefficients between the different factors are less than 0.8, the threshold for multicollinearity (Midi et al., 2010).

Because the processes by which FT occurs can affect the socioeconomic and governance conditions (Meyfroidt and Lambin, 2011), there is potential for endogeneity in our regression models. In absence of suitable instrumental variables to account for the endogeneity problem, we restrict our deductions to associations.

Since socioeconomic data could not be obtained for 2 landscapes in the Philippines, they were excluded from the regression analyses.

Given that the estimated coefficients from an ordinal generalized linear models are difficult to interpret as they are in log-odds units, we additionally estimated the average marginal effects. Marginal effects are interpreted relative to the category and sign. A positive coefficient for a category indicates that an increase in the respective variable increases the probability of being in that category, whereas a negative coefficient indicates a decrease in probability of being in the respective category (Agresti, 2010, O'Connell, 2006). All variables were standardised prior to the regression analysis.

4. Results

This chapter summarises the results obtained for each objective addressed by the three publications that form the basis for this dissertation thesis.

4.1 Relationships between the GFI thematic areas, indicators and elements of quality

The first three factors, which together explain 52.58% of the variation, are characterized by loadings of five elements of quality (Table 8). The first factor, accounting for 18% of the variance, correlated primarily with the indicator of formal law enforcement from the thematic area "forest management". The second factor, constituting 17.6% of the variance correlated primarily with the indicator of formal land use planning, from the thematic area "land use". The third factor, which explained 17% of the variance, correlated primarily with the indicator of customary law enforcement from the thematic area "forest management".

Each of the remaining four factors was characterized by loadings of a few (less than five) elements of quality (Table 8). Those elements allow the following interpretation of the meaning of these factors: the fourth represents central government capacities and effectiveness from the thematic area "cross-cutting institutions"; the fifth, traditional institutions capacities and effectiveness, thematic area "cross-cutting institutions"; the sixth, local government capacities and effectiveness, thematic area "cross-cutting institutions" and the seventh, tenure rights enforcement, thematic area "forest tenure". Moreover, some elements of quality loaded on different thematic areas than those they were hypothesised to represent i.e. factor five comprised tenure rights recognition from the thematic area "forest tenure" and traditional institution capacities and effectiveness from the thematic area "cross-cutting institutions".

Cronbach´s reliability analysis confirmed that the elements of quality, which correlated with the first three factors formed reliable measures for these underlying dimensions, with α coefficients of 0.92 for formal law enforcement, 0.89 for formal land use planning and 0.92 for customary law enforcement (Table 8).

Other elements of quality representing conservation and use restrictions (thematic area "forest management") were not present in all governance arrangements. Thus, their factor loadings could not be calculated. The data on the elements of quality for the indicator on public policy participation (thematic area "cross-cutting issues") and several institutional capacities including human resource, financial and scientific and technical information (all thematic area “cross-cutting issues”) were not variable. Therefore, their factor loadings could not be calculated (Table 8).

Table 8: Results of factor analysis showing relationships between GFI framework thematic areas, indicators and elements of quality (N=64). Factor loadings > 0.5 (highlighted in red) imply that variable correlated highly with the factor. Cronbach's α > 0.7 implies a reliable measure of the underlying indicator (Nansikombi et al., 2020a).

Thematic area	Indicator	Elements of quality	Assigned meaning of the Factors						
			Formal law enforcement	Land use planning	Customary law enforcement	Central government	Traditional institutions	Local government	Tenure rights enforcement
			Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Forest tenure	Tenure rights recognition and protection	Recognition	-0.17	0.09	-0.10	-0.18	**0.77**	0.14	0.03
		Demarcation	0.22	-0.15	-0.02	0.07	-0.23	0.18	**0.64**
		Enforcement	0.17	0.14	0.36	0.20	-0.16	-0.18	**0.49**
		Gender equity	0.24	0.03	0.28	0.21	-0.27	0.10	**-0.65**
		Tenure harmony	-0.52	0.02	0.07	0.40	-0.12	0.28	0.10
Land use	Formal land use planning	Procedures	0.41	**0.57**	-0.04	0.12	-0.37	-0.07	-0.16
		Transparency	-0.08	**0.98**	0.17	0.01	0.05	0.02	-0.01
		Participation	-0.08	**0.98**	0.17	0.01	0.05	0.02	-0.01
		Representation	-0.08	**0.98**	0.17	0.01	0.05	0.02	-0.01
		Capacities	-0.08	**0.98**	0.17	0.01	0.05	0.02	-0.01
Forest management	Conservation and use restrictions	Factor loadings could not be calculated because elements of quality were not present in all governance arrangements.							
	Formal law enforcement	Apprehension	**0.91**	-0.02	0.00	0.16	-0.19	-0.05	0.03
		Consistency	**0.95**	-0.05	0.02	0.06	0.01	0.01	0.07
		Compliance	**0.92**	-0.06	0.06	0.12	0.00	0.24	0.08
		Monitoring	**0.90**	-0.04	0.03	0.12	0.00	-0.07	0.00
		Transparency	**0.49**	-0.11	0.41	0.26	0.18	-0.03	0.10
	Customary law enforcement	Apprehension	0.02	0.33	0.72	0.01	-0.13	0.04	0.14
		Consistency	-0.10	0.16	0.89	0.05	0.00	-0.01	-0.09
		Compliance	0.05	0.11	0.91	0.07	0.07	0.08	0.01
		Monitoring	0.11	0.11	0.86	0.09	0.13	-0.20	-0.02

		Transparency	0.04	0.08	0.85	0.05	0.10	0.19	-0.11
Crosscutting institutions	Central government	Knowledge and skills	0.14	0.00	0.09	**0.87**	0.10	-0.04	-0.01
		Effectiveness	0.34	0.06	0.09	**0.62**	-0.18	-0.08	-0.02
	Traditional institutions	Knowledge and skills	-0.07	0.14	0.15	0.35	**0.51**	-0.36	-0.14
		Effectiveness	0.25	-0.05	0.27	0.08	**0.62**	-0.06	-0.12
	Local government	Knowledge and skills	0.00	0.06	0.09	-0.07	0.03	**0.94**	-0.02
Crosscutting issues	Public policy participation	Factor loadings could not be calculated due non-variant data set							
	Eigen value		5.83	4.92	2.89	1.69	1.52	1.15	1.12
	Variance explained (%)		18.04	17.58	16.96	6.86	6.82	5.41	4.81
	Cumulative Variance (%)		18.04	35.62	52.58	59.44	66.26	71.66	76.48
	Cronbach's α		0.92	0.89	0.92	0.53	0.24	0.00	0.03

4.2. Governance performance across governance arrangements and communities in the Zambian Miombo

4.2.1 Governance performance across governance arrangements in the Zambian Miombo

The mean (aggregated) scores of the nine governance indicators present in all sites were very low, with values between 1.23 and 1.51 per governance arrangement (Table 9).

As regards to the individual indicators, only the indicator of tenure rights recognition consistently scored above 3, the midpoint of the Likert scale in all arrangements. Tenure rights recognition scored significantly higher in the customary than in state arrangements. Conservation and use restrictions also scored above 3, the midpoint of the Likert scale in the traditionally restricted communal customary forests. This score differed significantly from that in the arrangements without traditional use restrictions, which consistently scored below 3, the midpoint of the Likert scale (Table 9). The indicators of formal land use planning and formal law enforcement scored significantly higher in state than in the customary arrangements. Most of the individual indicators did not show significant differences between governance arrangements. The active participation of the public i.e. community members in forest policy formulation was completely absent in all arrangements.

Taking all indicators into account, including those only present in specific sites, state arrangements (with more indicators present) had higher mean governance scores than customary arrangements (with less indicators present) (Table 9). The individual site-specific indicators did not differ significantly between arrangements even though they led to higher mean governance scores in all the arrangements in which they were present.

Table 9: Mean governance scores of different indicators per thematic area and type of governance arrangement. Mean 0 = non-existent; 1= very low; 2= low; 3= average, 4= high, 5= very high. Different superscript letters indicate means that differ significantly between arrangements at p<0.05, using the Wilcoxon rank test. S = restricted state forests; CTP=traditionally restricted communal customary forests; CC= non-restricted communal customary forests; CI=non-restricted individual customary forests; OC= forests with overlapping community claims. N indicates the number of polygons with observations. Overall N = 80. Indicators highlighted in green are present in all sites, others are site-specific. Component *Inst* predominantly captures institutions, *R*, rules and *I*, interactions amongst actors or between actors and rules (Nansikombi et al., 2020a, Nansikombi et al., 2020b).

Thematic area	**Indicator**	**Mean score by governance arrangement**										
			S		**CTP**		**CC**		**CI**		**OC**	
		Component assessed	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
Forest tenure	Tenure rights recognition & protection	*I*	6	3.28^{B}	8	4.08^{A}	22	3.85^{AB}	24	4.08^{A}	20	3.91^{AB}
Land use	Formal land use planning	*I*	6	0.58^{A}	8	0.00^{B}	22	0.23^{B}	24	0.21^{B}	20	0.50^{AB}
Forest management	Implementation of land use plans and strategies	*I*	3	1.79	-	NA	-	NA	-	NA	-	NA
	Conservation and use restrictions (include mean scores of timber, charcoal licences protection and conservation)	*R*	6	1.63^{B}	8	4.23^{A}	22	1.28^{B}	24	1.43^{B}	20	1.43^{B}
	Non-timber forest products licence administration	*R*	1	2.17^{A}	-	NA	1	2.17^{A}	1	2.17^{A}	1	2.17^{A}
	Implementation of reforestation program	*I*	2	2.20^{A}	-	NA	-	NA	2	2.90^{A}	-	NA
	Implementation of forest-based livelihood program/projects	*I*	1	3.00^{A}	-	NA	3	2.28^{A}	6	3.14^{A}	5	2.48^{A}
	Implementation of payment of ecosystem service program	*I*	-	NA	-	NA	-	NA	-	NA	-	NA
	Formal law enforcement	*R*	6	2.03^{A}	8	0.50^{BC}	22	1.04^{ABC}	24	0.49^{C}	20	0.79^{B}
	Customary law enforcement	*R*	6	0.58^{A}	8	1.98^{A}	22	1.59^{A}	24	1.41^{A}	20	1.49^{A}
Revenues	Implementation of benefit sharing mechanisms	*I*	-	NA	-	NA	-	NA	-	NA	-	NA
	Forest revenue administration	*I*	3	2.28^{A}	-	NA	9	1.67^{A}	10	2.08^{A}	8	1.84^{A}
Cross-cutting institutions	Central government capacities & effectiveness	*Inst*	6	1.92^{A}	8	1.34^{A}	22	1.65^{A}	24	1.66^{A}	20	1.57^{A}
	Local government capacities & effectiveness	*Inst*	6	0.02^{AB}	8	0.06^{AB}	22	0.07^{B}	24	0.07^{B}	20	0.16^{A}

	Customary institutions` capacities & effectiveness	*Inst*	6	1.54^{A}	8	1.39^{A}	22	2.20^{A}	24	1.76^{A}	20	1.69^{A}
	Non-government organizations capacities and effectiveness	*Inst*	2	3.30^{A}	-	NA	3	3.53^{A}	3	3.53^{A}	4	4.00^{A}
Cross-cutting issues	Public policy participation	*I*	6	0.00^{A}	8	0.00^{A}	22	0.00^{A}	24	0.00^{A}	20	0.00^{A}
Mean Governance score (aggregated for the 9 indicators applicable in all sites)			6	1.29^{A}	8	1.51^{A}	22	1.32^{A}	24	1.23^{A}	20	1.28^{A}
Final mean governance score (aggregated for all 19 indicators)			6	1.98^{A}	8	1.53^{A}	22	1.47^{A}	24	1.68^{A}	20	1.68^{A}

4.2.2 Governance clusters for forest frontier communities in the Zambian Miombo

Cluster analysis was carried out based on all the factor scores (Section 3.3.1) for governance attributes related to the communities. It allowed the identification of four main clusters of communities in which perceptions of forest governance conditions were similar. Similar groupings of communities were also revealed by the PCA results (Section 3.3.4) computed based on the two principal components that constituted the largest variations, i.e., formal law enforcement, 20.9%, and land use planning, 18.3% (Figure 5).

Cluster one, which is the smallest, comprises one community from North-Western province. The cluster shows the highest score in formal land use planning and the highest overall mean factor score. Cluster three, which is the second smallest, comprises two communities from North-Western province. These communities score significantly higher in formal law enforcement. Cluster two, the second largest, is composed of nine communities, mainly from North-Western and Copperbelt provinces. The largest cluster, four, comprises 12 communities, mainly from Eastern and Copperbelt provinces. Communities in clusters two score significantly higher in central government capacities and effectiveness and tenure rights enforcement than those in cluster four (Table 10). Moreover, the results show a weak provincial grouping of communities since communities from the same province (Eastern) only fall exclusively in the same group in one of the cases, cluster four. But even this cluster contains communities from other provinces.

Table 10: Summary of mean factor scores for each community cluster. Different superscript letters indicate means that are significantly different between clusters at $p<0.05$ (N=64)(Nansikombi et al., 2020a).

Factors	Assigned factor meaning	Statistical test	Mean factor score by community clusters			
			Cluster 1 (N=1)	Cluster 2 (N=9)	Cluster 3 (N=2)	Cluster 4 (N=12)
1	Formal law enforcement	Wilcoxon rank test	-0.47^{B}	-0.39^{B}	1.48^{A}	-0.07^{B}
2	Formal land use planning		3.57^{A}	-0.24^{A}	-0.36^{A}	-0.13^{A}
3	Customary law enforcement		0.96^{A}	-0.02^{A}	1.24^{A}	-0.23^{A}
4	Central government capacity and effectiveness		0.08^{AB}	0.58^{A}	1.16^{A}	-0.48^{B}
5	Traditional institutions capacity and effectiveness		0.18^{A}	0.16^{A}	-0.45^{A}	0.17^{A}
6	Local government capacity and effectiveness		0.13^{A}	0.20^{A}	0.13^{A}	-0.12^{A}
7	Tenure rights enforcement		0.77^{AB}	0.64^{A}	-0.53^{AB}	-0.41^{B}
Mean overall factor score		Student´s t-test	0.74^{A}	0.13^{B}	0.38^{AB}	-0.18^{C}

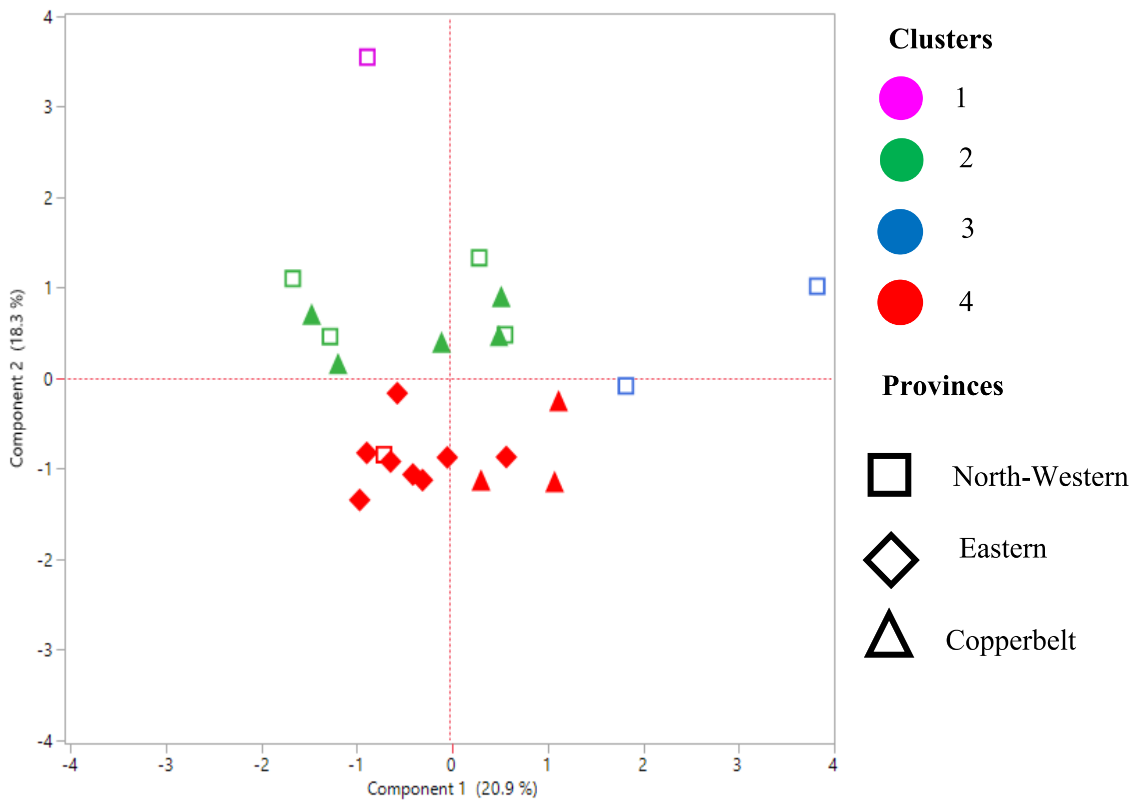

Figure 5: Patterns of community clusters along two principal components (N= 64). The colour indicates cluster assignment based on cluster analysis. The symbol indicates the provinces (Nansikombi et al., 2020a).

4.3 Influence of de facto forest governance on deforestation

4.3.1 Proximate and other drivers of deforestation in the Zambian Miombo

In both multiple regression models, three proximate predictors (distance to the road, percentage of area under crop agriculture and charcoal production) were statistically significant in explaining the annual rate of deforestation (Table 11).

As indicated by the magnitude of the regression coefficients, percentage of area under crop agriculture, with the highest magnitude, was the proximate driver with the strongest influence on the annual rate of deforestation. Charcoal production and distance to the road followed, respectively.

Percentages of area under crop agriculture and charcoal production were positively related with the rate of deforestation, i.e. the higher the percentage of area under crop agriculture and the higher the production of charcoal, the higher the rate of deforestation. On the other hand, location further from roads was associated with lower rates of deforestation.

Regarding the other factors (Model 2), two regional dummies (Eastern and North-Western) were statistically significant (Table 11). Eastern and North-Western regions, as compared to the reference regional dummy of Copperbelt, were associated with lower rates of deforestation.

Table 11: Results of the multiple regression models showing the linkages between the dependent variable (annual rate of deforestation), the independent variables (de facto forest governance indicators, governance arrangements and proximate drivers) and control variables (other drivers). * Implies parameter estimates are significant at 95% confidence interval using standardised variables**;** n/s, non-significant variables discarded in the backwards selection; — shows variable not included in the model, N=70. Copperbelt is chosen as a reference dummy since it represents the region of highest deforestation according to Global Forest Watch (2019). Adapted from (Nansikombi et al., 2020b).

Variable type	**Predictor**	**Model 1** No governance attributes; only proximate and other factors	**Model 2** Adds governance attributes (indicators & arrangements)
		Coefficients (Standard error)	Coefficients (Standard error)
	Intercept	0.536* (0.037)	0.475* (0.041)
Proximate	Distance to road (Meters)	-0.131* (0.036)	-0.112*(0.035)
	Area under crop agriculture (%)	0.167* (0.039)	0.155* (0.040)
	Charcoal production (Area weighted pebble score)	0.152* (0.036)	0.146* (0.037)
	Timber extraction (Area weighted pebble score)	n/s	n/s
	Pole extraction (Area weighted pebble score)	n/s	n/s
	Firewood extraction (Area weighted pebbles score)	n/s	n/s
	Livestock grazing (Area weighted pebble score)	n/s	n/s
	Built-up area (%)	n/s	n/s
Other factors	Mean slope (%)	n/s	n/s
	Area of arrangement (hectares)	n/s	n/s
	Eastern region (Yes)	-0.270* (0.041)	-0.322* (0.049)
	North-Western region (Yes)	n/s	-0.167* (0.059)
	Copperbelt region (Yes)	Reference dummy	Reference dummy
Governance	Local government capacity and effectiveness (Likert score)	—	-0.077* (0.037)

Indicators	Customary institutions capacity and effectiveness (Likert score)	—	0.092 (0.046)
	Central government capacity and effectiveness (Likert score)	—	n/s
	Tenure rights recognition and protection (Likert score)	—	n/s
	Land use planning (Likert score)	—	n/s
	Conservation and use restrictions (Likert score)	—	n/s
	Formal law enforcement (Likert score)	—	n/s
	Customary law enforcement (Likert score)	—	n/s
	Public policy participation (Likert score)	—	n/s
Governance arrangements	Restricted state forests (Yes)	—	n/s
	Traditionally restricted communal customary forests (Yes)	—	Reference dummy
	Non-restricted communal customary forests (Yes)	—	n/s
	Non-restricted individual customary forests (Yes)	—	n/s
	Forests with overlapping community claims (Yes)	—	n/s
	R-squared	0.462	0.544
	Adjusted R-squared	0.433	0.500
	Shapiro-Wilk p-values	0.13	0.12
	Bartlett´s P value	0.69	0.40
	Number of observations	80	80

4.3.2 Influence of governance on deforestation, proximate drivers and other factors

The multiple regression model which includes governance attributes (Model 2), showed a slightly higher adjusted coefficient of determination of 50.0% than the model without governance attributes (Model 1), whose adjusted coefficient of determination was 43.3% (Table 11).

The comparison between the two models (Table 11) indicates that the regression coefficients of the proximate drivers -(i) distance to the road, (ii) percentage of area under crop agriculture and (iii) charcoal production- remained significant when governance attributes were introduced in the analysis. The same coefficients only decreased slightly with the introduction of governance attributes i.e. -0.131 to -0.112 for distance to the road, 0.167 to 0.155 for percentage area under crop agriculture and 0.152 to 0.146 for charcoal production.

The regression coefficient of regional dummy for Eastern increased from -0.270 to-0.322, while that of North-Western became significantly negative with the introduction of governance attributes in the analysis.

Only two governance attributes, (i) local government capacity and effectiveness and (ii) customary institution's capacity and effectiveness, were retained in the model 2, which includes governance (Table 11). Local government capacity and effectiveness showed a significant negative association with the rate of deforestation i.e. effective local government institutions, with adequate capacities were associated with lower rates of deforestation. Although it was retained, customary institution's capacity and effectiveness did not show a statistically significant relationship with the rate of deforestation. Other governance indicators and the arrangements were not statistically significant and discarded in the backward elimination.

4.4 Linkages between governance and socioeconomic factors and the FT dynamics

4.4.1 Governance and socioeconomic factors during deforestation and forest recovery

As shown by the chi-squared test statistics, in both ordinal generalized linear (oglm) models, the combined effect of all the variables is different from zero, and the models are statistically significant compared to the null models with no predictors (Table 12).

The governance factor on institutional capacity and effectiveness and the socioeconomic factors on human population pressure and non-forest income are significantly associated with FT dynamics in the four-phase model (Table 12) and expressed by the marginal effects

(Table 13).

Surprisingly, the signs of the factors change for the pre-transition phase and not as expected for the post-transition phase (Table 13).

The governance factors on institutional capacities and effectiveness and access to forest resources have a significant marginal effect in the four-phase model, which captures both deforestation and forest recovery (Table 13). Increasing institutional capacity and effectiveness and increasing access to forest resources increase the landscapes' probability of being in the pre-transition phase and decrease the probability of being in either the early or late or post-transition phases.

The socioeconomic factors on non-forest income and human population pressure have a significant marginal effect in the four-phase model (Table 13). Surprisingly, increasing non-forest income (including crop, livestock, and non-farm income) increases the landscapes' probability of being in the pre-transition phase and decreases the probability of being in either the early or late or post-transition phases. Increasing human population pressure, reflected by increasing road and population densities, has an opposing effect, decreasing the landscapes' probability of being in the pre-transition phase and increasing the probability of being either in the early or late or post-transition phases.

The country in which landscapes are located, i.e., Ecuador, Philippines and Zambia, did not show a statistically significantly relationship with the FT dynamics.

Table 12: Results of ordered generalized linear regression models (oglm) showing the relationships between governance and socioeconomic factors and the FT phases, the dependent variable. *Implies significant factor at a 95% confidence interval; R is the reference country dummy and, na implies non-applicable, AIC is the Akaike Information Criterion. Cut-point 1, Cut-point 2 and Cut-point 3 are the estimated cut-points on the latent variable, Y*, used to differentiate the adjacent levels of categories of FT Phases. The + sign on the biophysical factor on elevation is interpreted in the opposite direction (-) because elevation is negatively correlated with this factor (Nansikombi et al., Submitted).

Explanatory variables	Four FT phases (deforestation and recovery)		First three FT phases (deforestation)	
	Coefficient	Standard error	Coefficient	Standard error
Governance				
Institutional capacity and	**-4.3909***	1.4885	**-6.4656***	2.7188

effectiveness				
Access to forest resources	-1.6306	0.8916	-0.8652	1.1507
Socioeconomic				
Non-forest income	**-1.8811***	0.8719	**-2.9138***	1.3582
Human population pressure	**2.5063***	0.748	**3.5820***	1.3089
Forest income	-0.737	0.4336	**-1.5257***	0.7355
Biophysical				
Elevation	1.6952	1.6425	4.1883	2.3934
Soil fertility	0.6684	0.6587	0.6309	0.9986
Country dummies				
Ecuador	4.4948	4.0518	2.8331	5.114
Philippines	5.5807	5.0584	1.0071	6.9547
Zambia	R	-	R	-
Cut-point 1	0.996	2.8924	-0.5611	3.3561
Cut-point 2	5.1343	3.0815	5.2377	3.6607
Cut-point 3	6.96	3.2599	na	na
Number of observations	34		28	
Likelihood Ratio $chi^2(9)$	35.93		26.17	
Prob > chi^2	0.0000		0.0019	
Pseudo R-squared	**0.41***		**0.47***	
Log likelihood	-25.92		-14.95	
AIC	75.83		51.90	

4.4.2 Differences in the linkage of governance and socioeconomic factors to deforestation and forest recovery

The ordinal generalized linear model that omits the phase of forest recovery (post-transition) from the categories of outcome variable yields a better fit (lower AIC, and higher Pseudo R-squared) than the model that integrates both the deforestation and forest recovery in a single analysis (Table 13).

The marginal effect of the governance factor on access to forest resources becomes insignificant when the phase of forest recovery (post-transition) is excluded from the analysis in the three-phase model (Table 13).

The marginal effect of the socioeconomic factor on forest income becomes significant. It increases the landscapes' probability of being in the pre-transition phase but decreases the probability of being in either the early or late transition phase when forest recovery (post-transition) is excluded from the analysis in the three-phase model (Table 13).

The marginal effect of the biophysical factor that is negatively linked to elevation and positively linked to temperature becomes significant when the phase of forest recovery (post-transition) is excluded from the analysis in the three-phase model. Because elevation is negatively linked to this factor and temperature positively linked, increasing elevation, and decreasing temperature, increases the landscapes' probability of being in the pre-transition phase and decreases the probability of being in either the early or late transition phases (Table 13).

The marginal effects of the governance factors on institutional capacities and effectiveness, non-forest income and socioeconomic factors on human population pressure, which also explain most of the variations in FT phases, remain significant and retain their signs across all FT phases when forest recovery (post-transition) is excluded from the analysis in the three-phase model (Table 13).

Table 13: Average marginal effects of the explanatory factors on the specific FT phases. The - sign on the biophysical factor on elevation is interpreted in the opposite direction (+) because elevation is negatively correlated with this factor (Nansikombi et al., Submitted).

Explanatory variables	Four FT phase model (N= 34)				Three FT phase model (N=28)		
	Pre-transition	**Early transition**	**Late transition**	**Post-transition**	**Pre-transition**	**Early transition**	**Late transition**
Governance							
Institutional capacity and effectiveness	**0.594***	**-0.305***	-0.049	**-0.240***	**0.896***	**-0.673***	**-0.223***
Access to forest resources	**0.221***	**-0.113**	-0.018	**-0.089***	0.120	-0.090	-0.030
Socioeconomic							
Non-forest income	**0.255***	**-0.131***	-0.021	**-0.103***	**0.404***	**-0.303***	**-0.101***
Human population pressure	**-0.339***	**0.174***	0.028	**0.137***	**-0.496***	**0.373***	**0.124***
Forest income	0.100	-0.051	-0.008	-0.040	**0.211***	**-0.159***	**-0.053***
Biophysical							
Elevation	-0.229	0.118	0.019	0.093	**-0.580***	0.436	**0.145***
Soil fertility	-0.090	0.046	0.007	0.037	-0.087	0.066	0.022
Country dummies							
Ecuador	-0.608	0.313	0.050	0.246	-0.393	0.295	0.098
Philippines	-0.755	0.388	0.062	0.305	-0.140	0.105	0.035

5 Discussions and policy implications

In this chapter, the findings obtained for each objective are discussed together with their policy or methodological implications.

5.1 Relationships between the GFI thematic areas, indicators and elements of quality.

The results (Table 8) show that the framework explains 76.5% of the variations in forest governance quality. This demonstrates that the selected GFI indicator set is a valuable tool to describe overall governance on the ground, as was highlighted by Davis et al. (2013). It was found that each factor reflects a distinct indicator of the GFI framework, either exclusively, i.e. the first three strongest factors, or to a certain degree, i.e. the remaining four factors. This may imply that the GFI framework distinguishes underlying de facto governance processes in Zambia´s Miombo, underscoring its fitness in this respect. The distinct first and third factor demonstrate that formal and customary laws issues are independent factors in the Zambian forest governance context, along with central government, local government and traditional institutions (Kalinda et al., 2008, Caron and Fenner, 2017). In line with Williams (2011), the results imply the need to specify and differentiate between formal and customary governance legislation and institutions.

The first three factors, i.e. formal law enforcement, formal use planning and customary law enforcement, are consistently loaded by elements of quality of the same indicators. This could indicate the overlapping nature of the respective elements, which were not easily distinguishable by participants. The detailed assessment through five elements of quality could be simplified to reflect the most relevant processes.

Some indicators that are posited to characterize similar thematic areas load as separate factors. This may imply that thematic areas at a higher hierarchical level are not precisely reflected by the actual governance processes or functions of the different GFI indicators across the Zambian Miombo. This indicates that thematic areas might be useful to categorize different indicators. However, they are not always mechanisms of distinct governance functioning, as their different indicators load on separate independent factors.

The results show an association between customary institutions and tenure rights recognition, both of which were loaded on the fifth factor, contrary to the GFI postulations. In Zambia, customary institutions are legally mandated and socially legitimated to drive the recognition of tenure rights, especially on customary lands (Payne and Durand-Lasserve, 2012, Caron and Fenner, 2017, GRZ, 2015a). Because similar situations are likely in several other African countries that have customary land governance structures, such as Botswana, Mozambique and Tanzania (Knight, 2010), adapting the GFI indicators to suit the local governance context is recommended. This can be ascertained through scoping visits and a review of the existing legal framework.

5.2 Governance performance across governance arrangements and communities in the Zambian Miombo

5.2.1 Governance performance across governance arrangements in the Zambian Miombo

The results show low mean scores for governance indicators. This may imply weak de facto governance in the Zambian Miombo forests. This is in line with the findings of Kalaba (2016) and Musole and Chunda-Mwango (2018) in Zambia and Gumbo et al. (2018) elsewhere in the Miombo, who report weak forest governance characterized by the unsatisfactory implementation of relevant rules and governance processes on the ground. This is noteworthy, especially following the de jure governance reforms in Zambia´s forest sector that embrace decentralization (Ministry of Tourism Environment and Natural Resources, 2009), the demarcation of restricted forest reserves (GRZ, 2015a) and participatory forest governance. Moreover, in Zambia´s strategy for REDD+, the improvement of governance is a key issue within the preparatory phase, as a basis for incentive-based mechanisms (Matakala et al., 2015). However, up to now the REDD+ strategy has only been implemented to a limited extent (Ministry of Lands and Natural Resources and Ministry of National Development Planning, 2019). The weak enforcement of forest rules is mentioned as constituting the underlying driver of deforestation in the tropics (Korhonen-Kurki et al., 2014, Kanninen et al., 2007, Stickler et al., 2017, Umemiya et al., 2010). Moreover, weak forest governance is linked to the failure of mechanisms that aim to address deforestation and forest degradation (Korhonen-Kurki et al., 2014). With this in mind, the results indicate the necessity of strengthening the implementation of forest rules and governance processes at the local level (Pettenella and Brotto, 2012).

It was found that forest governance quality does not differ significantly between the state, individualised customary arrangements and communal customary arrangements when comparable indicators are used. This challenges common assumptions that state actors are likely to foster improved forest governance as compared to individual and communal actors (Ferraro et al., 2013, Hardin, 2009) and vice versa (Agrawal and Ostrom, 2001, Ostrom, 2008). In fact, the satisfactory enforcement of rules combined with good institutional capacities are components of improved governance on the ground (Muñoz Brenes et al., 2018, Agrawal et al., 2014, Hayes and Persha, 2010). Despite the distinct policy interventions, forest rules in Zambia are hardly enforced due to the absence of adequate financial and human institutional capacities (Kalaba, 2016). In light of that, the results affirm the need to increase the financial and human capacities of relevant institutions, as this is likely to improve their rule enforcement capabilities.

The higher mean governance score in state than in customary arrangements when site-specific indicators are considered to some extent reveals the de facto implications of contradicting land tenure policies in customary lands. While Zambia´s local government act authorises state institutions to manage customary forests, the land act places the administration of these forests under customary authorities, creating ambiguous responsibility and institutional tension (Chikulo, 2009). In the absence of effective institutional coordination and appropriate accountability mechanisms (Kalaba, 2016), the situation may constrain the implementation of non-legally binding governance processes on customary lands, including reforestation and livelihood programs. These processes drive the higher overall mean governance scores on state land. Moreover, as the same processes were implemented by non-government organizations and private enterprises, the results might mirror the role of non-state institutions in improving forest governance, which was also remarked by (Turner et al., 2014, Hayes and Persha, 2010) in the tropics. In this respect, the results indicate the necessity for legal reforms to address the inconsistencies in institutional mandates coupled with augmented formal support for the non-state institutions in Zambia´s forest sector.

The relatively high scores for tenure rights recognition, particularly on customary lands mirror the de- jure, de facto discrepancy vis-à-vis the security of tenure on customary lands in Zambia. Whereas customary land is the least secure de jure option due to an absence of formal documentation to prove the landholders´ de facto rights (Mulolwa, 2016, Bojang and Ndeso-Atanga, 2013), similar to other studies (Stickler et al., 2017, Jain et al., 2016), our results indicate that people in Zambia feel secure in their rights to customary forests. Despite the absence of any de facto formal documentation, customary tenure may be more socially legitimated and thus more dominant than de jure tenure (Payne and Durand-Lasserve, 2012).

As customary forests account for the largest proportion of forests in Zambia, this result is promising especially as tenure security is acknowledged to foster sustainable use, efficient forest investment behaviour (Irwin and Ranganathan, 2007) and the desire of local people to protect their forests from encroachment (Larson et al., 2010, Mayers and Vermeulen, 2002). Besides, tenure security is reputed to lessen conflicts resulting from overlapping claims of ownership between different formal and customary institutions (Robinson et al., 2018). Nonetheless, de jure requirements for formal documentation could further strengthen customary tenure security as long as formal documentation is in line with the customary tenure.

The differences in scores for central government institutions and formal processes of land use planning and law enforcement between the state and customary forests again reflect the de jure weakness vis-à-vis formal processes in customary forests. While Zambia´s Urban and Regional Planning Act of 2015 recommends formal land use planning, the activity is not strictly required on customary lands. Furthermore, although formal institutions are legally mandated to manage all forests, the control of customary forests is largely enshrined in customary laws, which are articulated by the traditional institutions and lack systematic procedures (Kalinda et al., 2008). Moreover, since the customary institutions occasionally challenge the authority of local government actors (Mfune, 2013) their willingness to enforce formal governance processes on customary lands is likely to lessen. Formal activities are also constrained by the inadequate implementation of forest management plans and strategies and the poor monitoring of illegal activities due to inadequate funds and staff (Kalaba, 2016). Since formal land use planning and law enforcement are crucial for regulating unsustainable forest use (McDermott et al., 2010, Kaimowitz, 2012), it is imperative to establish legally binding requirements for these processes on customary lands. Additionally, augmented support for human and financial capacities and coordination amongst institutions could foster greater enforcement exercises (Kalinda et al., 2008).

The differences in scores for use restrictions between the culturally-restricted forests and those not restricted by traditions demonstrate the role of traditional values and norms in promoting forest conservation, as has been reported by other scholars too (Colding and Folke, 2001, Jimoh et al., 2012). The results indicate the need to reinforce traditional norms within prevailing forest governance arrangements as they reflect locally important cultural values of forest resources and are likely to foster voluntary compliance with access and use restrictions, even in the absence of effective law enforcement systems. This could be strengthened by a greater harmonization of state and customary structures within the existing decentralization system in order to lessen opposition during the implementation of pertinent forest governance processes in Zambia´s Miombo.

5.2.2 Governance clusters for forest frontier communities in the Zambian Miombo

In the cluster analysis, four main community clusters were identified. The existence of varied clusters reflects different governance approaches amongst communities, generally differentiated by the processes of formal and customary law enforcement and land use planning.

The community in cluster one, is characterized by high scores for formal land use planning. Unlike in other communities, participatory land use planning on customary land within this community has been executed through a collaboration between the United Nations Development Programs (UNDP), Global Environmental Facility (GEF), Forest Department and the traditional leaders. Since this community had the highest mean factor/governance score, the result again underscores the significance of participatory land use planning in improving de facto governance.

Communities in cluster three had high scores for formal law enforcement, which might result from the presence of timber concessions in these communities. This finding is consistent with that of Ng'andwe et al. (2015) who report a comparatively higher enforcement of forest use restrictions by the Forest Department in forests with timber concessions than in those without in Zambia. This is mainly because the concessionaires usually provide transportation and other resources for the forest officers to conduct forest inventories, consultation with the communities and monitoring of the concession.

It is notable that cluster two mainly comprises communities from North-Western and Copperbelt and cluster four, from Eastern and Copperbelt. As these are the largest clusters, as distinguished clearly by the loadings of several factors, the results might indicate that governance processes of North-Western and Eastern are generally distinct, while in Copperbelt we can find patterns from both regions. This finding might reflect a de facto variation in the coordination between customary and formal institutions across the different regions. Zambia´s provincial officials operate under the same forest policy and legal framework that assigns the same general rights and responsibilities to all local governments

(Ministry of Tourism Environment and Natural Resources, 2009). At the lower levels, provincial officials are required to harmonise with the customary institutions to facilitate the enforcement of forest laws and the proper administration of forest estates, in line with the forestry policy and existing legal framework (Ministry of Tourism Environment and Natural Resources, 2009, Chileshe, 2011). In Eastern province, communities reported recurrent conflicts over forest ownership between customary and formal institutions. This might explain the very low scores for central government capacities and effectiveness and tenure rights enforcement that differentiate the Eastern communities, in cluster four, from those in cluster two, from North-Western and Copperbelt. The result confirms the necessity for consistency in the integration of customary structures into the decentralized governance structure, considering regional and local differences.

5.3 Influence of de facto forest governance on deforestation

5.3.1 Proximate and other drivers of deforestation in the Zambian Miombo

The results (Table 11) suggest that the percentage of area under crop agriculture is the most important proximate predictor of deforestation in the Zambian Miombo. This is not surprising since scholars in Zambia (Phiri et al., 2019, Vinya et al., 2011, Mwitwa et al., 2012, Handavu et al., 2019) and elsewhere in the tropics (Acheampong et al., 2019, Hosonuma et al., 2012, Ferrer Velasco et al., 2020) have reported similar findings. According to community members, diminishing soil fertility and the accompanying reduction in crop yield force farmers to abandon their crop fields and open up new forest areas for agriculture. Community members also reported clearing of forest areas for crop agriculture following immigration and high birth rates. Sustainable agriculture intensification practices e.g. crop rotation, conservation tillage and mulching (Wezel et al., 2015) could increase crop yield and reduce forest clearing for agriculture.

Charcoal production also emerged as a significant predictor of deforestation. Differing from (Chomba et al., 2012, Vinya et al., 2011, Ratnasingam et al., 2014), firewood and timber extraction were not significant. In Zambia there is a high market demand for charcoal because it is the major source of energy for cooking in the urban areas (Handavu et al., 2019, Gumbo et al., 2013). Charcoal also generates higher income than firewood (Kazungu et al., 2020). Moreover, unlike timber, which is mostly extracted by external private firms and, predominantly in North-Western, charcoal is produced by the community members in nearly all three provinces (Gumbo et al., 2013, Ng'andwe et al., 2015). Besides, although in some cases Miombo woodlands can recover rapidly from the influence of charcoal production (Chidumayo, 2014), a considerable share of forests initially cut for charcoal are subsequently converted to croplands, reducing the possibility for recovery. Augmented monitoring of charcoal licences to curb illegal production is proposed. This is less likely to adversely impact food security and rural incomes, with many farmers depending on agricultural income and, with charcoal production predominated by the affluent households (Kazungu et al., 2020). Guidelines for sustainable charcoal production systems are also proposed given the high regenerating ability of the Miombo forests (Campbell et al., 2007).

The results suggest proximity to roads as another important driver of deforestation. The deforestation rate is higher closer to the roads than in distant forests. Roads open up forests for settlement, agriculture and wood extraction by lowering transport-related transaction costs (Pujiono et al., 2019, Phiri et al., 2019, Barber et al., 2014, Laurance et al., 2002, Poor et al., 2019). Because roads are inevitable for economic development through enhanced rural connectivity (Gibson and Rozelle, 2003) and for facilitating market access and commercialization of products (Ojeda Luna et al., 2020), greater control over newly accessible forests through regular patrols is needed.

Similar to the study categorization of deforestation contexts in Zambia (Table 1), North-Western and Eastern regions showed lower deforestation rates than Copperbelt. Copperbelt is more urbanized (Central Statistical Office, 2016) and has a higher population density than North-Western and Eastern (Worldpop, 2018). High population density and growth implies an increasing demand for food and a corresponding need to convert forests to agriculture (Asongu and Jingwa, 2012). High population density is also associated with high demand for charcoal and firewood, and therefore with high deforestation (Collins, 1984). Actually, charcoal production in Zambia is greatest in Copperbelt (Kalinda et al., 2008). There is need to promote forest restoration in Copperbelt to meet the rising demand for wood, thus reducing pressure on the remnant forests (Fay, 2012) and to foster non wood energy sources. In Eastern province, with deforestation mainly caused by small-scale crop cultivation (Shakacite et al., 2016), promoting sustainable agriculture intensification is suggested. In North-Western, with deforestation attributed to unsustainable timber extraction (Shakacite et al., 2016), promoting sustainable forest management is recommended.

5.3.2 Influence of governance on deforestation, proximate drivers and other factors

There was only a small increase in the explanatory power of the model explaining deforestation (Table 11) when governance attributes were introduced in the analysis. This demonstrates that governance has some effect, but proximate drivers explain most deforestation in the Zambian Miombo. Similar to (Larson and Petkova, 2011, Tacconi, 2007), the results suggest that improvement of forest governance alone does not exclusively guarantee successful forest outcomes. Measures that tackle governance drivers should be complemented with strategies that specifically tackle the proximate and other underlying drivers e.g. sustainable production systems, incentive mechanisms and alternative livelihood and poverty eradication measures. This is relevant for REDD+ and climate change adaptation initiatives that propose governance improvement to reduce deforestation and forest degradation.

Additionally and surprisingly, proximate drivers remained at unchanged significance levels when governance attributes were included in the analysis. This is perhaps because governance was hardly varying between arrangements and was in general very low (Table 8). Statistically, it is impossible to explain deforestation by a predictor that is mostly the same in all governance arrangements. Actually, the only governance indicator that was significant was among those that showed differences between the arrangements (Table 8). Scholars (Hayes and Persha, 2010, Davis et al., 2013, Eklund and Cabeza-Jaimejuan, 2017, Fischer et al., 2020) underline the high quality of forest governance as a prerequisite for regulating human-induced drivers of deforestation.

There are lower deforestation rates where local government institutions are effective and possess adequate capacities. In Zambia, local government institutions are responsible for developing land use plans to guide sustainable forest management in addition to controlling the extraction and transportation of forest products (Mfune, 2013). District local councils occasionally monitor transportation of timber and charcoal contingent on their financial and human capacities. Similar to (Larson, 2002, Kaimowitz et al., 2000), the result emphasizes that strengthened institutional capacities (financial, human, technical) are vital for successful forest conservation. Besides, local government institutions represent a fundamental decentralization structure (Andersson and Gibson, 2004, Andersson, 2006) and thus reveal the potential for curbing deforestation through effective decentralization. Their influence might still be increased by financial and human resources and the state's willingness to cede power over forest management (Kalaba, 2016, Mfune, 2013).

It was found that customary institutional capacities and effectiveness did not significantly influence the rate of deforestation. This result is surprising because Zambia's customary institutions are responsible for granting rights of use over customary forests to new immigrants (Mason-Case, 2011) and for mineral exploration (Mwitwa et al., 2011). The new immigrants are likely to convert forests to agriculture to protect them from being re-allocated (Unruh et al., 2005). The result could be attributed to the fact that customary institutional capacities and effectiveness did not show so much variation across study sites, as shown in Table 9.

None of governance arrangements was retained in the model that integrates governance. This result is surprising given that governance arrangements have been emphasized to influence deforestation patterns owing to the different use restriction and ownership rights attached (Robinson et al., 2014). This could imply that the significant drivers, charcoal production, area under crop agriculture and road extension, are associated with specific governance arrangements.

The regression coefficients of the regional dummies for Eastern and North-Western increase, and become significantly negative, respectively, when governance attributes are included in the analysis. This implies that the significant governance attribute, local institutions' capacities and effectiveness, is region-specific. This means that local institutions' capacities and effectiveness are different across regions and certainly related to deforestation in all places. In agreement with (Nansikombi et al., 2020a) the result suggest that regional differences ought to be reflected in the strategies for strengthening local-level institutional capacities and effectiveness.

5.4 Linkages between governance and socioeconomic factors and the FT dynamics

5.4.1 Governance and socioeconomic factors during deforestation and forest recovery

In both models (Table 12) the combined effect of all the variables is different from zero, and both models are significant compared to the null models with no predictors. Analogous to (Mather, 1992, Yackulic et al., 2011), this result confirms our hypothesis that underlying governance, socioeconomic and biophysical conditions are related to FT dynamics. This is valid across different tropical contexts.

The results reveal that the signs of all factors change between the pre-transition phase and the early-transition phase for both models and not as expected at the post-transition phase. This indicates that the processes which distinguish the pre-transition phase from the rest of the phases are more clearly pronounced than those that differentiate the post-transition phase from the early and late transition phases. Accordingly, the development pathway changes at the transition between pre- and early FT phases and not as expected between late and post-transition phases. Similar to (Angelsen and Rudel, 2013), the result suggests that initiatives for controlling deforestation and forest degradation e.g. REDD+ and other conservation programs ought to establish alternatives to the usual agriculture-based development pathway already in the pre-transition phase. This is because once ongoing, the destructive processes relating to deforestation are hard to reverse in the later FT stages.

It was found that a higher institutional capacity and effectiveness is associated with the pre-transition phase whereas a lower institutional capacity and effectiveness is linked to the early, late, and post-transition phases. The model does not allow to establish cause effect relationships and thus implies that either low governance in the form of low institutional capacities and effectiveness can lead to advanced deforestation or that during advancing deforestation governance quality is decreasing. The presence of customary/local institutions in the pre-transition landscapes, also reported by (Nansikombi et al., 2020a) and Fischer et al. (Submitted) may elucidate the registered institutional effectiveness unlike in the early, late and post-transition landscapes, in which customary institutions have been degraded following immigration (Angelsen and Rudel, 2013). The results emphasize the necessity for strengthening local and customary institutions to curb forest loss. Effective institutions may impose additional costs on the economic agents and reduce their potential to convert forests to agriculture (Buys, 2007).

The results show that higher individual and communal access to forestlands /lower restrictions on forestlands is associated with the pre-transition phase whereas low individual and communal access to forestlands/high restrictions on forestlands is associated with the post-transition phases. In the pre-transition landscapes, the relatively low restrictions to forest access and use may be accredited to a low demand for forest resources given the low population density (Rademaekers et al., 2010) and limited market access due to remoteness. A low demand implies low forest exploitation and a minimal requirement for governments to restrict individual and communal access to forestlands. In the post-transition landscapes, forest products scarcity from continuous deforestation could propel governments to implement policies that restrict forest exploitation and reduce individual and communal access to forestlands (Nelson and Chomitz, 2011). Nevertheless, restrictions have been found to negatively affect rural livelihoods since they deprive the rural poor of income from forests (Kaimowitz, 2003). Collaborative forest management would enable sustainable use of forest resources (Kant, 2004).

It was found that lower human population pressure, reflected by a low population density is linked to the pre-transition phase while higher human population pressure, reflected by a higher population density is linked to the early, late, and post-transition phases. This finding confirms standard FT predictions that population density is lower in the pre-transition phases and increases with in the early, late, and post-transition phases. The low population density implies less demand for forest products and alternative land uses e.g. agriculture and settlements (Angelsen and Rudel, 2013, Culas, 2012) and therefore, a higher forest cover as reflected by the pre-transition landscapes. Conversely, a higher population density implies a greater land use intensity and consequently, a shift towards the early, late and post-transition FT phases (Rademaekers et al., 2010, Ferrer Velasco et al., 2020).

Moreover, similar to Glover and Simon (1975) road density was also strongly positively correlated to the factor on human population pressure. This implies that increased road density has similar effects as population density, reducing the probability of being in pre-transition and increasing the probability of either early, late, or post-transition phases. A poor road network renders forests inaccessible for external commercial exploitation. This preserves the forest cover and prolongs the pre-transition period. Increased road density on the other hand facilities deforestation through improved forest and market access (Nansikombi et al., 2020b, Ulimwengu et al., 2009). This lowers the forest cover and triggers the shift towards the early, late, and post-transition phases. Because roads are inevitable for economic development, effective monitoring through community-based associations would minimise unsustainable forest exploitation in the easily accessible and densely populated areas. Besides, roads have been demonstrated to provide more diversified income opportunities that can relieve pressure on forests (Angelsen, 2010).

Our results show that higher non-forest income (crop, livestock and non-farm) is surprisingly associated with the pre-transition phase whereas lower non-forest income is linked to the early, late or post-transition phases. Similar to (Trædal and Angelsen, 2020), this implies that non-forest income (agriculture and non-farm), which also reflects the welfare of most tropical rural households (Brück, 2004), decreases with subsequent shift in FT phase (Angelsen and Rudel, 2013, Angelsen, 2007). Because population density has an opposite relation (Table 13), the result might imply that whereas population increases during deforestation, non-forest income per household decreases. This might indicate a marginalisation in the context of agricultural expansion, which occurs in the early, late and in some cases post-transition phases and is mainly driven by external actors, in-migrants, and resource exploitation companies, with limited benefits to residents. The removal of forest cover and forest degradation deprives forest dwellers of their livelihoods and aggravates their poverty levels (Angelsen, 2007). In-migration and or population growth also provide a steady supply of labour, which dampens local wages (Angelsen, 2007). This reduces the non-farm income in the early and late FT phases, with in-migration and high population densities. In the pre-transition phase, poor infrastructure makes the forest area inaccessible for immigrants and external commercial users (Angelsen and Rudel, 2013). Thus, the challenge is to avoid the agriculture-dependent deforestation trap. Alternative off-farm livelihood opportunities and land-use independent development strategies on one side as well as sustainable forest-based value chains, but with strict controls on the other side should be promoted as a substitute for deforesting agricultural practices already in the pre-transition phase.

The country in which landscapes are located did not show a statistically significant relationship with the FT dynamics. This result is surprising given that the landscapes are expected to reflect the forest cover dynamics of the respective countries. According to Hosonuma et al. (2012) and Ferrer Velasco et al. (2020), Zambia is still in the pre-/ early stage of the forest transition, Ecuador in the early-/late stage of forest transition and Philippines in the late/post-transition stage of forest transition. The finding may be attributed to the contextual factors that modify the FT dynamics at the local scale. The lack of significance may, on the other hand, result from a low number of observations.

5.4.2 Differences in the linkage of governance and socioeconomic factors to deforestation and forest recovery

Although only marginally, the model yields a better fit and explains the variations in FT phases better when forest recovery (post-transition) is excluded from the categories of the outcome variable (Table 12). This on one side implies that the patterns of forest transition are better examined by separating deforestation from forest recovery. On the other side the marginal effects of the factors that explain most of the variations in FT phases i.e. institutional capacities and effectiveness, population density and non-forest income, remain significant and retain their signs across all FT phases when forest recovery is excluded from the analysis. Coupled with the rather identical structure of factors in the factor analysis (Appendices B, C and D) for the two models this is a strong indication that recovery and deforestation are driven by similar processes. According to (Grainger, 1995), the factors that drive deforestation and forest recovery are partly overlapping, given that the two processes largely mirror each other. Because the arguments are pro and contra, we can neither clearly confirm nor clearly falsify the hypothesis that deforestation and forest recovery are distinct processes that are also associated with different factors (Rudel et al., 2005, Lambin et al., 2006, Grainger, 1995). Besides, the difference in the significant predictors in the two models may be accredited to a small sample size that is also unequally distributed i.e. 6 landscapes undergoing recovery against 28 landscapes undergoing deforestation. The sample sizes of the two models are also different. Because the post-stratification approach of categorizing landscapes into the FT Phases may partly explain this, future studies would benefit from a pre-stratification.

The marginal effects that remain significant and retain their signs across all FT phases indicate that institutional capacities and effectiveness, population density and non-forest income, also revealing household welfare, are important predictors of both deforestation and forest recovery.

The marginal effect of the governance factor on access and restrictions to forestlands becomes insignificant when the phase of forest recovery (post-transition) is excluded from the analysis. This implies that restrictions and limiting individual and communal access to forests is more connected to forest recovery than deforestation. This could be attributed to the fact that restrictions are mostly implemented as a policy measure to facilitate forest recovery following prolonged deforestation and accompanying forest products scarcity (Angelsen and Rudel, 2013, Angelsen, 2007, Meyfroidt et al., 2010). The effects of purely restricting forest use are discussed controversially. Restrictions have been found to reduce deforestation in the tropics by limiting unsustainable forest resource extraction (Spracklen et al., 2015, Busch and Ferretti-Gallon, 2017). On the other hand, it has been argued that restrictions alone are hard to enforce (Porter-Bolland et al., 2012, Bae et al., 2012). Whatever the effects might be, they obviously have a specific relevance in the later FT phases and need to be considered within forest recovery in the tropics.

When forest recovery (post-transition) is excluded from the analysis the marginal effect of the socioeconomic factor on forest income becomes significant, increasing probability of landscapes with higher forest income to be in the pre-transition phase and decreasing the probability of being in either the early or late transition phase. The result shows that forest income is more connected to deforestation than to forest recovery. This means that forest income contributes to deforestation or deforestation contributes to forest income, but forest recovery does not or not yet contribute to forest income or forest income is not yet sufficient to promote forest recovery. Forest income reveals the quantity of timber and non-timber forest products that households extract for subsistence and commercial purposes (Heubach et al., 2011, Vedeld et al., 2007, Kamanga et al., 2009). Forest resource extraction is dependent on the resource availability (Pandey et al., 2014). Therefore, it is most likely to be associated with the pre-transition landscapes, with a considerable forest cover. The post-transition phase, with a comparatively low forest cover and forest resource scarcity resulting from previous deforestation, is likely to register a low rate of forest resource extraction (Angelsen, 2007) and thus, a negligible forest income. The result indicates that there is potential to reduce the pressure on natural forests if forest income could be generated from planted or naturally regenerated forests because in the moment the income from plantations/succession is not significantly related to the FT phases. Moreover, if wood resources are needed e.g. for construction or energy purposes but cannot be imported, then higher income without accompanying reforestation would bear the risk of deforestation and leakage elsewhere.

The marginal effect of the biophysical factor for elevation becomes significant when the phase of forest recovery (post-transition) is excluded from the analysis. This indicates that elevation is a more important predictor of deforestation than of forest recovery. Because elevation is negatively associated with the factor, our results show that higher elevations are associated with pre-transition landscapes while lower elevations are linked to either early or late or post-transition landscapes. This is probably because most of the pre-transition landscapes are located in Zambia (above 1000masl) in contrast to the landscapes from Ecuador and Philippines (under 1000masl), which predominate the later FT stages. However, because we control for country effects in our models, the results might reflect the fact that forest landscapes at higher elevations are less accessible and therefore, with higher costs of forest resource extraction and land clearing (Southworth and Tucker, 2001). For that reason, they retain a considerable forest cover and rather remain in the pre-transition phase. At lower elevations, improved accessibility lessens the cost of transporting forest products and clearing for agriculture (Gaveau et al., 2009). This facilitates the shift towards the early or late FT phases. Although mostly associated with a low deforestation rate, higher elevations have also been linked to forest recovery in the tropics given the milder temperatures at higher altitudes that favour tree growth (Lippok et al., 2013, Beck et al., 2008). Forest recovery might be specifically challenging at lower elevations with their higher temperatures and better accessibility.

6 Contribution to science and practise and study limitations

This section discusses the contribution of the study to existing debates and knowledge gaps on forest governance quality and its effects on forest transitions in the form of deforestation and forest recovery. The section additionally discusses the contribution of the study to existing forest governance assessment frameworks and methodologies and the practical implications of the findings for forest governance challenges in Zambia and other tropical countries. The section as well highlights the limitations of the study together with the recommendations for future research.

6.1 Contribution to scientific literature

(a) Forest governance assessment frameworks

This study complements the existing literature on the applicability of the World Resource Institute's Governance of Forest Initiatives (GFI) indicator framework for forest governance assessment. Whereas the GFI framework is widely recommended for governance analysis, hardly has its applicability been tested, as only a few scientific studies have utilized it to quantitatively analyse forest governance progress e.g., Agung et al. (2014) and Pettenella and Brotto (2012). The particular studies have, moreover, been conducted at the national scale, where policy design occurs. This study, on the other hand, tests the applicability of the proposed GFI indicators at the local scale, where policy implementation occurs in practise.

The findings show that the GFI indicator set is a valuable tool to describe overall governance at the local scale, as factors generally mirror the GFI indicators. However, in some cases indicators from the same thematic area load on different factors from completely different thematic areas, implying that they may be related to different processes (Nansikombi et al., 2020a). The methodological implication is that one indicator alone should not be used to exclusively represent of a thematic area. The findings, additionally, reveal that compared to the GFI framework, customary rules and institutions are more clearly differentiated on the ground (Nansikombi et al., 2020a). The methodological implication is that specific attention ought to be paid to customary rules and institutions when applying the GFI framework on the ground.

This study, furthermore, combines the process-oriented GFI framework with effect-oriented analytical frameworks to examine the effects of governance on forests at the local scale. This permits a comprehensive analysis, as according to Giessen and Buttoud (2014), forest governance comprises both formal and informal processes and their effects on forests. In Publication II (Nansikombi et al., 2020b), the GFI is combined with the framework by Geist and Lambin (2001) to examine governance effects on deforestation. In Publication III (Nansikombi et al., Submitted), the GFI is combined with the concept of the FT phases, based on the FT theory as described by Angelsen and Rudel (2013) and Hosonuma et al. (2012) to analyse governance and socioeconomic linkages to the FT dynamics. Past related studies have either only applied the process-oriented GIF framework e.g., Agung et al. (2014) and Pettenella and Brotto (2012) or only the effect-oriented frameworks e.g., Umemiya et al. (2010), and Riggs et al. (2018).

(b) The quality of forest governance

This study complements the existing scientific literature on the quality of forest governance in the tropics. Although past studies have generated related information, they are mostly undertaken at the national scale and address the legal (de jure) conditions, e.g., Kalaba (2016). This study, however, focuses on the local scale and captures the dynamics from the differential implementation of forest legislation and institutional reforms on the ground using a case of Zambia. The results show low mean scores for governance indicators, which implies weak de facto governance characterized by weak institutions and unsatisfactory enforcement of relevant rules and processes (Nansikombi et al., 2020a, Nansikombi et al., 2020b). Although previous studies have shown similar findings at the national level e.g., Kalaba (2016), it can now be confirmed that this also holds true at the local scale.

The study additionally contributes to scientific debates on the actors/institutions that are associated with improved forest governance conditions. Past studies link improved forest governance conditions to differing actors: Dudley and Stolton (2010) and Hardin (2009) underscore state actors, Agrawal (1996), Ostrom (1990) and Woldie and Tadesse (2019), community actors, and Koyuncu and Yilmaz (2013b) and Koyuncu and Yilmaz (2013a), private actors. This study, however, demonstrates that governance performance is not necessarily linked to specific actors, as governance performance did not significantly vary between state, individual and communal governance arrangements (Nansikombi et al., 2020a, Nansikombi et al., 2020b). In fact, it depends on the de facto enforcement of rules combined with good institutional capacities on the ground, as foreseen by Muñoz Brenes et al. (2018), Agrawal et al. (2014) and Hayes and Persha (2010).

This study, furthermore, contributes to scientific literature on the potential implication of decentralization on the performance of forest governance. This is relevant for prioritizing governance solutions across local government administrative boundaries (Charron et al., 2014). The study examines the quality of governance within communities in provinces/regions with differing governance structures. Although past studies have been undertaken in this regard, they have mainly focused on the temperate developed countries and utilize rather general than forest-specific governance measures e.g., Charron et al. (2012) and Charron et al. (2014). This study, on the other hand, uses forest-specific governance indicators in the tropics using a case of Zambia. The results show that governance processes in some cases follow provincial local government administrative boundaries and in other cases go beyond the established administrative boundaries (Nansikombi et al., 2020a). This implies that there is a high variability of governance processes within and across provincial local government administrative boundaries. This finding contradicts that from the temperate developed countries, which show a clear regional differentiation vis-à-vis the general governance performance as a consequence of decentralization (Charron et al., 2014, Charron et al., 2012).

(c) Linkages between forest governance and deforestation

This study feeds into the existing literature on the influence of forest governance quality on deforestation in the tropics, e.g., by Hosonuma et al. (2012) and Rademaekers et al. (2010). Previous studies in this regard use rather general than forest-specific governance indicators such as corruption, democracy, voice and accountability, political stability, violence, and rule of law research e.g., Abman (2018), Wehkamp et al. (2018), Umemiya et al. (2010), Li et al. (2005), and Bhattarai and Hammig (2004). The respective studies have, moreover, been undertaken at the national scale, missing capturing the effects from differential implementation of forest legislation, which occur at the local scale (Secco et al., 2014). This study, however, uses forest-specific governance indicators to examine the influence of forest governance in the tropics. They comprise indicators on forest tenure rights recognition and protection, land use planning, conservation and use restrictions, formal law enforcement and customary law enforcement. Also included are indicators on public participation in forest policymaking, central, local, and customary institutional capacities and effectiveness and the different categories of forest governance arrangements with differing tenure and forest use restrictions. Besides, unlike the previous national scale analyses, this study is undertaken at the local scale.

The results reveal that de facto governance quality has some effect but proximate drivers particularly charcoal production, crop agriculture and proximity to roads explain most of the deforestation patterns in the Zambian Miombo (Nansikombi et al., 2020b). Those drivers seem hardly affected by the weak forest governance. Although the previous studies have highlighted comparable dynamics at the national scale with general governance measures e.g., Umemiya et al. (2010), and (Wehkamp et al., 2018), it can now be confirmed that this also holds true at the local scale with forest-specific governance indicators.

(d) Linkages between forest governance and forest transition (FT) dynamics

This study complements the existing scientific literature on the relationships between governance and socioeconomic factors and FT dynamics. Previous studies in this regard have mainly been conducted at the national scale, where policy design occurs e.g., Riggs et al. (2018), Wolfersberger et al. (2015) and Barbier and Tesfaw (2015). This study, on the other hand, focuses on the local scale, where according to Secco et al. (2014) and Perz and Walker (2002), implementation of forest legislation and the socioeconomic processes of household decision-making occur. Moreover, different from the previous studies, which only address the variability between countries, this study addresses both the variability within and between countries (Nansikombi et al., Submitted). This study, furthermore, substantiates the hypothesis by (Grainger, 1995, Barbier et al., 2010) that deforestation and forest recovery are two distinct processes of forest transition that are shaped by differing socio-economic and governance factors. This hypothesis has so far not been empirically verified in the existing literature in the tropics, particularly at the local scale.

The results show that both governance factors (i.e., institutional capacities and effectiveness and access to forest resources) and socioeconomic factors (i.e., human population pressure and non-forest income) explain the FT dynamics (Nansikombi et al., Submitted). Although previous studies have shown similar findings at the national level, it can now be confirmed that this also holds true at the local scale, considering completely different tropical contexts. The results also reveal that, the explanatory factors clearly distinguish the pre-transition phase from the rest of the phases. This may indicate that the underlying development pathway already changes at the transition between the pre- and early phases. This deviates from prior postulations by Angelsen (2007), Angelsen and Rudel (2013) and Culas (2012) that this change occurs at the transition between the late and post-phases.

Surprisingly, a high non-forest income (agriculture and non-farm) is associated with the pre-transition phase whereas a low non-forest income is associated with the early and late transition phases (Nansikombi et al., Submitted). This implies that non-forest income, which also reflects the welfare of most tropical rural households (Brück, 2004), decreases with subsequent shift in FT phase. This finding deviates from that by Angelsen (2007) and Angelsen and Rudel (2013) that suggest that non-forest income increases with subsequent shift in FT phase. The findings neither clearly confirm nor clearly falsify the hypothesis by Grainger (1995) and Barbier et al. (2010) that forest recovery and deforestation are distinct processes. Because this inference is made based on the fact that there are statistical arguments pro and contra, there is still need for further studies in this regard.

6.2 Practical implications for forest governance challenges in Zambia and elsewhere in the tropics

The results reveal that there is poor implementation of relevant rules (customary and formal) and governance processes on the ground in Zambia, particularly concerning land use planning, forest use restrictions and public participation in forest policy formulation. In addition, there are inadequate institutional capacities to enable effective enforcement processes. The practical implication is that there is need for greater enforcement of forest rules and use restrictions in Zambia. This can be realized through regular monitoring, apprehension and graduated sanctions for lawbreakers. This can be strengthened by enhanced support for financial, human and technical institutional capacities. Participatory land use planning and participatory policy formulation are also needed in Zambia, although, with social safeguard policies to protect the marginalized land users. This would certainly contribute towards achieving targets for Zambia's climate change response strategy, national development plan 2017-2021 and REDD+ preparedness phase.

The results suggest that there is possibility for conflicts between the customary and formal institutions resulting from unclear institutional mandates for customary forest management. This implies that customary and formal governance processes have to be better harmonized, otherwise implementation of the national and international forestry agenda will not be feasible. In addition, the participation of the customary leaders is necessary to achieve the international forestry goals.

The results show that governance processes do not spatially depict the provincial administrative structure. Therefore, implementation of policy goals, including the initiatives to integrate customary structures into the decentralized governance structure, needs to consider regional differences in governance processes. Regional differences should particularly be considered in the strategies for strengthening institutional capacities and effectiveness, as results further reveal that the respective aspects are different across regions and related to deforestation in all places.

The results reveal that the proximate drivers of charcoal production, cropland cultivation and road extension, have stronger effects on deforestation than governance. Those drivers seem hardly affected by the in general very weak governance processes. This implies that global initiatives for addressing deforestation e.g., REDD+ need to complement long term governance improvement with measures that are able to specifically target proximate drivers faster e.g., sustainable production systems and alternative livelihoods opportunities. Such measures can be supported by incentives, as these are likely to make forest conservation more profitable than forest clearing for agriculture. Focusing on governance and enabling conditions alone might not be effective for sectoral policy goals. The illegal deforestation from charcoal production could further be addressed through effective monitoring of charcoal licences. This is less likely to adversely impact food security and rural incomes, with many farmers depending on agricultural income and, with charcoal production predominated by the affluent households. Because governance (formal and customary) is very still weak, establishment of community-based organization/ associations with lower transaction costs for monitoring illegal charcoal production is recommended.

The results suggest that the development pathway changes at the transition between the pre- and early phases, and not as expected between late and post-transition. This suggests that initiatives for reducing deforestation and forest degradation, e.g., REDD+ and other conservation programs, ought to establish alternatives to the usual agriculture-based development pathway already in the pre-transition phase. Opportunity costs, market forces and population trends are likely to develop strong dynamics in the early and late transition, making policy interventions expensive and less effective.

The results reveal that a high non-forest income (agriculture and non-farm) is associated with the pre-transition phase, whereas a low non-forest income is associated with the early and late transition phases. Together with increasing population, this indicates a marginalization of the population during the deforestation process. Because deforestation-related processes obviously deprive small-holder farmers of their livelihood and push them further into forestlands, there is need to avoid the agriculture-dependent deforestation trap. Alternative off-farm income opportunities and sustainable forest-based value chains should be promoted as substitutes for agriculture already in the pre-transition phase, under the condition that strict controls can be realised.

The results suggest that forest income is linked to deforestation, but forest recovery does not yet link to forest income. The practical implication is that there is potential to reduce the pressure on natural forests if forest income could be generated from planted or naturally regenerated forests because currently income from plantations/succession is not significant. Additionally, if wood resources are needed e.g., for construction or energy purposes but cannot be imported, then higher income without accompanying reforestation would bear the risk of deforestation and leakage elsewhere because consumption and thus, ecological footprint usually increases with income.

6.3 Study limitations and recommendations for future research

To guide similar research in future, the limitations of the analytical techniques applied in this research are identified and discussed in this section.

The first objective (Publication I) explores the patterns of forest governance quality at the local scale, where policy implementation occurs in practise (de facto governance). The discrepancies and or synergies between de facto governance and the de jure (legal) conditions are, however, only partially reflected in the discussions of this study. Future research may, therefore, consider integrating the discrepancies between de jure and de facto governance more comprehensively.

For objective III (Publication II) on examining the influence of de facto forest governance on deforestation, the results reveal that the proximate drivers seem hardly affected by governance perhaps because the governance indicators that were considered showed very limited variability between the different study sites. Statistically, it is impossible to explain an outcome by a predictor that has insufficient variations between study sites. Future research would, therefore, utilize a more variant but methodologically comparable dataset to examine the influence of de facto governance on deforestation. A similar study across different tropical countries would have a more variant but comparable dataset.

For objective IV (Publication III) on examining the links between governance and socioeconomic factors and FT dynamics in tropical landscapes from Ecuador, Philippines and

Zambia, there was potential for endogeneity in the ordered generalized linear regression regression models, given that the processes by which FT occurs may have various reciprocal effects with the explanatory variables (socioeconomic and governance factors). Due to the absence of suitable instrumental variables to account for the endogeneity problem, the deductions in this study were mostly restricted to associations and not necessarily cause-effects relationships. Future research should thus, consider using suitable instrumental variables to establish cause-effect relationships.

7 Conclusions

This thesis sets out to expand the current knowledge base on governance structures and assessment tools. The thesis also purposes to identify the specifics of forest governance with potential to curb deforestation and facilitate forest recovery in the tropics. It examines forest governance quality and its effects on forest transitions in the form of deforestation and forest recovery, accounting for socioeconomic and biophysical factors. It also tests the applicability of the widely recommended GFI framework based on community perceptions. Different from previous studies at the national scale, the analysis is conducted at the local scale, where policy implementation and the socioeconomic processes of household decision-making, which are essential to understand forest cover dynamics occur.

To address objectives I and II (Publication I), and objective III (Publication II), empirical evidence is generated from 24 communities spanning three provinces, Copperbelt, North-western and Eastern in Zambia. Unlike previous local level studies, which either consider the variability within regions or the variability between regions, this study considers both the variability within and between regions. To address objective IV (Publication III), empirical evidence is generated from 34 landscapes spanning three countries, Ecuador, Philippines, and Zambia. Different from previous national level studies, which only consider the variability between countries, this study addresses the local level effects, considering both the variability within and between countries.

Based on the findings presented in this research, the following main conclusions are drawn for the different objectives.

7.1 Applicability of the GFI indicator frameworks for governance assessment

The GFI framework turned out to be a very useful tool for assessing governance processes on the ground as factors generally mirror GFI indicators. However, as in some cases de facto governance processes do not precisely reflect thematic areas of the framework and as factor analyses reveals several distinct factors, the use of single indicators to exclusively represent a thematic area should be taken with caution. This is not intended by the authors of the GFI framework but could be the pragmatic interpretation of users in the field. As the local setting might partly influence the relationships between some elements of quality, it is recommended that the elements are adapted to suit the local context and additionally refined to reflect the most relevant governance processes.

Customary rules and institutions need specific attention when applying the GFI framework because in comparison to the framework, the respective aspects are more clearly differentiated on the ground.

7.2 Governance performance across governance arrangements and communities in the Zambian Miombo.

The results reveal that state actors do not necessarily result into improved forest governance performance as compared to individual and communal actors and vice versa. In fact, the enforcement of rules and relevant governance process e.g., land use planning coupled with adequate institutional capacities to permit enforcement processes condition improved forest governance.

The results suggest that there is possibility for conflicts between the customary and formal institutions resulting from unclear institutional mandates for customary forest management. This shows how competing actors/institutions (formal and customary), as a result of overlapping configurations of power, challenge policy implementation on the ground. The result implies that customary and formal governance processes have to be better harmonized, otherwise implementation of the national and international forestry agenda including REDD+, Bonn challenge, and other climate change initiatives will not be feasible.

Governance processes do not spatially depict the provincial/regional administrative structure. This highlights the need of improving and streamlining de facto and de jure governance factors beyond the established administrative boundaries. This should be considered in the design of co-management strategies as well as in jurisdictional and landscape approaches.

7.3 Influence of de facto forest governance on deforestation

The direct drivers, charcoal production, crop agriculture and road extension, have stronger effects on deforestation than governance as an underlying driver. Those drivers also seem hardly affected by the in generally very weak governance processes. This shows a rather actor-dominated than rules and/structure-dominated phenomenon. The rules need to be better integrated together with other structures such as land use planning to regulate the unsustainable forest use actions of the actors. In addition, global initiatives to address deforestation such as REDD+ need to complement long term governance improvement with measures that are able to specifically target direct drivers faster e.g. sustainable production systems and alternative livelihoods opportunities. Such measures can be supported by like market-based mechanisms and incentives that make forest conservation more profitable than forest clearing for agriculture and charcoal production. Focusing on governance and enabling conditions alone might not be effective for sectoral policy goals.

Local government institutions seem to reduce deforestation where they are more effective and with better capacities. This emphasizes, the necessity for strengthening local institutional capacities (financial, human, technical) in order to achieve successful forest conservation. Additionally, because local government institutions represent a fundamental decentralization structure, this reveals the potential for curbing deforestation through effective decentralization.

7.4 Linkages between governance and socioeconomic factors and the FT dynamics

Governance factors (i.e. institutional capacities and effectiveness and access to forest resources) and socioeconomic factors (i.e. human population pressure and non-forest income) explain the forest transition dynamics at the local scale. This mostly confirms previous findings at the national level for one county, for the local scale considering completely different tropical contexts and countries.

The governance and socioeconomic factors clearly distinguish the pre-transition phase from the rest of the FT phases. This can be interpreted as an indication that the underlying development pathway already changes at the transition between the pre- and early phases and not as expected between the late and post-transition. This suggests that initiatives for reducing deforestation and forest degradation e.g. REDD+ and other conservation programs ought to establish alternatives to the usual agriculture-based development pathway already in the pre-transition phase.

Surprisingly, a high non-forest income is associated with the pre-transition phase whereas a low non-forest income is associated with the early and late transition phases. Together with increasing population this could indicate a marginalization of the population during the deforestation process. Because deforestation-related processes obviously deprive small-holder farmers of their livelihood and push them further into forestlands, the challenge is to avoid the agriculture-dependent deforestation trap. Alternative off-farm income opportunities and sustainable forest-based value chains should be promoted as substitutes for agriculture already in the pre-transition phase, under the condition that strict controls can be realised.

The findings neither clearly confirm nor clearly falsify the hypothesis that forest recovery and deforestation are distinct processes. This inference is made because there are statistical arguments pro and contra. Thus, there is still need for further studies in this regard.

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9 Appendices

Appendix A: Description of the governance indicators and the elements of quality and thematic areas of the GFI framework. ✓ implies present and X absent. P represents Philippines, E, Ecuador and Z, Zambia.

Thematic area	Indicator	P	E	Z	Elements of quality
Forest tenure	1.Tenure recognition	✓	✓	✓	Recognition**.** Most individual and communal rights-holders have their rights recognized and recorded Demarcation. Most individual and communal forestlands have boundaries demarcated Enforcement. Infringements (violation) of rights are addressed quickly and fairly Gender equity. Rights registered to individuals or households are often registered in the names of women, jointly or individually Customary tenure. Minimal conflict exists between customary forest tenure systems and statutory systems on the ground
Land use	2. Land use planning	✓	✓	✓	Procedure. Land use decisions are taken in a formally established process Transparency. Planning process is transparent, and procedures are clearly defined Opportunities for participation. Communities or entitled individuals have the chance to participate in land use planning processes Representation. Representatives in land use planning processes reflect a range of community perspectives, including women and different socioeconomic classes Capacity to engage. Representatives in land-use planning have the information and skills to effectively engage and participate in land use planning processes
Forest management	3.Strategies and plans	✓	✓	✓	Coordination. Implementing agencies/persons/enterprises effectively coordinate when performing their roles and responsibilities Timeliness. Implementation takes place according to the timeline specified by the plan/strategy Monitoring. Implementation is subject to regular monitoring of impacts and effectiveness Transparency. Land use plans and monitoring reports are publicly disclosed on a regular basis Review. Plans and strategies are reviewed and updated regularly
	Licences:				Procedural clarity. Clear administrative procedures regulate the obtaining of licenses and permits Transparency. Application status can be tracked
	4. Timber	✓	✓	✓	Accessibility. The process for acquiring a license or permit is not prohibitively complicated and expensive

	5. Charcoal	X	X	✓	Timeliness. Licenses and permits can be obtained in a reasonable time and within the time prescribed
	6. Non-timber forest products	✓	✓	✓	Implementation. Licenses and permits are honoured during harvesting and transport of forest products
	7. Reforestation programs	✓	✓	✓	Procedures. Stakeholders understand the procedures and terms of the program, including planting sites and species, duration, as well as associated benefits and responsibilities Coordination. The implementing agency coordinates implementation by establishing clear agreements with people and organizations
	8. National Greening program (NGP)	✓	X	X	Capacities. Communities have been capacitated to implement the program Benefits. Participants have received compensation as agreed Monitoring. Implementation is subject to regular monitoring to ensure compliance and effectivity
	9. Protection and conservation	✓	✓	✓	Demarcation. Boundaries of protected or conservation forests areas are clearly demarcated. Use restrictions. Stakeholders clearly understand the timeframe and what activities are allowed and not allowed within the protection or conservation area Enforcement. Implementing agencies are aware of and effectively coordinate to carry out their roles and responsibilities Penalties. Stakeholders understand penalties for failing to comply with the rules of the arrangement Monitoring. Implementation is subject to regular monitoring of impacts and effectiveness
	10. Protection and logging moratorium	✓	X	X	Demarcation. There are no demarcation and people are unaware on the location of their natural forest Use restrictions. Participants know that it is not allowed to cut trees as informed by the DENR Respect of rights. They think that the law has an advantage since it restrict commercial logging. However, they also think that the law did not respect their rights since they need timber for personal use Transparency. The DENR coordinates with them if there are reported logging in the area Accountability. The participants said that those caught were penalized
	11. Payment for Ecosystem Services programs	✓	✓	✓	Procedures. The procedures for establishing PES have been made clear to the stakeholders Coverage. PES schemes have been established on the ground. Benefit-sharing. The schemes for benefit sharing have been jointly decided, understood and acceptable to the stakeholders Protection. The protection of the forests providing these ecosystem services has been put in place Monitoring. Implementation is subject to regular monitoring
	12. Forest-base	✓	✓	✓	Procedures. Stakeholders clearly understand the procedures for setting up sustainable livelihood projects.

	livelihood programs				Coordination. Government agencies coordinate and provide support in implementing and sustaining projects Resources. Forest resources are adequate to sustain livelihoods Facilities. Credit facilities and capacity building were made available to local communities Benefits. Community members receive shares and benefits equitably
	Law enforcement: 13. Formal law	✓	✓	✓	Apprehension. Violators are apprehended and brought to trial by concerned authorities Consistency. Assigned penalties are generally consistent with the law and appropriate given the nature of the offence Compliance. Penalties are served or are paid in full in a timely manner
	14. Customary law	✓	✓	✓	Monitoring of compliance. Compliance with penalties is monitored and further legal action is taken in cases of non-compliance Transparency. Information about penalties and their state of compliance is publicly disclosed
Revenues	15. Revenues	✓	✓	✓	Fairness. Fees collected are reasonable and the basis of computation is understood. Transparency. Field staff generate comprehensive and accurate records of all fees collected and these are made available to the public. Awareness. The government takes action to ensure that non-governmental “payers” are aware of their obligations. Timeliness. Fees are collected in a timely manner. Monitoring. Regular monitoring evaluates whether appropriate fees are collected as agreed
	16 Benefit-sharing mechanisms	✓	✓	✓	Participation. The community has participated in the design of local benefit-sharing arrangements. Compliance. Benefits are delivered in accordance with the agreed terms set out in relevant legal or project documents Awareness. Community members are aware of the benefits received and obligations associated with these benefits Fairness. The type and extent of benefits are fair and appropriate Monitoring. Regular monitoring evaluates whether benefits, as agreed, have reached intended recipients
Cross-cutting Institutions	Capacities and effectiveness				Knowledge and skills. Institutions capacitated with up-to-date knowledge and skills to play an active role in forest management
	17. Central government	✓	✓	✓	Human resources. Institutions capacitated with an adequate number of staff personnel to play an active role in forest management
	18. Local government	✓	✓	✓	Financial resources. Institutions capacitated with sufficient financial resources to play an active role in forest management
	19. Non-government organizations	✓	✓	✓	Scientific and technical information. Institutions capacitated with relevant scientific and technical information to take an active role in forest management

	20. Customary institutions	X	X	✓	Effective. Institutions are effective in implementing forest management objectives
Cross-cutting issues	21. Participatory policymaking	✓	✓	✓	Awareness. Community members are notified in due time of policies to be developed, reviewed and revised that are relevant for land use in their community Platforms. Platforms are provided for multi-stakeholder participation in policymaking Representation. Policy-making platforms allow the participation of key representatives from the different forestry sector Effectiveness. Facilitation methods allowed key stakeholders to participate actively in the process Transparency. The stakeholders are informed of the results of policy engagements

Appendix B: Description of major land use classes from the community participatory mapping exercises.

Land use type	Description	Area (ha)
Secondary forest reference-Degraded (interventions)	Forest with anthropogenic disturbance from extraction followed by natural regeneration.	133,737.67
Secondary forest succession	Forest once completely deforested for crop agriculture and abandoned. With natural regeneration greater than or equal to five meters height.	37,509.97
Plantation forest	Forest once completely deforested followed by anthropogenic regeneration	29.02
Woody shrubland	Forest once completely deforested for crop agriculture and abandoned. With natural regeneration, less than five meters height.	50,035.42
Annual croplands	Land used for growing annual crops	53,672.94
Wetlands	Land consisting of marshes or swamps	13,774.13
Roads	Hard ground that is built to facilitate movement from one place to the other.	256.77
Water bodies	Rivers and lakes	9,705.94
Bare surfaces	Land covered by only soil	232.67
Settlements	Land where people have established buildings	1,509.06
Grasslands	Land that mostly contains grasses	3,112.60

Appendix C: Correlation between estimated population and variables on infrastructure development at 95% confidence interval using standardized variables**.** Coefficients (ρ) range between +1 and −1, where 1 is the total positive linear correlation, 0 is no linear correlation and −1 is total negative linear correlation. Low p-values below the significance level of 0.05 indicate that relationships are statistically significant (Bewick et al., 2003) , Number of observations = 91

Infrastructure Variable	Number of people Spearman (ρ)	P-value
Built up area (%)	0.4125	<.0001
Distance to roads (Meters)	-0.504	<.0001

Appendix D: Resultant factors of governance variables

Governance variable	Assigned meaning of principal factors			
	Three FT phases (deforestation) N= 29		Four FT phases (deforestation and recovery) N= 36	
	Factor 1 **Institutional capacity and effectiveness**	**Factor 2** **Access to forest resources**	**Factor 1** **Institutional capacity and effectiveness**	**Factor 2** **Access to forest resources**
Tenure rights recognition and protection	0.41	**0.64**	0.09	**0.77**
Forest management	-0.47	**0.63**	**-0.59**	**0.57**
Forest law enforcement	**0.67**	**0.58**	**0.52**	**0.68**
Government institutions capacities and effectiveness	**0.85**	0.09	**0.85**	0.17
Non-Government Organizations capacities and effectiveness	**0.84**	-0.35	**0.86**	-0.12
Local institutions capacities and effectiveness	**0.81**	-0.19	**0.85**	-0.05
Public policy participation	**0.70**	0.38	**0.61**	0.42
Percentage of restricted area	0.33	**-0.73**	**0.51**	**-0.66**
Eigen value	3.52	1.98	3.46	2.02
Variance explained (%)	43.99	24.79	43.19	25.28
Cumulative variance (%)	43.99	68.78	43.19	68.47

Appendix E: Resultant factors of socioeconomic variables

Socioeconomic variable	Assigned meaning of principal factor					
	Three FT phases (deforestation) N= 28			Four FT phases (deforestation and recovery) N= 34		
	Factor 1	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**
	Non-forest income	**Human population pressure**	**Forest income**	**Non-forest income**	**Human population pressure**	**Forest income**
Crop income	**0.97**	0.02	0.00	**0.94**	0.10	0.07
Livestock income	**0.90**	0.06	-0.17	**0.90**	0.15	-0.16
Forest income	0.38	0.10	**0.86**	0.34	-0.13	**0.89**
Non-farm income	**0.82**	0.34	-0.17	**0.80**	0.45	-0.09
Population density	-0.21	**0.83**	-0.38	-0.33	**0.86**	-0.17
Road density	-0.30	**0.75**	0.40	-0.41	**0.64**	**0.50**
Eigen value	2.69	1.39	1.10	2.74	1.39	1.10
Variance explained (%)	44.81	23.08	18.34	45.64	23.24	18.35
Cumulative variance (%)	44.81	67.89	86.23	45.64	68.88	87.23

Appendix F: Resultant factors of biophysical variables

Biophysical variables	Assigned meaning of principal component factor			
	Three FT phases (deforestation) N= 29		Four FT phases (deforestation and recovery) N= 36	
	Factor 1	**Factor 2**	**Factor 1**	**Factor 2**
	Elevation	**Soil fertility**	**Elevation**	**Soil fertility**
Precipitation (1979-2013)	**0.67**	**0.61**	**0.59**	**0.69**
Temperature (1979-2013)	**0.95**	-0.09	**0.96**	-0.04
Slope	**0.79**	-0.31	**0.81**	-0.28
Elevation	**-0.94**	0.16	**-0.94**	0.15
Soil nutrients	0.09	**0.93**	0.01	**0.93**

Eigen value	2.87	1.37	2.80	1.46
Variance explained (%)	57.32	27.43	56.00	29.00
Cumulative variance (%)	57.32	84.75	56.00	85.00

Appendix G: Correlation analysis of between factors that were included in the regression model with three FT phases in the outcome variable

Principal factors	Institutional capacity and effectiveness	Access to forest resources	Non-forest income	Human population pressure	Forest income	Elevation	Soil fertility
Institutional capacity and effectiveness	1.000						
Access to forest resources	0.000	1.000					
Non-forest income	0.280	0.431	1.000				
Human population pressure	0.469	-0.176	0.000	1.000			
Forest income	-0.415	0.119	0.000	0.000	1.000		
Elevation	0.779	0.073	0.644	0.214	-0.381	1.000	
Soil fertility	0.218	0.683	0.177	-0.184	0.011	0.026	1.000

Appendix H: Correlation analysis of between factors that were included in the regression model with four FT phases in the outcome variable

Principal component factors	Institutional capacity and effectiveness	Access to forest resources	Non-forest income		Forest income	Elevation	Soil fertility
Institutional capacity and effectiveness	1.000						
Access to forest resources	0.041	1.000					
Non-forest income	0.005	0.508	1.000				
Human population pressure	0.611	-0.052	0.000	1.000			

Forest income	-0.252	0.076	0.000	0.000	1.000		
Elevation	0.751	0.064	0.440	0.447	-0.299	1.000	
Soil fertility	0.171	0.667	0.114	-0.180	0.039	-0.006	1.000

Appendix I: Publication I

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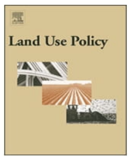

Exploring patterns of forest governance quality: Insights from forest frontier communities in Zambia´s Miombo ecoregion

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ABSTRACT

Good forest governance is a prerequisite for sustainable forest management and the successful implementation of initiatives that aim to reduce deforestation and forest degradation. The necessity for good governance is high in Zambia´s Miombo ecoregion, which is characterised by persistent deforestation that also threatens forest-dependent livelihoods. Zambia has adopted policies and initiatives to improve forest governance. We use the Governance of Forests Initiatives (GFI) indicator framework from the World Resource Institute in 24 communities in the Miombo ecoregion to examine Zambia´s status in this respect. The Wilcoxon rank test is applied to compare the de facto governance performance between different arrangements with differing tenures and restrictions to forest access and use. We employ factor analysis to test the applicability of the GFI framework based on community perceptions and cluster analysis to examine whether patterns of community clusters reflect the governance structure of the provincial local government administration. Comparative results show low mean scores for governance indicators, which do not differ significantly between arrangements. This indicates a weak de facto forest governance performance across arrangements, specifically characterised by an inadequate enforcement of rules and restrictions on use, insufficient institutional financial, human and technical capacities and unsatisfactory participatory land use planning and forest policy-making processes. We recommend support for financial and technical institutional capacities combined with coordination mechanisms to permit the satisfactory enforcement of forest rules. Frequent monitoring, apprehension and graduated sanctions are proposed as part of the rule enforcement procedures. Stringent de jure requirements coupled with capacity building for participatory land use planning and public policy participation also need to be adopted. This would also contribute towards achieving targets for Zambia´s climate change response strategy, national development plan 2017–2021 and REDD + preparedness phase. The factor analysis largely confirms the GFI framework's suitability for governance analysis on the ground since factors generally mirror GFI indicators. However, because de facto governance processes sometimes do not precisely reflect thematic areas of the framework, we warn against the use of single indicators to exclusively represent a thematic area. Similarly, specific attention has to be paid to customary rules and institutions when applying the GFI framework because compared to the framework, the respective aspects are more clearly differentiated on the ground. Cluster analysis reveals a high variability of governance processes within and across provinces. Decentralization measures should take into account clusters that may in some cases follow administrative levels or in other cases go beyond the established administrative boundaries. Specifically, initiatives to integrate customary structures into the decentralized governance structure should take these regional differences into account.

1. Introduction

Globally, forests are under enormous pressure from deforestation and forest degradation. Approximately 7.6 million hectares of forest are lost annually, especially in the poorest tropical regions (FAO, 2015). Deforestation is a result of several factors, many of them related to poor forest governance (Eliasch, 2012; Umemiya et al., 2010; Kanninen et al., 2007; Kaimowitz, 2012), which has failed to regulate anthropogenic pressures. Deforestation is linked to increased greenhouse gas emissions (Seymour and Busch, 2016), the loss of a functioning forest

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ecosystem (Millennium Ecosystem Assessment, 2003), and the deterioration of socio-economic conditions, particularly in Africa with its more than 160 million forest-dependent households (FAO, 2018). There is thus a need for improved forest governance, especially since governance is considered a precondition for sustainable forest management and for the successful implementation of global initiatives such as Reducing Emissions from Deforestation and Forest Degradation (REDD+), Payment for Ecosystem Services (PES) (Pettenella and Brotto, 2012) and forest landscape restoration (Mansourian, 2016).

The necessity for improved forest governance is high in countries like Zambia, which has alarmingly high deforestation rates with around 0.63 % annual forest loss between 2000 and 2018 (Hansen et al., 2013; Global Forest Watch, 2018). The greatest loss is reported in the Miombo ecoregion, the most extensive forest type in Zambia, covering 45 % of the total land area (Matakala et al., 2015). The Miombo is characterized by the dominance of *Brachystegia, Julbernardia* and *Isoberlinia* tree species (Matakala et al., 2015). The woodlands are of significant economic importance, providing a variety of ecosystem goods and services essential for human wellbeing including firewood, charcoal, timber and non-timber forest products (Turpie et al., 2015). The ecosystems are experiencing considerable deforestation due to charcoal production, firewood collection and clearing for farming (Kalinda et al., 2008). Deforestation not only threatens the livelihoods of rural Zambians, who derive nearly 44 % of their income from the Miombo forest ecosystem goods and services (Kalaba, 2013), it also undermines Zambia´s commitment towards the Aichi biodiversity targets, i.e. to reduce biodiversity loss through deforestation and forest degradation by 25 % by 2020 (MLNREP, 2015).

Several definitions are proposed for governance. In general, recent definitions understand governance as a broad and comprehensive concept that goes far beyond governments. Common governance definitions all denote rules/structures, actors and processes/practices (Mansourian, 2017; Larson and Petkova, 2011; Broekhoven et al., 2012; Giessen and Buttoud, 2014; Kishor and Rosenbaum, 2012). A widely accepted forest governance definition "comprises a) all formal and informal, public and private regulatory structures, i.e. institutions consisting of rules, norms, principles, decision procedures, concerning forests, their utilisation and their conservation, b) the interactions between public and private actors therein and c) the effects of either on forests" (Giessen and Buttoud, 2014). Since it is difficult to cover all aspects within the methodology of one study, while simultaneously maintaining scientific rigour, the definition can be adapted to reflect the relevant aspects (Giessen and Buttoud, 2014). As our study does not reflect on effects on forests, we define forest governenace as the "norms, processes, instruments, people and organizations that control how people interact with forests" (Kishor and Rosenbaum, 2012). The concept of "forest governance" is operationalized by several indicator frameworks. They include the "framework for assessing and monitoring forest governance" of the Food and Agriculture Organization (Kishor and Rosenbaum, 2012), the "natural resource governance framework assessment guide" of the International Union for Conservation of Nature (Campese, 2016), and the "governance of forest initiatives indicator framework" of the World Resource Institute (Davis et al., 2013). While these frameworks do not offer direct inferences on the economic, ecological and social outcomes of governance systems, they provide a comprehensive understanding of governance processes that is likely to contribute to improvements in the quality of decision-making and implementation (Rauschmayer et al., 2009). The Governance of Forest Initiative (GFI) indicator framework is widely recommended for forest governance assessments given its comprehensive coverage, providing a series of indicators for analysing different dimensions of forest governance systems (Agung et al., 2014; Brito et al., 2009). Although primarily practise-oriented, we hypothesize that the the GFI framework builds on aspects necessary for applying the normative concept (Giessen and Buttoud, 2014) as a scientific analytical approach, i.e value judgements on desirable conditions within a methodological framework to provide recommendations towards selected ends. Thus, it permits the integration of scientific and practical aspects and provides added value to real world challenges. Moreover, while previous models underscore either actors (Hardin, 1968) or rules/institutions (Goodin, 1996; Ostrom, 1990) as the theoretical basis, the GFI framework, with its practise-oriented approach, is able to integrate both aspects (Arts et al., 2014) as, based on theoretical foundations of the governance concept, it includes agency and structure components (Fischer et al., 2020). It emphasiszes the diversity of actors, the links between formal and informal practises and the rules that shape governance (Davis et al., 2013).

A few scientific studies have utilized the GFI framework to quantitatively analyze progress towards proposed governance improvements: Agung et al. (2014) and Pettenella and Brotto (2012) analyse the impact of REDD + readiness on forest governance in Indonesia and the successful features for REDD + project organizations, respectively. Such progress needs to be assessed specifically for communities with diverse forest governance arrangements. This implies the need to scientifically test the applicability of the proposed indicators on the basis of community perceptions. Community perceptions can indicate the extent to which governance structures are legitimated by community members (DeCaro and Stokes, 2013). Community perceptions have also been found to correlate with local compliance with rules for common pool resource management (Jenny et al., 2007). Furthermore, community perceptions may capture the de facto reality that exists on the ground, which was found to differ substantially from the fact-based de jure notions of laws (Kaufmann et al., 2011). Although perception-based measures have been criticized as reflecting factors other than governance, such as economic performance or poverty (Kurtz and Schrank, 2007), Kaufmann et al. (2007) found this notion does not withstand empirical scrutiny.

Several African countries including Zambia have adopted policies and initiatives that take the importance of forest governance into account. In Zambia, the revised decentralization policy of 2013 provides for the devolution of decision-making power, functions, responsibilities and resources to the provincial, district and sub-district levels to improve the quality of service delivery at the sub-national level, including forest management (GRZ, 2002). Zambia also developed a national strategy for reducing emissions from deforestation and forest degradation (REDD+), which integrates strengthening forest governance in the preparatory phase (Matakala et al., 2015). Zambia´s National development plan 2017–2021 similarly proposes improved forest governance as part of its strategies towards achieving sustainable forest use (Ministry of National Development Planning, 2017). The country has also developed strategies for the Convention on Biological Diversity, the United Nations Convention to Combat Desertification and the United Nations Framework Convention on Climate Change (Kalaba et al., 2014), all of which contribute to sustainable development goal 15 on sustainable forest management (United Nations, 2015). Moreover, Zambia´s Forest Act of 2015 and Forest Policy of 2014 provide for the establishment of diverse forest governance arrangements. These range from (i) hierarchical command and control systems in state-owned National Forest Reserves and National Parks to (ii) participatory arrangements with restrictions of forest use and management in state-owned Local Forest Reserves, and Game Management Areas, to (iii) inclusion of communities, customary institutions and private entities into forest conservation initiatives in customary and private forests (GRZ, 2015a, 2015b). However, there has been almost no comparative examination of the governance status within these diverse arrangements. Given the co-existence of customary and formal institutions, with overlapping jurisdictions and operating within parallel customary and formal legislation (GRZ, 2015a, 2015b), it is imperative to understand how interrelationships amongst these distinct structures of authority shape forest governance outcomes in Zambia. As hypothesised by several scholars (e.g. ANDERSON et al., 1998; Rescher, 1993), conflicts between overlapping regulations and institutions are often inevitable. As this is likely to have implications on governance progress, knowledge about forest governance performance in Zambia is crucial for the further development of policy in the context of legal and institutional pluralism, which is typical for many African countries in the post-colonial era.

1. Aims

This study aims to contribute to a more robust understanding of forest governance assessment tools and governance structures and purposes to identify the possible influence of overlapping formal and customary administrative structures on de facto governance. Methodologically, we aim to draw conclusion on the applicability of the GFI framework at a community level. The study addresses three key research questions: (i) How does forest governance differ across different governance arrangements with differing tenure and restrictions to forest access and use? (ii) Given the broad and very comprehensive understanding of forest governance, does the GFI framework help to differentiate distinct aspects of forest governance based on the perception of the local population? (iii) Can communities be clustered into distinct groups of similar governance conditions? If so, does the pattern of community clusters reflect the governance structure of the provincial local government administration? By answering these questions, we aim to draw conclusions on the strengths and weaknesses of different restriction regimes as instruments of national policy implementation on the ground in communities, which are influenced by customary and governmental rules and actors.

1.2. Forest administrative structure in Zambia

Zambia´s forest administration has been decentralized to provide citizens with more authority and power in decision-making at the local level. The central government agency with a legal mandate to manage forest resources is the Forest Department of the Ministry of Lands and Natural Resources. Forest department is responsible for formulating and reviewing all legislation related to forest management in addition to coordinating its implementation (Chileshe, 2001; Ministry of Tourism, Environment and Natural Resources, 2009). The sub-national government levels are structured into the provincial, district, and sub-district administration units i.e. area and ward (Fig. 1). Provincial and district units are responsible for formulating and enforcing by-laws, and facilitating the proper and smooth administration of forest estate, in accordance with the forestry policy and existing legal framework (Chileshe, 2001; Ministry of Tourism, Environment and Natural Resources, 2009). The district unit is additionally responsible for providing extension services, collecting revenues from the sale of forest products, the enforcement of regulation through licences and patrols, managing forest woodlots and plantations and coordinating and monitoring lower administrative levels (Chileshe, 2001). Currently, Zambia has 10 provinces and 117 districts, each comprising a district council, which is the main policy and decision-making body at the district level. At the sub district level, the council is represented by the Area Development Committees (ADCs). The ADCs are democratically elected, local governance structures that ought to work together with members in each ward to develop natural resource plans and participate in the management thereof (GZR, 2015). Although the ADCs are theoretically the official focal point of local collective action for the improvement of the environment and livelihoods on customary lands, these governance structures in reality appear to be dysfunctional and are not viewed as a political administrative unit in some communities (Mfune, 2013).

There is a strong customary administrative structure operating in parallel to the aforementioned political administration within each district that is guaranteed by the Constitution of the Republic of Zambia (Mason-Case, 2011). Customary administration is made up of 73 tribes headed by 240 chiefs, 8 senior chiefs and 4 paramount chiefs, who delegate rights and responsibilities to headpersons and sub-chiefs within their jurisdictions (Mason-Case, 2011). Traditional leaders are mandated to administer customary lands based on local traditions. Traditional leaders determine land use, access and user rights on customary land. The political administration often has little authority over traditional administration and must engage in consultations with traditional institutions before undertaking any activities on customary lands.

In practice, however, the central government is unwilling to relinquish power over protected forests to local governments (Mfune, 2013). Moreover, local government´s financial, human and technical capacity to manage open forests is limited. Furthermore, local government´s involvement in the governance of customary forests is constrained by the contradicting land tenure policies (Chikulo, 2009). While the Local Government Act of 1991 gives the district council a mandate to plan

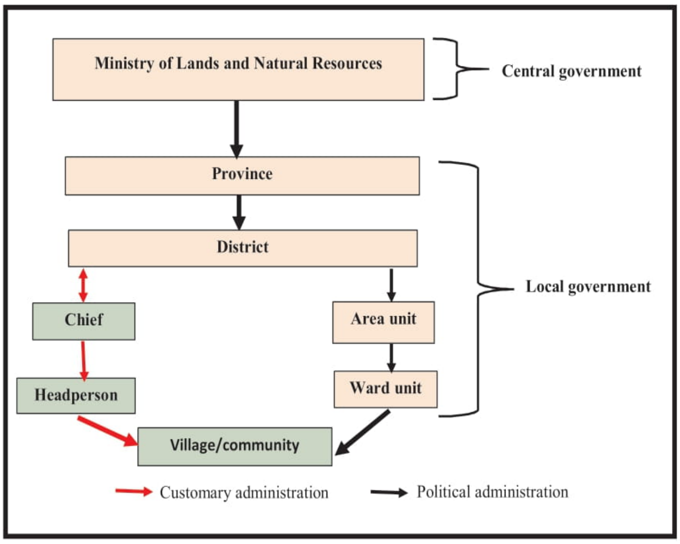

Fig. 1. Administrative units of central, local and traditional government in Zambia´s decentralised forest governance structure (Chileshe, 2001, Ministry of Tourism, Environment and Natural Resources, 2009).

and lead the management of customary forests, the Land Act of 1995 places the administration of these lands under customary authority. Besides, customary authorities sometimes challenge the authority of the sub-district governance structures (Mfune, 2013).

1.3. Zambia´s forest governance arrangements

The forest governance arrangements of Zambia are grounded in the land reform of 1924, dating back to the colonial period. During this period, land in Zambia was demarcated into crown and native reserve land, designated for exclusive use by Africans and European settlers, respectively (Van Loenen, 1999; Brown, 2005). The chiefs administered forests on native reserves based on customary law. In contrast, forests on crown land were administered by the British colonial government based on formal law (Brown, 2005). At independence, customary land administration was sub-ordinated to formal law, which previously only applied to crown land. However, the method of customary land alienation continued under customary law. Following Zambia's independence in 1964, crown land was converted to state land and subsequently administered by the Ministry of Lands (Brown, 2005).

Zambia currently has various forest governance arrangements under the responsibility of different institutions, across different tenure categories and with differing access and use restrictions (Table 1). The majority (65.7 %) of Zambia´s forest is on customary land as either individual or communal forests. These either have or lack cultural norms, such as graveyard forests, which are governed by chiefs and their representatives including village headpersons and sub-chiefs under customary law (GRZ, 2015a; Kalinda et al., 2008). Under formal law, the commercial use of forest products without a licence on customary lands is restricted, although access and subsistence use are not (GRZ, 2015a). Other forests (23.7 %) in Zambia are located on state lands. State forests include National and Local Forest Reserves, administered by the Forest Department (GRZ, 2015a; Kalinda et al., 2008), as well as National Parks and Game Management Areas, administered by the Department of National Parks and Wildlife (GRZ, 2015b). Under formal law, access to and use of forest resources in state forests is restricted, except with special permits. Private forests also exist on state lands, which constitute 10.6 % of the total forest area. These are owned by registered individuals or companies through leasehold tenure.

2. Methods

2.1. Study sites and site selection

The study was conducted in the Miombo woodland, which is the major forest type in Zambia, and employed a nested design to capture the diversity of communities in the Miombo ecoregion. Three provinces, namely Copperbelt, North Western and Eastern were selected to represent different socio-economic and demographic conditions as well as different forest cover and deforestation contexts (Table 2). North Western is characterised by a low population density of 6 persons/km^2 (Central Statistical Office, 2010), high forest cover (81.1 %) and low rate of forest loss (0.43 % annually) between 2000 and 2018 (Global Forest Watch, 2018), mostly from unsustainable timber extraction (Shakacite et al., 2016). According to the same sources, Eastern province has a medium population density of 31 persons/km^2, low forest cover (50.4 %) and a relatively low rate of forest loss (0.48 % annually) between 2000 and 2018 (Global Forest Watch, 2018), mostly from small scale crop farming. Copperbelt is characterised by a very high population density of 63 persons/km^2, a medium to high forest cover (76.6 %) and high rate of forest loss (1.3 % annually) between 2000 and 2018, mostly from charcoal production.

Four landscapes each of 12*12km, with typical land-use, socio-economic, demographic and biophysical attributes and a distinct traditional administration (chiefdom) were selected for the study within

Table 1
Zambia´s forest governance arrangements with differing tenures, institutions, and restrictions to forest access and use (Kalinda et al., 2008).

Arrangement	Access and use restrictions	Tenure	Administrative institutions	IUCN Category	% forest area
National Parks	Access and use of timber and NTFPs: restricted	State	Department of National Parks and Wildlife (DNPW)	IUCN II	23.7
National Forest Reserves	Access and NTFPs use: restricted; Use of timber: regulated by license	State	Forest Department	IUCN II	
Local Forest Reserves	Access: restricted; Use of timber and NTFPs: regulated by license	State	Forest Department Traditional institutions	IUCN VI	
Game Management Areas	Access: restricted; Use of timber and NTFPs: regulated by license	State	Department of National Parks and Wildlife Traditional institutions	IUCN VI	
Traditional/ cultural forests	Access: restricted; Use of Timber and NTFPs: restricted	Customary	Traditional institutions	IUCN III	65.7
Individually owned customary forests	Access: Non-restricted; Commercial Timber and NTFPs use: regulated by license; Subsistence use of timber and NTFPs: non-restricted	Customary	Traditional institutions; Forest Department	None	
Communal customary forests	Access: Non-restricted; Commercial timber and NTFPs use: regulated by license; Subsistence use of timber and NTFPs; non-restricted	Customary	Traditional institutions; Forest Department	None	
Private forests	Access and use: restricted by owner	State/ leasehold	Registered individual/company	None	10.6

Table 2
Description of demographic, forest cover and deforestation attributes of study provinces (Global Forest Watch, 2018; Central Statistical Office, 2010; Shakacite et al., 2016).

Attributes	Copperbelt	North Western	Eastern
Forest area (%)	76.6	81.1	50.4
Annual forest loss (%)	1.3	0.43	0.48
Population density (people/km^2)	63	6	31
Main driver of deforestation	Charcoal production	Unsustainable timber extraction	Small scale farming

each of the three provinces, thus a total of 12 landscapes. Two communities within each landscape were selected for the study, thus a total of twenty-four communities (Fig. 2). Areas of distinct de jure governance arrangements, representing different tenure and restrictions to forest access and use, were identified a priori within the communities through scoping visits to the traditional headperson´s offices and forest department maps. Five types of governance arrangements were identified:

i State forests with restrictions to access and use
ii Individual customary forests with no restrictions to access and use
iii Communal customary forests with no restrictions to access and use
iv Communal customary forests with cultural restrictions to access and use
v Private forests with use decided by the registered land owner

2.2. Governance indicator assessment

The study relies on the Governance of Forests Initiatives framework of the World Resource Institute. The GFI framework provides a comprehensive diagnostic tool that covers six core governance issues in forestry. These are: 1) forest tenure, 2) land use planning, 3) forest management, 4) forest revenues, 5) cross-cutting institutions and 6) cross-cutting issues, denoted as thematic areas (Davis et al., 2013). The framework assesses these governance areas through a set of detailed indicators, each specified by five elements of quality that are rated on a scale of pre-coded statements, ranging from lack of good governance to good practice.

The GFI framework recommends that the indicators should be "adapted based on contextual factors such as scale of assessment, type of forest biome, or ownership regime" from the large multitude of governance aspects covered. After a thorough literature analysis, coupled with a pre-test workshop conducted with 15 community participants in Zambia, we selected at least one indicator from each of the thematic areas, choosing those that reflect pertinent issues in Zambia´s

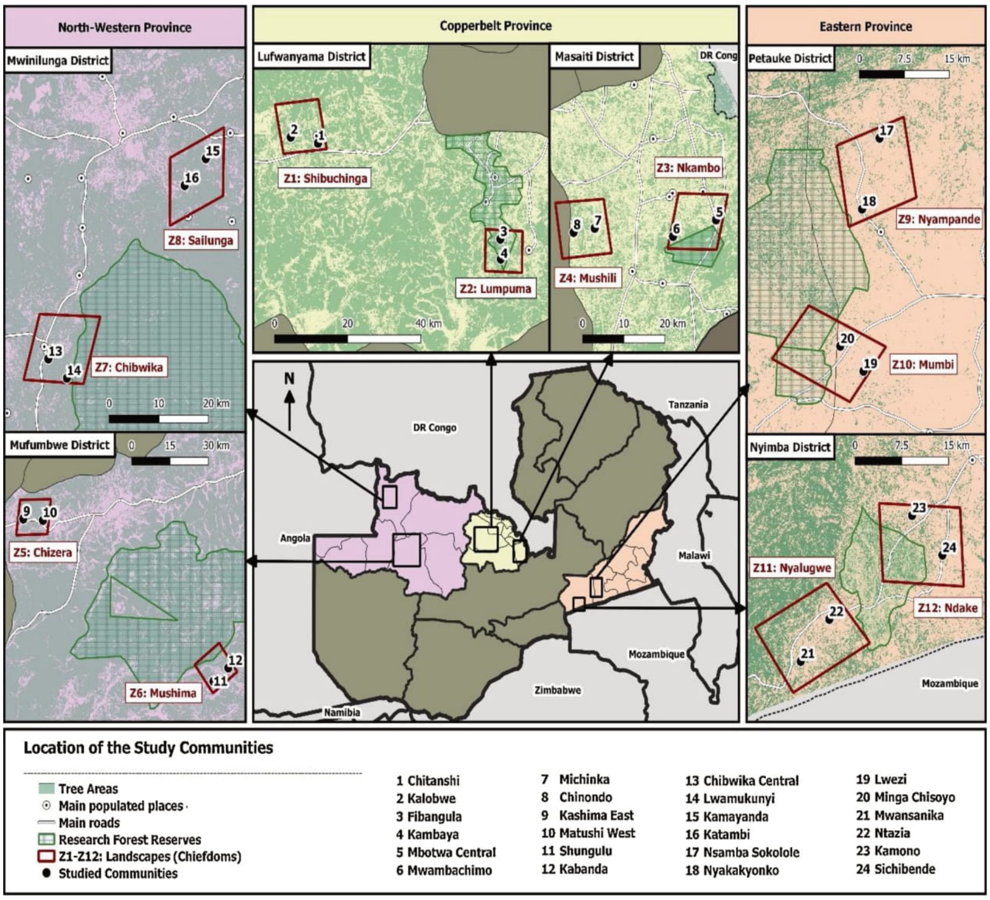

Fig. 2. Locations of the study provinces, landscapes and communities in Zambia. Landscapes are labelled according to the chiefdoms within which they are located. Sources: Tree Areas (ESA, 2017), main populated places (SERVIR, 2015), main roads (Center for International Earth Science Information Network et al., 2013) and Research Forest Reserves (UNEP-WCMC and IUCN, 2016).

forest governance. We finally selected 19 quantitative governance indicators covering all thematic areas of the GFI and adapted them to the Zambian context as follows:

- Thematic area "forest tenure": (1) recognition and protection of tenure rights
- Thematic area "land use": (2) formal land use planning.
- Thematic area "forest management": (3) implementation of land use strategies and plans, administration of licences for (4) timber, (5) charcoal and, (6) non-timber forest products, implementation of (7) reforestation, (8) forest protection and conservation, (9) payment for ecosystem services, (10) sustainable, forest-based livelihood programs and enforcement of (11) formal and (12) customary forest laws.
- Thematic area "revenues": (13) forest revenue distribution and, (14) implementation of benefit sharing mechanisms.
- Thematic area "cross-cutting institutions": capacities and efficiencies of (15) central, (16) local government, (17) non-government organizations and (18) customary institutions
- Thematic area "cross-cutting issues": (19) public participation in policy-making.

Each indicator was specified by five elements of quality (Appendix A)

Mapping of the governance arrangements on the ground and de facto scoring of governance elements of quality was carried out through focus group discussions. Mapping was essential to create an awareness of the different governance arrangements and to ensure correct spatially differentiated subsequent scoring for the different arrangements. Scoping visits were conducted in each landscape to organise the focus group discussions. These enabled the establishment of contacts to representatives from all communities and major stakeholder groups. Focus group discussions were carried out in all 24 communities, each with fifteen key stakeholder representatives including sub-village leaders, customary leaders and forest committee representatives. Participants comprised men, women, young people and long-term members of the community. During the focus group discussions, mapping was carried out on print outs of high-resolution Google satellite images of approximately 80*120 cm for the period November 2017 and October 2018. Prior to mapping, participants were asked to discuss the categories of governance arrangements within their community based on tenure, use restrictions and formal and customary institutions. When participants could distinguish between arrangements, they were tasked to map out the boundaries of each arrangement in their community. The mapping produced seventy three de facto governance polygons from the twenty four communities: 24 individual customary forests without access and use restrictions, 22 communal customary forest without access and use restrictions, 10 state forests with access and use restrictions, 8 communal customary forests with cultural access and use restrictions (in this case norms) and 9 private forests (Appendix B).

In the governance assessments, focus group participants were asked to discuss and agree on governance scores that were assigned to each of the governance polygons as Likert scores (Likert, 1932) on a scale from 0 (not present), 1 (very low) to 5 (very high) per element of quality (Appendix A). Likert scales transform qualitative data to quantitative data (Flynn et al., 1990). This permits the reliable integration of information across observations or cases (Kirk et al., 1986). Moreover, although criticized for producing ordinal data, Likert scales have been found to provide interval data that is suitable for parametric statistical analysis (Parker et al., 2002). It was not possible to establish contacts to private landowners to a meaningful extent, thus we could not score governance on private land. The Likert scores of all five elements of quality per indicator were aggregated as an arithmetic mean in order to derive indicator values for each of the governance polygons. All qualitative comments made for the governance scores were also noted.

2.3. Data analysis

A non-parametric, Wilcoxon rank test was applied to determine whether governance quality differed between the restricted state, non-restricted communal customary, non-restricted individual customary and culturally restricted communal customary arrangements. This test is recommended for comparing mean ranks, when the assumption of data normality is violated (Bridge and Sawilowsky, 1999). Since the data remained skewed, even when a log transformation was performed, we applied this test.

We applied factor analysis (FA), using principal component factoring and varimax rotation methods, to examine the relationships between the elements of quality, indicators and thematic areas of the GFI framework. FA tests whether hypothesized constructs are represented by the measured variables by identifying variables that are correlated with each other (Byrne, 2016). Our aim here was to examine whether the factors reproduce the hypothesised relationships between the different elements of quality, indicators and thematic areas of the GFI. The eigenvalue criterion (> 1) was used to determine the number of factors. Based on recommendations from Comrey and Lee, 2013, only those variables with loadings of 0.5, -0.5, or greater were considered significant items, and thus good indicators of a factor. To confirm whether the resulting factors represent their postulated measurement variables, we performed a bivariate correlation analysis between the loadings of the assigned factors and the respective mean Likert scores of the corresponding indicators. Coefficients (r) range between $+1$ and -1, where 1 is the total positive linear correlation, 0 is no linear correlation, and -1 is total negative linear correlation (Bewick et al., 2003). Furthermore, low p-values below the significance level of 0.05 indicate that relationships are statistically significant (Bewick et al., 2003). To determine whether the correlated variables formed a reliable scale that effectively measured the factors, Cronbach's reliability analysis was also conducted. Coefficients (α) range from 0 to 1, with values over 0.7 indicating a reliable measure of the underlying concept (Nunnally and Bernstein, 1967; Kline, 2013). Only when indicators belonging to the same GFI thematic area were loaded on the same factor did we conclude that these indicators actually reflect the thematic areas of the GFI framework.

We used a hierarchical cluster analysis based on the factor scores from the preceding factor analysis to identify patterns in governance performance of communities. Hierarchical clustering, unlike other clustering procedures, does not require a pre-specified number of clusters (Kaushik and Mathur, 2014). Accordingly, it was appropriate for this study, which was aimed at exploring the likelihood for the emergence of clusters. Moreover, by using the factor scores, we wanted to avoid any potential multicollinearity, which could result in an overrepresentation of variables (Sarstedt and Mooi, 2014). In particular, we ran the Ward criterion with Euclidean distances, which is often recommended as the best method for detecting group structures in data (Lassar and Kerr, 1996). Communities falling within the same cluster were interpreted as reflecting similar governance conditions. As data on factor scores were not distributed normally, a non-parametric Wilcoxon rank test was used for the comparison of clusters. Conversely, the data on mean factor scores were distributed normally so that the Student t-test was used for the comparison of clusters. A principal component analysis (PCA) was also performed to determine whether community clusters reflect the provincial governance structure. PCA results were visualised using a score plot showing the distribution of community clusters along the two principal components that constituted the largest variations. The closer the communities were together on the score plot, the more similar their performance was related to the two principal components. Additionally, when all of the communities from one province were grouped exclusively in the same cluster, it was inferred that provincial administrative structures determine patterns of community clusters, thus forest governance performance, and vice versa. All of the analyses were conducted using JMP

Table 3
Summary of selected indicators per thematic area and proportion of governance polygons in which indicators are present. Indicators highlighted in green are present in all governance polygons (N = 64).

Thematic area	Indicator	Percentage of governance polygons (N = 64)
Forest tenure	1. Tenure rights recognition and protection	100
Land use	2. Formal land use planning	100
Forest management	3. Implementation of land use plans and strategies	16
	4. Timber licences administration	88
	5. Charcoal licences administration	72
	6. Non-timber forest products licences administration	88
	7. Implementation of reforestation programs	4
	8. Protection and conservation	28
	9. Implementation of payment of ecosystem services program	0
	10. Implementation of forest-based livelihood program	14
	11. Formal law enforcement	100
	12. Customary law enforcement	100
Revenues	13. Forest revenue administration	88
	14. Implementation of benefit sharing mechanisms	0
Cross-cutting institutions	15. Central government capacities and effectiveness	100
	16. Local government capacities and effectiveness	100
	17. Traditional institutions capacities and effectives	100
	18. Forest non-government organisations capacities and effectiveness	9
Cross-cutting issues	19. Public policy participation	100

statistical software.

3. Results

3.1. Forest governance quality

Sixty four governance polygons were mapped and scored with governance indicators in 24 communities. Of the 19 selected indicators, only eight were present in all governance arrangements (Table 3). Only these could be used to calculate comparable mean governance scores (Table 4). All of these indicators represent different thematic areas of the GFI framework, namely: thematic area "forest tenure"; (1) recognition and protection of tenure rights; thematic area "land use"; (2) formal land use planning; thematic area "forest management" (3) formal law enforcement and (4) customary law enforcement; thematic area "cross-cutting institutions" (5) central government, (6) local government and (7) traditional institutions; thematic area "cross-cutting issues" (8) public participation in policy-making.

Other indicators from the thematic area "forest management", including administration of timber (88 %) and charcoal licences (72 %) as well as protection and conservation (28 %), were only applicable in a lower proportion of polygons (Table 3). However, since at least one of these indicators could be measured for each polygon and these all represent procedures for regulating forest use, they were grouped into one indicator referred to as forest use restrictions, which in this case reflects forest conservation measures. Forest use restrictions then constituted the ninth indicator in the comparative assessment.

The remaining indicators were only present in specific polygons and

Table 4
Summary of mean governance scores for different indicators per thematic area and type of governance arrangement. Indicators highlighted in green are present in all arrangements. Mean scores 0 = non − existent; 1 = very low; 2 = low; 3 = average, 4 = high, 5 = very high. Different superscript letters indicate means that differ significantly between arrangements at $p < 0.05$, using the non − parametric Wilcoxon rank test. CC = non − restricted communal customary forest; State = restricted state forest; CI = non − restricted individual customary forest; CTP = culturally − restricted communal customary forest, No indicates the number of polygons with observations.

Thematic area	Indicator	Governance arrangements							
		CC		CTP		CI		State	
		No	Mean	No	Mean	No	Mean	No	Mean
Forest tenure	Tenure rights recognition and protection	22	3.9^{AB}	8	4.1^{A}	24	4.1^{A}	10	3.4^{B}
Land use	Formal land use planning	22	0.2^{B}	8	0.0^{B}	24	0.2^{B}	10	0.6^{A}
Forest management	Implementation of land use plans and strategies	_	NA	_	NA	_	NA	4	1.9
	Forest use restrictions: timber, charcoal licences & protection conservation	22	1.3^{B}	8	4.2^{A}	24	1.4^{B}	10	1.8^{B}
	Non-timber forest products licence administration	1	2.2^{A}	NA	NA	1	2.2^{A}	1	2.2^{A}
	Implementation of reforestation program	_	NA	_	NA	2	2.9A	2	2.2^{A}
	Implementation of forest-based livelihood program	3	2.3^{A}	NA	NA	6	3.1^{A}	1	3.0^{A}
	Implementation of payment of ecosystem service program	_	NA	_	NA	_	NA	_	NA
	Formal law enforcement	22	1.0^{AB}	8	0.5^{B}	24	0.5^{B}	10	2.3^{A}
	Customary law enforcement	22	1.6^{A}	8	2.0^{A}	24	1.4^{A}	10	0.7^{A}
Revenues	Implementation of benefit sharing mechanisms	_	NA	_	NA	_	NA	_	NA
	Forest revenue administration	8	1.6^{A}	_	NA	11	1.9^{A}	5	2.2^{A}
Cross-cutting institutions	Central government capacities and effectiveness	22	1.7^{AB}	8	1.3^{B}	24	1.7^{AB}	10	2.1^{A}
	Local government capacities and effectiveness	22	0.1^{A}	8	0.1^{A}	24	0.1^{A}	10	0.0^{A}
	Traditional institutions capacities and effectiveness	22	2.2^{A}	8	1.4^{A}	24	1.8^{A}	10	1.5^{A}
	Non-government organizations capacities and effectiveness	3	3.5^{A}	_	NA	3	3.5^{A}	3	3.5^{A}
Cross-cutting issues	Public policy participation	22	0.0^{A}	8	0.0^{A}	24	0.0^{A}	10	0.0^{A}
Governance score (only indicators applicable in all arrangements)		22	1.3^{A}	8	1.5^{A}	24	1.2^{A}	10	1.4^{A}
Governance score (only site specific indicators)		12	2.2^{A}	_	NA	15	2.7^{A}	9	2.6^{A}
Final governance score (all indicators)		22	1.5^{B}	8	1.5^{B}	24	1.7^{AB}	10	2.1^{A}

thus not comparable across arrangements (Table 3). These indicators were nevertheless taken into consideration in the computation of the final mean governance score (Table 4).

Overall, mean governance as the mean value of the nine governance indicators that were applicable in all arrangements, was very low, with values between 1.2 and 1.5, and did not differ significantly between arrangements (Table 4). Of the nine fully comparable indicators, only tenure rights recognition and protection consistently scored above the average Likert score of 3. Tenure rights recognition and protection moreover, scored significantly higher in the customary than in state arrangements. The governance aspect of forest use restrictions, which in this case reflects conservation measures, scored significantly higher in the arrangements with cultural use restrictions than in those devoid of cultural restrictions. Other fully comparable indicators of formal land use planning and formal law enforcement, central government capacities and effectiveness scored significantly higher in state than in the customary arrangements. Public participation is forest policy formulation was completely absent in all arrangements.

Taking all indicators into account, including those only present in specific sites, state arrangements (with more indicators present) had significantly higher mean governance scores than customary arrangements (with less indicators present) (Table 4). The individual, site-specific indicators did not differ significantly between arrangements even though they led to higher mean governance scores in all the arrangements in which they were present.

A comparative analysis of the elements of quality in governance arrangements revealed that gender equity was significantly lower in individually-owned customary forests compared to state and communal customary arrangements (Appendix C). Apprehension, compliance and monitoring of customary law was significantly lower in state than customary forests.

3.2. Relationships between the GFI thematic areas, indicators and elements of quality

Factor analysis resulted in seven main factors that together explain 76.5 % of the variation. The first three factors, which together explain 52.58 % of the variation, are characterized by loadings of five elements of quality (Table 5). The first factor, accounting for 18 % of the variance, correlated primarily with the indicator of formal law enforcement from the thematic area “forest management”. The second factor, constituting 17.6 % of the variance, correlated primarily with the indicator of formal land use planning from the thematic area “land use”. The third factor, which explained 17 % of the variance, was highly correlated with the indicator of customary law enforcement from the thematic area “forest management”.

Each of the remaining four factors was characterized by loadings of a few (less than five) elements of quality (Table 5). Those elements allow the following interpretation of the meaning of these factors: the fourth represents central government capacities and effectiveness from the thematic area “cross-cutting institutions”; the fifth, traditional institutions capacities and effectiveness, thematic area “cross-cutting institutions”; the sixth, local government capacities and effectiveness, thematic area “cross-cutting institutions” and the seventh, tenure rights enforcement, thematic area “forest tenure”. Moreover, some elements of quality loaded on different thematic areas than those they were hypothesised to represent i.e. factor five comprised tenure rights recognition from the thematic area “forest tenure” and traditional institution capacities and effectiveness from the thematic area “cross-cutting institutions”.

A bivariate analysis that related the factor loadings to the respective mean Likert scores of the assigned indicators showed significant correlations between the first three factors and the respective indicators. The r coefficients are 0.96 for factor one and the mean score of the indicator of formal law enforcement, 0.95 for factor two and the mean score of the indicator of formal land use planning and 0.94 for factor three and the mean score of the indicator of customary law enforcement. Cronbach´s reliability analysis confirmed that the elements of quality, which correlated with the first three factors, formed reliable measures for these underlying dimensions, with α coefficients of 0.92 for formal law enforcement, 0.89 for formal land use planning and 0.92 for customary law enforcement (Table 5).

Other elements of quality representing use restrictions (thematic area “forest management”), public policy participation (thematic area “cross-cutting issues”) and several institutional capacities including human resource, financial and scientific and technical information (all thematic area “cross-cutting issues”) did not load whatsoever (Table 5)

3.3. Patterns of governance clusters for forest frontier communities in Zambia´s Miombo

Cluster analysis was carried out based on all the factor scores for governance attributes related to the communities. It allowed the identification of four main clusters of communities in which perceptions of forest governance conditions were similar. Similar groupings of communities were also revealed by the PCA results computed on the basis of the two principal components that constituted the largest variations, i.e. formal law enforcement, 20.9 %, and land use planning, 18.3 % (Fig. 3).

Cluster one, which is the smallest, comprises one community from North Western province. The cluster shows the highest score in formal land use planning and the highest overall mean factor score. Cluster three, which is the second smallest, comprises two communities, both from North Western province. These communities score significantly higher in formal law enforcement. Cluster two, the second largest, is composed of nine communities, mainly from North Western and Copperbelt provinces. The largest cluster, four, comprises 12 communities, mainly from Eastern and Copperbelt provinces. Communities in clusters two score significantly higher in central government capacities and effectiveness and tenure rights enforcement than those in cluster four (Table 6). Moreover, the results show a weak provincial grouping of communities since communities from the same province (Eastern) only fall exclusively in the same group in one of the cases, cluster four.

4. Discussion and implications

5.1. Forest governance quality

Our results show low mean scores for governance indicators. This implies weak de facto governance in the Zambian Miombo forests. This is in line with the findings of scholars (Musole and Chunda-Mwango, 2018; Kalaba, 2016; Vinya et al., 2011) in Zambia and Gumbo et al. (2018) elsewhere in the Miombo, who report weak forest governance characterized by the unsatisfactory implementation of relevant rules and governance processes on the ground. This is remarkable, especially following the propitious de jure governance reforms in Zambia´s forest sector that embrace decentralization (Ministry of Tourism Environment and Natural Resources, 2009), the demarcation of restricted forest reserves (GRZ, 2015a) and participatory forest governance. Our results may suggest that existing strategies have remained largely at a rhetoric policy level, with hardly any influence on forest management on the ground. In Zambia´s strategy for REDD+, the improvement of governance is a key issue within the preparatory phase as a basis for incentive-based mechanisms (Matakala et al., 2015). However, up to now the REDD + strategy has only been implemented to a limited extent (Ministry of Lands and Natural Resources and Ministry of National Development Planning, 2019). The weak enforcement of forest rules is mentioned as constituting the underlying driver of deforestation in the tropics (Korhonen-Kurki et al., 2014; Kanninen et al., 2007; Stickler et al., 2017; Umemiya et al., 2010). Moreover, weak forest governance is linked to the failure of mechanisms that aim to address deforestation and forest degradation (Korhonen-Kurki et al., 2014). In this regard, our

Table 5
Results of factor analysis showing relationships between GFI framework thematic areas, indicators and elements of quality (N = 64). Factor loadings > 0.5 (highlighted in red) imply that variable correlated highly with the factor. Cronbach's α > 0.7 implies a reliable measure of the underlying indicator.

Thematic area	Indicator	Elements of quality	Assigned meaning of the Factors						
			Formal law enforcement	Land use planning	Customary law enforcement	Central government	Traditional institutions	Local government	Tenure rights enforcement
			Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Forest tenure	Tenure rights recognition and protection	Recognition	-0.17	0.09	-0.10	-0.18	**0.77**	0.14	0.03
		Demarcation	0.22	-0.15	-0.02	0.07	-0.23	0.18	**0.64**
		Enforcement	0.17	0.14	0.36	0.20	-0.16	-0.18	**0.49**
		Gender equity	0.24	0.03	0.28	0.21	-0.27	0.10	**-0.65**
		Tenure harmony	-0.52	0.02	0.07	0.40	-0.12	0.28	0.10
Land use	Formal land use planning	Procedures	0.41	**0.57**	-0.04	0.12	-0.37	-0.07	-0.16
		Transparency	-0.08	**0.98**	0.17	0.01	0.05	0.02	-0.01
		Participation	-0.08	**0.98**	0.17	0.01	0.05	0.02	-0.01
		Representation	-0.08	**0.98**	0.17	0.01	0.05	0.02	-0.01
		Capacities	-0.08	**0.98**	0.17	0.01	0.05	0.02	-0.01
Forest management	Use restrictions	No elements loaded							
	Formal law enforcement	Apprehension	**0.91**	-0.02	0.00	0.16	-0.19	-0.05	0.03
		Consistency	**0.95**	-0.05	0.02	0.06	0.01	0.01	0.07
		Compliance	**0.92**	-0.06	0.06	0.12	0.00	0.24	0.08
		Monitoring	**0.90**	-0.04	0.03	0.12	0.00	-0.07	0.00
		Transparency	**0.49**	-0.11	0.41	0.26	0.18	-0.03	0.10
	Customary law enforcement	Apprehension	0.02	0.33	0.72	0.01	-0.13	0.04	0.14
		Consistency	-0.10	0.16	0.89	0.05	0.00	-0.01	-0.09
		Compliance	0.05	0.11	0.91	0.07	0.07	0.08	0.01
		Monitoring	0.11	0.11	0.86	0.09	0.13	-0.20	-0.02
		Transparency	0.04	0.08	0.85	0.05	0.10	0.19	-0.11
Cross-cutting institutions	Central government	Knowledge and skills	0.14	0.00	0.09	**0.87**	0.10	-0.04	-0.01
		Effectiveness	0.34	0.06	0.09	**0.62**	-0.18	-0.08	-0.02
	Traditional institutions	Knowledge and skills	-0.07	0.14	0.15	0.35	**0.51**	-0.36	-0.14
		Effectiveness	0.25	-0.05	0.27	0.08	**0.62**	-0.06	-0.12
	Local government	Knowledge and skills	0.00	0.06	0.09	-0.07	0.03	**0.94**	-0.02
Cross-cutting issues	Public policy participation	No elements not loaded							
	Eigen value		5.83	4.92	2.89	1.69	1.52	1.15	1.12
	Variance explained (%)		18.04	17.58	16.96	6.86	6.82	5.41	4.81
	Cumulative Variance (%)		18.04	35.62	52.58	59.44	66.26	71.66	76.48
	Cronbach's α		0.92	0.89	0.92	0.53	0.24	0.00	0.03

results indicate the necessity of strengthening the implementation of forest rules and governance processes at the local level (Pettenella and Brotto, 2012).

We find that forest governance quality does not differ significantly between the restricted state and non-restricted customary arrangements, when comparable indicators are used. This challenges common assumptions that de jure state control and its associated restrictions are likely to result in better de facto governance compared to customary governance, with more open access and fewer use restrictions (Ferraro et al., 2013; Hardin, 1968) and vice versa (Agrawal and Ostrom, 2001; Ostrom, 2008). In fact, the satisfactory enforcement of rules combined with good institutional capacities is likely to produce better governance performance on the ground (Brenes et al., 2018; Agrawal et al., 2014; Ostrom, 1993; Hayes and Persha, 2010; Ostrom, 2009). Despite the distinct policy interventions, forest rules in Zambia are hardly enforced due to the absence of adequate financial and human institutional

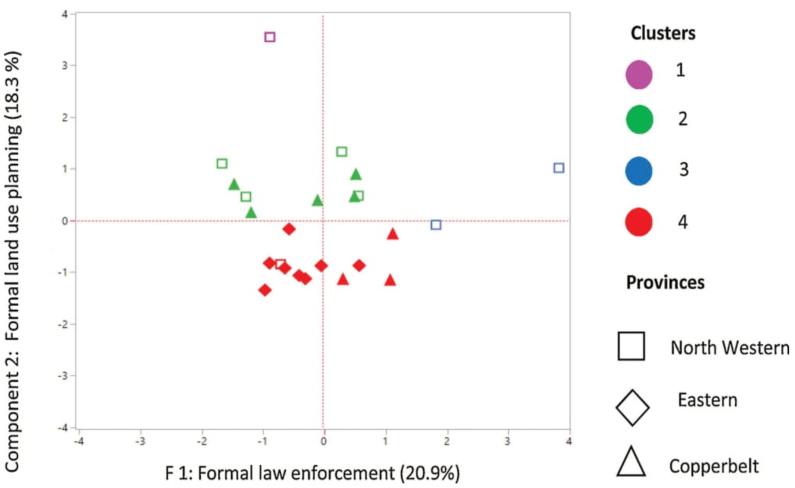

Fig. 3. Patterns of community clusters along two principal components (N = 64). The colour indicates cluster assignment based on cluster analysis. The symbol indicates the Province.

Table 6
Summary of mean factor scores for each community cluster. Different superscript letters indicate means that are significantly different between clusters at $p < 0.05$ (N = 64).

Factors	Assigned factor meaning	Statistical test	Mean factor score by community clusters			
			Cluster 1 (N = 1)	Cluster 2 (N = 9)	Cluster 3 (N = 2)	Cluster 4 (N = 12)
1	Formal law enforcement	Non-parametric Wilcoxon rank test	-0.47^{B}	-0.39^{B}	1.48^{A}	-0.07^{B}
2	Formal land use planning		3.57^{A}	-0.24^{A}	-0.36^{A}	-0.13^{A}
3	Customary law enforcement		0.96^{A}	-0.02^{A}	1.24^{A}	-0.23^{A}
4	Central government capacity and effectiveness		0.08^{AB}	0.58^{A}	1.16^{A}	-0.48^{B}
5	Traditional institutions capacity and effectiveness		0.18^{A}	0.16^{A}	-0.45^{A}	0.17^{A}
6	Local government capacity and effectiveness		0.13^{A}	0.20^{A}	0.13^{A}	-0.12^{A}
7	Tenure rights enforcement		0.77^{AB}	0.64^{A}	-0.53^{AB}	-0.41^{B}
Mean overall factor score		Student´s t- test	0.74^{A}	0.13^{B}	0.38^{AB}	-0.18^{C}

capacities (Kalaba, 2016). In light of that, the results affirm the need to increase the financial and human capacities of relevant institutions, as this is likely to improve their rule enforcement capabilities.

The higher mean governance score in state than in customary arrangements when site-specific indicators are considered to some extent reveals the de facto implications of contradicting land tenure policies in customary lands. While Zambia´s local government act authorises state institutions to manage customary forests, the land act places the administration of these forests under customary authorities, creating ambiguous responsibility and institutional tension (Chikulo, 2009). In the absence of effective institutional coordination and appropriate accountability mechanisms (Kalaba, 2016), the situation may constrain the implementation of non-legally binding governance processes on customary lands, including reforestation and livelihood programs. These processes drive the higher overall mean governance scores on state land. Moreover, as the same processes were implemented by non-government organizations and private enterprises, the results might mirror the role of non-state institutions in improving forest governance, which was also remarked by (Turner et al., 2014; Hayes and Persha, 2010) in the tropics. In this respect, the results indicate the necessity for legal reforms to address the inconsistencies in institutional mandates coupled with augmented formal support for the non-state institutions in Zambia´s forest sector. An alternative interpretation, in line with recommendations by Williams, 2011, is that merely relying on mean governance values can be deceptive, as these varied greatly depending on the indicators under consideration. In agreement with (Dwyer et al., 2008; Turner et al., 2014), the findings imply the need to systematically understand the organisation and context of governance processes, especially when discussing policy implications.

The relatively high scores for tenure rights recognition, particularly on customary lands, mirror the de jure, de facto discrepancy vis-à-vis the security of tenure on customary lands in Zambia. Whereas customary land is the least secure de jure option due to an absence of formal documentation to prove the landholders´ de facto rights (Mulolwa, 2016; Bojang and Ndeso-Atanga, 2013), similar to other studies (Stickler et al., 2017; Jain et al., 2016), our results indicate that people in Zambia feel secure in their rights to customary forests. Despite the absence of any formal documentation, de facto customary tenure may be more socially legitimated and thus more dominant than de jure tenure (Payne and Durand-Lasserve, 2012). As customary forests account for the largest proportion of forests in Zambia, this result is promising, especially as tenure security is acknowledged to foster sustainable use, efficient forest investment behaviour (Irwin and Ranganathan, 2007) and the desire of local people to protect their forests from encroachment (Larson et al., 2010; Mayers and Vermeulen, 2002). Besides, tenure security is reputed to lessen conflicts resulting from overlapping claims of ownership between different formal and customary institutions (Robinson et al., 2018). Nonetheless, de jure requirements for formal documentation could further strengthen customary tenure security.

The differences in scores for central government institutions and formal processes of land use planning and law enforcement between the state and customary forests again reflect the de jure weakness vis-à-vis formal processes in customary forests. While Zambia´s Urban and Regional Planning Act of 2015 recommends formal land use planning, the activity is not strictly required on customary lands. Furthermore, although formal institutions are legally mandated to manage all forests, the control of customary forests is largely enshrined in customary laws, which are articulated by the traditional institutions and lack systematic procedures (Kalinda et al., 2008). Moreover, since the customary institutions occasionally challenge the authority of local government actors (Mfune, 2013), their willingness to enforce formal governance processes on customary lands is likely to lessen. Formal activities are also constrained by the inadequate implementation of forest management plans and strategies and the poor monitoring of illegal activities due to inadequate funds and staff (Kalaba, 2016). Since formal land use planning and law enforcement are crucial for regulating unsustainable forest use (McDermott et al., 2010; Kaimowitz, 2012), it is imperative to establish legally binding requirements for these processes on customary lands. Additionally, augmented support for human and financial capacities and coordination amongst institutions could foster greater enforcement exercises (Kalinda et al., 2008).

The differences in scores for use restrictions between the culturally-restricted forests and those not restricted by traditions demonstrate the role of traditional values and norms in promoting forest conservation, as has been reported by other scholars too (Colding and Folke, 2001; Jimoh et al., 2012). The results indicate the need to reinforce traditional norms within prevailing forest governance arrangements as they reflect locally important cultural values of forest resources, and are likely to foster voluntary compliance with access and use restrictions, even in the absence of effective law enforcement systems. This could be strengthened by a greater harmonization of state and customary structures within the existing decentralization system in order to lessen opposition during the implementation of pertinent forest governance processes in Zambia´s Miombo.

The differences in gender equity between the individually-owned customary forests and other arrangements (state and communal) reflect the actual de jure inconsistency in women´s control over and ownership rights to individual forestland. While Zambia´s statutory law recognizes men and women equally in terms of property rights, i.e. access, use and ownership of forestlands, customary law, which dominates the distribution of rights to forestlands, discriminates women's ownership and control rights (Spichinger and Kabala, 2014; Machina, 2002). As these rights shape the opportunities and constraints that women face in securing their livelihoods (Daley, 2013), it is essential to support their enforcement in the more socially legitimated, de facto forest tenure systems.

The finding that the apprehension, compliance with and monitoring of customary law was significantly lower in state-owned than in customary forests once more echoes the unsatisfactory decentralization process that was also highlighted by (Mfune, 2013; Chikulo, 2009). The forest policy and act provide for the participation of customary institution in the management of state forests through Joint Forest Management programs. However, analogous to other studies in Zambia (Bwalya, 2007), there is no real recognition of traditional leader´s rights to make fundamental decisions in state forests. The Forest Department still has complete control and approves all the important decisions, including apprehending and penalizing forest lawbreakers. The scenario leads to the under-utilization of the customary institution´s capacity to contribute to sustainable forest management. This is particularly true given that the traditional leaders are socially recognized as legitimate arbitrators, including forest offenses (Bwalya, 2007). The situation conforms the need to better integrate customary structures into the decentralized governance structure and to strengthen their capacity to participate in forest management.

4.2. Relationships between the GFI thematic areas, indicators and elements of quality

The results show that the framework explains 76.5 % of the variance. This demonstrates that the GFI indicator set is a valuable tool to describe overall governance on the ground, as was highlighted by Davis et al. (2013). We find that each factor reflects a distinct indicator of the GFI framework, either exclusively, i.e. the first three strongest factors, or to a certain degree, i.e. the remaining four factors. This may imply that the GFI framework distinguishes underlying de facto governance processes in Zambia´s Miombo, underscoring its fitness in this respect. The distinct first and third factor demonstrate that formal and customary laws issues are independent factors in the Zambian forest governance context, along with central government, local government and traditional institutions (Kalinda et al., 2008; Caron and Fenner, 2017). This implies that merely outlining governance themes, i.e. laws and institutions, can be misleading, particularly in the context of overlapping customary and formal laws and institutions, as is the case in Zambia. In line with Williams, 2011, we recommend specifying and differentiating between formal and customary governance legislation and institutions.

Some indicators that are posited to characterize similar thematic areas load as separate factors. This may imply that thematic areas at a higher hierarchical level are not precisely reflected by the de facto governance processes or functions of the different GFI indicators across the Zambian Miombo. This indicates that thematic areas might be useful to categorize different indicators. However, they are not always mechanisms of distinct governance functioning, as they can comprise different independent indicators.

The first three factors, i.e. formal law enforcement, formal use planning and customary law enforcement, are consistently loaded by elements of quality of the same indicators. This could indicate the overlapping nature of the respective elements, which were not easily distinguishable by participants. The detailed assessment through five elements of quality could be simplified to reflect the most relevant processes

The results show an association between customary institutions and tenure rights recognition, both of which were loaded on the fifth factor, contrary to the GFI postulations. In Zambia, customary institutions are legally mandated and socially legitimated to drive the recognition of tenure rights, especially on customary lands (Payne and Durand-Lasserve, 2012; GRZ, 2015a; Caron and Fenner, 2017). Because similar situations are likely in several other African countries that have customary land governance structures, such as Botswana, Mozambique and Tanzania (Knight, 2010), we recommend adapting the GFI indicators to suit the local governance context. This can be ascertained through scoping visits and a review of the existing legal framework.

4.3. Patterns of governance clusters for forest frontier communities in Zambia´s Miombo

In the cluster analysis, we identified four main community clusters. The existence of varied clusters reflects different governance approaches amongst communities, generally differentiated by the processes of formal and customary law enforcement and land use planning.

The community in cluster one is characterized by high scores for formal land use planning. Unlike in other communities, participatory land use planning on customary land within this community has been executed through a collaboration between the United Nations Development Programs (UNDP), Global Environmental Facility (GEF), Forest Department and the traditional leaders. Since this community had the highest mean factor/governance score, the result again underscores the significance of participatory land use planning in improving de facto governance.

Communities in cluster three had high scores for formal law enforcement, which might result from the presence of timber concessions in these communities. This finding is consistent with that of NG'ANDWE et al. (2015), who report a comparatively higher enforcement of forest use restrictions by the Forest Department in forests with timber concessions than in those without in Zambia. This is mainly because the concessionaires usually provide transportation and other resources for the forest officers to conduct forest inventories, consultation with the communities and monitoring of the concession.

It is notable that cluster two mainly comprises communities from North Western and Copperbelt and cluster four, from Eastern and Copperbelt. As these are the largest clusters, as distinguished clearly by the loadings of several factors, the results might indicate that governance processes of North Western and Eastern are generally distinct, while in Copperbelt we can find patterns from both regions. This finding might reflect a de facto variation in the coordination between customary and formal institutions across the different regions. Zambia´s provincial officials operate under the same forest policy and legal framework that assigns the same general rights and responsibilities to all local governments (Ministry of Tourism Environment and Natural Resources, 2009). At the lower levels, provincial officials are required to harmonise with the customary institutions to facilitate the enforcement of forest laws and the proper administration of forest estates, in line with the forestry policy and existing legal framework (Chileshe, 2001; Ministry of Tourism Environment and Natural Resources, 2009). In Eastern province, communities reported recurrent conflicts over forest ownership between customary and formal institutions. This might explain the very low scores for central government capacities and effectiveness and tenure rights enforcement that differentiate the Eastern communities, in cluster four, from those in cluster two, from North Western and Copperbelt. The result confirms the necessity for consistency in the integration of customary structures into the decentralized governance structure, taking into account regional and local differences.

5. Conclusion and recommendations

Our data show low mean scores for governance indicators, implying weak de facto governance in Zambia´s Miombo forests. Various forest governance arrangements with differing tenure as well as access and use restriction exist de jure. However, our results show that they lack the implementation of relevant rules (customary and formal) and governance processes on the ground, particularly concerning land use planning, forest use restrictions and public participation in forest policy formulation. In addition, there are inadequate financial, technical and human institutional capacities to enable effective enforcement processes. As weak governance is linked to forest loss, the results may partly explain the persistent deforestation in Zambia´s Miombo. In light of that, the increased enforcement of forest rules and use restrictions comprising regular monitoring, apprehension and graduated sanctions for law breakers is recommended. This can undoubtedly be strengthened by the establishment of robust coordination mechanisms between customary and formal institutions, coupled with better support for their financial, human and technical capacities. Participatory land use planning and policy formulation processes are needed. This would also contribute towards achieving the targets of Zambia´s national climate change response strategy and the national development plan 2017–2021. These national initiatives propose the integration of strengthened forest governance to combat climate change and promote sustainable forest use, although without specific operational measures for its implementation (Ministry of Tourism, Environment and Natural Resources, 2010; Ministry of National Development Planning, 2017). Moreover, the REDD + strategy proposes the same governance measures, but again without specific details of their implementation (Matakala et al., 2015). In the light of a controversial general discussion on the success and future of REDD + and the applicability of results-based payments in international forest policy (Angelsen, 2017; Fischer et al., 2016; Fletcher et al., 2016), and taking into account critical voices that have been raised against REDD + in other countries such as Uganda and Nepal (Dawson et al., 2018), we conclude that REDD + can be promising. However, it should certainly not overshadow Zambia´s own national initiatives mentioned above.

We have shown that formal and customary rules and institutions are clearly differentiated on the ground. This justifies the fact that Zambia´s legislation, including the constitution, recognizes and takes into account the importance of customary rules and institutions. Our findings, however, imply the possibility of conflicts between customary and formal institutions resulting from overlapping claims on customary forest management. As this is likely to impede the execution of pertinent governance processes, we recommend legal reforms to address the inconsistencies in institutional mandates and the coherent integration of customary structures and cultural values into the decentralized structure. We believe that the recognition of customary tenure rights and use restrictions actually work quite well, despite the absence of any formal documentation. Nevertheless, de jure requirements for formal documentation that also takes gender issues into account could further strengthen these rights.

We found the GFI framework to be a very useful tool for assessing governance processes on the ground since the factors generally mirror GFI indicators. However, because de facto governance processes in some cases do not precisely reflect thematic areas of the framework, and as a factor analysis reveals several distinct factors, we warn against the use of single indicators to exclusively represent a thematic area. This is not intended by the authors of the GFI framework, but could be the pragmatic interpretation of users in the field. As the local setting may have some influence on the relationships between certain elements of quality, we suggest adapting the elements to suit the local context and also refining these to reflect the most relevant governance processes.

Our statistical analysis reveals clusters of distinct governance within and across provinces. Specific processes have a differing relevance within or across such different spatial jurisdictions. Examples include forest concessions that influence governance processes, especially in the North Western, or unclear tenure situations that influence the broader governance situation in the Eastern province, whereas Copperbelt communities are more diverse and cannot be assigned to specific clusters. This highlights the need to improve and streamline de facto and de jure governance factors beyond the established administrative boundaries. This should be taken into account in the design of co-management strategies as well as in jurisdictional and landscape approaches. Communities that are part of different governance pattern clusters within the same province may need different policy measures. Initiatives to integrate customary structures into the decentralized governance structure are required across all of the different governance clusters, though different coordination mechanisms may be needed between customary and formal institutions.

CRediT authorship contribution statement

Hellen Nansikombi: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Richard Fischer:** Conceptualization, Methodology, Investigation, Validation, Data curation, Writing - review & editing, Supervision. **Gillian Kabwe:** Investigation, Writing - review & editing. **Sven Günter:** Conceptualization, Methodology, Validation, Writing - review &editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare no conflict of interest. The funders were not involved in the collection, analysis and interpretation of data, in the writing of the manuscript or in the decision to submit the article for publication.

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Appendix A

Description of elements of quality by indicators and thematic area

Thematic area	Indicator	Elements of quality
Forest tenure	1.Tenure recognition	Recognition. Most individual and communal rights-holders have their rights recognized and recorded Demarcation. Most individual and communal forestlands have boundaries demarcated Enforcement. Infringements (violation) of rights are addressed quickly and fairly Gender equity. Rights registered to individuals or households are often registered in the name of women, jointly or individually Customary tenure. Minimal conflict exists between customary forest tenure systems and statutory systems on the ground

Land use	2. Land use planning	Procedure. Land use decisions are taken in a formally-established process
		Transparency. Planning process is transparent and procedures are clearly defined
		Opportunities for participation. Communities or entitled individuals have the chance to participate in land use planning processes
		Representation. Representatives in land-use planning processes reflect a range of community perspectives, including women and different socioeconomic classes
		Capacity to engage. Representatives in land-use planning have the information and skills to effectively engage and participate in land-use planning processes
Forest management	3.Strategies and plans	Coordination. Implementing agencies/persons/enterprises effectively coordinate when performing their roles and responsibilities
		Timeliness. Implementation takes place according to the timeline specified by the plan/strategy
		Monitoring. Implementation is subject to regular monitoring of impacts and effectiveness
		Transparency. Land-use plans and monitoring reports are publicly disclosed on a regular basis
		Review. Plans and strategies are reviewed and updated regularly
	Licences:	Procedural clarity. Clear administrative procedures regulate the obtaining of licenses and permits
	4. Timber	Transparency. Application status can be tracked
	5. Charcoal	Accessibility. The process for acquiring a license or permit is not prohibitively complicated and expensive
	6. Non-timber forest products	Timeliness. Licenses and permits can be obtained in a reasonable time and within the time prescribed
		Implementation. Licenses and permits are honoured during harvesting and transport of forest products
	7. Reforestation programs	Procedures. Stakeholders understand the procedures and terms of the program, including planting sites and species, duration as well as associated benefits and responsibilities
		Coordination. The implementing agency coordinates the implementation by establishing clear agreements with people and organizations
		Capacities. Communities have been capacitated to implement the program
		Benefits. Participants have received compensation as agreed
		Monitoring. Implementation is subject to regular monitoring to ensure compliance and effectivity
	8. Protection and conservation	Demarcation. Boundaries of protected or conservation forests areas are clearly demarcated.
		Use restrictions. Stakeholders clearly understand the timeframe and what activities are allowed and not allowed within the protection or conservation area
		Enforcement. Implementing agencies are aware of and effectively coordinate the performance of their roles and responsibilities
		Penalties. Stakeholders understand penalties for failing to comply with the rules of the arrangement
		Monitoring. Implementation is subject to regular monitoring of impacts and effectiveness
	9. Payment for Ecosystem Services Programs	Procedures. The procedures for establishing PES have been made clear to the stakeholders
		Coverage. PES schemes have been established on the ground.
		Benefit sharing. The schemes for benefit sharing have been jointly decided, understood and accepted by the stakeholders
		Protection. The protection of the forests providing these ecosystem services has been put in place
		Monitoring. Implementation is subject to regular monitoring
	10. Forest-based livelihood programs	Procedures. Stakeholders clearly understand the procedures for setting up sustainable livelihood projects.
		Coordination. Government agencies coordinate and provide support in implementing and sustaining projects
		Resources. Forest resources are adequate to sustain livelihoods
		Facilities. Credit facilities and capacity building were made available to local communities
		Benefits. Community members receive shares and benefits equitably
	Law enforcement:	Apprehension. Violators are apprehended and brought to trial by concerned authorities
	11. Formal law	Consistency. Assigned penalties are generally consistent with the law and appropriate given the nature of the offense
	12. Customary law	Compliance. Penalties are served or are paid in full in a timely manner
		Monitoring of compliance. Compliance with penalties is monitored and further legal action is taken in cases of non-compliance
		Transparency. Information about penalties and their state of compliance is publicly disclosed
Revenues	13. Revenues	Fairness. Fees collected are reasonable and the basis of computation is understood.
		Transparency. Field staff generate comprehensive and accurate records of all fees collected and these are made available to the public.
		Awareness. The government takes action to ensure that non-governmental "payers" are aware of their obligations.
		Timeliness. Fees are collected in a timely manner.
		Monitoring. Regular monitoring evaluates whether appropriate fees are collected as agreed
	14. Benefit-sharing mechanisms	Participation. Community has participated in the design of local benefit-sharing arrangements.
		Compliance. Benefits are delivered in accordance with the agreed terms set out in relevant legal or project documents
		Awareness. Community members are aware of benefits received and obligations associated with these benefits
		Fairness. The type and extent of benefits are fair and appropriate
		Monitoring. Regular monitoring evaluates whether benefits as agreed have reached intended recipients
Cross-cutting Institutions	Capacities and effectiveness	Knowledge and skills. Institutions capacitated with up to date knowledge and skills to play an active role in forest management
	15. Central government	Human resources. Institutions capacitated with an adequate number of staff to play an active role in forest management
	16. Local government	Financial resources. Institutions capacitated with sufficient financial resources to play an active role in forest management
	17. Non-government organizations	Scientific and technical information. Institutions capacitated with relevant scientific and technical information to play an active role in forest management
	18. Customary institutions	Effective. Institutions are effective in implementing forest management objectives
Cross-cutting issues	19. Participatory policy-making	Awareness. Community members are notified in due time of policies to be developed, reviewed and revised that are relevant for land use in their community
		Platforms. Platforms are provided for multi-stakeholder participation in policy-making
		Representation. Policy-making platforms allow the participation of key representatives from the different forestry sectors
		Effectiveness. Facilitation methods allow key stakeholders to participate actively in the process
		Transparency. The stakeholders are informed of the results of policy engagements

Appendix B

Summary of governance polygons by arrangements and community within each landscape and province. Landscapes named by the name of chiefdom in which they occur. CC = non-restricted communal customary forest; State = restricted state forest; CI = non-restricted individual customary forest; CTP = culturally restricted communal customary forest

Provinces	Landscapes	Community name	Type of governance arrangement				
			CI	CC	State	CTP	Private
Copperbelt	Z1: Shibuchinga	Chitanshi	✓	✓			✓
		Kalobwe	✓	✓			
	Z2: Lumpuma	Fibangula	✓	✓			
		Kambaya	✓		✓		
	Z3: Nkambo	Mbotwa Central	✓		✓		
		Mwambachimo	✓		✓		✓
	Z4: Mushili	Michinka	✓				✓
		Chinondo	✓	✓			✓
North Western	Z5: Chizera	Kashima East	✓	✓			✓
		Matushi West	✓	✓			✓
	Z6: Mushima	Shungulu	✓	✓	✓		
		Kabanda	✓	✓	✓		
	Z7: Chibwika	Chibwika Central	✓	✓	✓		✓
		Lwamukunyi	✓	✓	✓		
	Z8: Sailunga	Kamayanda	✓	✓			
		Katambi	✓	✓			✓
Eastern	Z9: Nyampadde	Nsamba Sokolole	✓	✓			
		Nyakachonko	✓	✓		✓	
	Z10: Mumbi	Lwezi	✓	✓		✓	
		Minga Chisoyo	✓	✓	✓	✓	✓
	Z11: Nyalugwe	Mwansanika	✓	✓		✓	
		Ntazia	✓	✓		✓	
	Z12: Ndakke	Kamono	✓	✓	✓	✓	
		Sichibende	✓	✓	✓	✓	
Total	12	24	24	22	10	8	9

Appendix C

Summary of mean governance scores for the elements of quality with significant results using the non−parametric Wilcoxon rank test at $p < 0.05$. Mean scores: 0 = non−existent; 1 = very low; 2 = low; 3 = average, 4 = high, 5 = very high. Different superscript letters indicate means that differ significantly between arrangements. CC = non−restricted communal customary forest; State = restricted state forest; CI = non−-restricted individual customary forest; CTP = culturally restricted communal customary forest (N = 64)

Thematic area	Indicator	Elements	Mean score by governance arrangements			
			CC (N = 22)	CTP (N = 8)	CI (N = 24)	State (N = 10)
Forest tenure	Tenure rights recognition	Gender equality	4.9^{A}	5.0^{A}	3.5^{B}	4.9^{A}
Forest management	Informal law enforcement	Apprehension	1.1^{A}	2.4^{A}	0.6^{A}	0.0^{B}
		Compliance	1.9^{A}	1.9^{A}	1.9^{A}	1.0^{B}
		Monitoring	1.9^{A}	1.9^{A}	1.8^{A}	1.0^{B}

Appendix D. Supplementary data

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Appendix J: Publication II

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Can de facto governance influence deforestation drivers in the Zambian Miombo?

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ABSTRACT

Weak forest governance is posited as a key underlying driver of deforestation and forest degradation, but empirical evidence of this linkage is scarce. Many related studies capture the de jure (legal) conditions and miss out the de facto (implementation practices on the ground), particularly when considering the proximate drivers and other factors of deforestation. However, this is central for identifying the specifics of governance for curbing deforestation and forest degradation. We analyse the influence of de facto governance quality on deforestation, accounting for proximate drivers and other factors using stepwise regression. We further compare deforestation rates and drivers across different governance arrangements with differing institutions, tenure and forest access restrictions using Wilcoxon tests to derive conclusions for promising policy instruments that address deforestation. Data for the analysis were obtained through participatory mapping, focus group discussions and geographical information systems. To generate empirical evidence, 238,296 ha of land were mapped within 24 communities spanning three provinces, Copperbelt, North-Western and Eastern, in the Zambian Miombo. Regression results revealed that de facto governance quality has some effect but proximate drivers particularly charcoal production, crop agriculture and proximity to roads explain most of the deforestation patterns in the Zambian Miombo. Those drivers seem hardly affected by the weak governance processes. Since scores of governance quality were in general low and hardly varying, we conclude that in our case they were too weak to show effects on the proximate drivers. Only the governance indicator ‘local government capacity and effectiveness’ although still weak, was significantly linked to low deforestation rates. Comparative results further showed that restricted arrangements (state and traditionally restricted) exhibit lower deforestation than non-restricted arrangements (communal, forests with overlapping community claims, private and individual customary forests). But while crop agriculture was negligible, forest resource extraction was still substantial in restricted state forests, indicating a higher possibility for forest degradation instead. Although private and individual customary forests had higher tenure security, they showed higher deforestation rates than communal and state arrangements. This challenges the notion that tenure security alone guarantees successful forest conservation. Our results suggest that governance can only affect deforestation drivers positively above certain thresholds. This needs to be further complemented by specific measures such as sustainable production systems, incentives and alternative livelihoods to regulate the proximate and other underlying drivers of deforestation.

1. Introduction

1.1. Deforestation in the Zambian Miombo

Deforestation and forest degradation are threats to biodiversity, ecosystem functioning and well-being of millions of humans who derive their livelihoods from forests (Millennium Ecosystem Assessment, 2003, FAO, 2018, Naeem et al., 2016). This is particularly important in Africa, with the largest annual rate of net forest loss at 3.9 million ha, between 2010 and 2020 (FAO, 2020) and is projected to increase by 4% by 2030 (d'Annunzio et al., 2015). With Africa's forests linked to the rural livelihoods of over two-thirds of its population and 70% of its

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households'energy requirements (FAO, 2018), it is imperative to curb deforestation and forest degradation on this continent.

In sub-Saharan Africa (SSA), the countries with relatively weak forest cover e.g. *Madagascar*, Ivory Coast and Nigeria and those predominated by dry forests e.g. Zambia exhibit higher deforestation rates than the humid forest-rich countries e.g. Congo and Gabon (Rudel, 2013; Mayaux et al., 2013). In Zambia, although available estimates differ due to methodological differences (Kamelarczyk and Gamborg, 2014), studies report escalating deforestation and forest degradation. According to Phiri et al. (2019a) the annual rate of deforestation in Zambia ranged from 0.54% to 3.05% between 1972 and 2016, higher than reported by FAO (2015) at 0.3%. Similarly, according to Global Forest Watch (2019), the mean annual tree cover loss rate of the country, considering a 30% tree cover threshold, increased from 0.22% to 0.54%, when comparing the 2000–2009 and the 2010–2018 periods. Forest loss is likely to adversely impact the functioning of the Zambian Miombo woodland, the major forest type in the country.

The Miombo woodland is the most extensive dryland forest ecosystem in SSA, covering about 2.7 million km^2 (Gumbo et al., 2018; Frost, 1996). Characterized by the dominance of *Brachystegia*, *Julbernadia* and *Isoberlinia* species (Matakala et al., 2015), the Miombo is one of the five global biodiversity hotspots (Mittermeier et al., 2003), harbouring about 8500 higher plant species (Frost, 1996), 54% of which are endemic (Rodgers et al., 1996). Additionally, on average the woodland sequesters between 0.5 and 0.9 tons of carbon per hectare annually (Chidumayo, 2014; Williams et al., 2008), contributing to global climate change mitigation. Further, over 100 million rural people directly rely on Miombo's timber and non-timber forest products for income (Gumbo et al., 2018; Bradley and Dewees, 1993). Despite its importance, deforestation and forest degradation persist in the Miombo (Vinya et al., 2011; Chomba et al., 2012; Kalinda et al., 2008), weakening its ability to provide forest ecosystems goods and services (Millennium Ecosystem Assessment, 2003).

1.2. Drivers of deforestation in the Zambian Miombo

Many studies report small scale crop agriculture as a key proximate driver of deforestation and forest degradation in SSA and accordingly Zambia (Phiri et al., 2019b; Mayaux et al., 2013; Curtis et al., 2018). Timber logging, infrastructure extension, charcoal production, firewood collection and livestock grazing are also notable proximate drivers of forest loss in SSA (Kissinger et al., 2012; Hosonuma et al., 2012). The underlying drivers of deforestation and forest degradation in SSA are demographic/population pressure, economic, technological, governance and socio-cultural factors (Geist and Lambin, 2001; Rudel, 2013). Amongst the underlying drivers, mostly population density/growth is linked to deforestation and forest degradation in SSA (Mayaux et al., 2013; Rudel, 2013; DeFries et al., 2010) because it is interrelated with increased demand for agricultural land and forest products (Rademaekers et al., 2010).

An equally important underlying driver is weak forest governance, with 90% of the SSA countries in the reduced emissions from deforestation and degradation (REDD+) readiness phase, including Zambia, linking it to the detected forest loss (Kissinger et al., 2012). Weak governance fails to limit unsustainable anthropogenic forest use activities, which also constitute the proximate drivers of deforestation and forest degradation (Geist and Lambin, 2001). Forest governance "comprises all formal and informal, public and private regulatory structures i.e. institutions consisting of rules, norms, principles, decision procedures, concerning forests, their utilization and their conservation, the interactions between public and private actors therein and c) the effects of either on forests" (Giessen and Buttoud, 2014). In Zambia, the Miombo included, forest governance is characterized by weak institutions that fail to adequately enforce forest policies, rules and regulations, weak policy and insecure and unclear land tenure (Nansikombi et al., 2020; Gumbo et al., 2018; Kalaba, 2016). Because of this situation, there is demand for improved governance solutions in Zambia's Miombo forests (Gumbo et al., 2018; Dewees et al., 2010; Stickler et al., 2017).

1.3. Research gap

Although improved forest governance is posited a prerequisite for reducing deforestation and forest degradation in the Zambian Miombo (Matakala et al., 2015; Gumbo et al., 2018; Kazungu et al., 2020), there is limited understanding of the specifics of governance that are likely to foster successful outcomes (Umemiya et al., 2010). Moreover, as governance attributes are only part of the underlying drivers (Geist and Lambin, 2001; Hosonuma et al., 2012), it is necessary to account for the role of the proximate and other drivers in governance-deforestation relationships. Specific governance attributes that have been linked to forest conservation are tenure security (Robinson et al., 2014), land use planning (Nolte et al., 2017), participatory policy processes (Wright et al., 2016), law enforcement (Nugroho et al., 2018; Tacconi et al., 2019) and government, non-government and customary institutions (Banana et al., 2001; Ostrom, 2009). Likewise, included are the diverse arrangements that indicate the tenure (Holland et al., 2014; Robinson et al., 2014), access and use restrictions (Pfaff et al., 2014), and the institutions with the responsibility for forest management (Lund et al., 2009). In Zambia, these range from (i) restricted command and control arrangements in state-owned National Forest Reserves and National Parks, (ii) participatory arrangements with restrictions of forest use and management in state-owned Local Forest Reserves, and Game Management Areas, to (iii) inclusion of communities, customary institutions and private entities into forest conservation initiatives in customary and private forests (GRZ, 2015a; GRZ, 2015b). However, not in all cases these governance attributes are equally supportive of forest conservation (Wehkamp et al., 2018; Bray et al., 2008). Besides, different studies underscore differing institutional arrangements i.e. communal (Rights and Initiative, 2018; Oldekop et al., 2019), private (Koyuncu and Yilmaz, 2013b; Koyuncu and Yilmaz, 2013a) and state (Dudley and Stolton, 2010; Wilshusen et al., 2002), as optimal policy options for effective forest conservation. The mixed results imply the necessity for further studies in this respect, also recommended for the Zambian Miombo by Nansikombi et al. (2020).

Understanding governance-deforestation relationships has also become a priority topic in the global deliberations on forests e.g. New York declaration on forests (United Nations Climate Summit, 2014). The subject has as well received growing attention in the recent global environmental change research (Umemiya et al., 2010; Wehkamp et al., 2018; Bhattarai and Hammig, 2004; Li and Reuveny, 2006; Abman, 2018). However, the respective studies use rather general than forest-specific governance indicators such as corruption democracy, voice and accountability, political stability, violence and rule of law. Although they provide valuable insights, general governance indicators may capture broader phenomena and mask the effects of forest-specific governance aspects on deforestation (Kishor and Belle, 2004; Wehkamp et al., 2018). Besides, in absence of reliable governance data at the local scale (Secco et al., 2014), most studies are conducted at the national scale and only capture the de jure (legal) conditions. As de jure notions have been found to differ substantially from the de facto, reality that exists on the ground (Agarwala and Ginsberg, 2017; Kaufmann et al., 2007; Ribot, 2003), such studies fail to account for variations from differential implementation of forest policy and institutional reforms on the ground (Wehkamp et al., 2018; Puyravaud, 2003).

1.4. Aim/research question

We examine the influence of forest governance quality on deforestation in the Zambian Miombo, accounting for the proximate drivers and other factors. We aim to identify the specifics of forest governance with potential for reversing deforestation trends in the Miombo. We also aim to highlight more clearly the potential implications of tackling underlying drivers, herein governance challenges, without adequate consideration for the proximate drivers and vice versa. This is relevant for Zambia's initiatives for reducing emissions from deforestation and forest degradation (Matakala et al., 2015) and climate change strategies (Ministry of Tourism Environment and Natural Resources, 2010), which propose improved forest governance to curb forest loss. We additionally compare deforestation across diverse governance arrangements with differing institutions, tenure and restrictions to forest access and use, aiming to develop conclusions for promising policy instruments for addressing deforestation on the ground in the Miombo.

We address three research questions. (i) How does the annual rate of deforestation vary between diverse forest governance arrangements with differing institutions, tenure and restrictions to forest access and use? (ii) Which are the proximate drivers and other factors that influence deforestation rates in the Zambian Miombo? (iii) Does governance quality explain deforestation patterns if considered in addition, and if yes, which specific governance attributes play a significant role?

We employ a research approach that combines participatory mapping, focus group discussions, and geographical information systems (GIS) to collect data and use the comparative statistical approach (Wilcoxon test) and stepwise multiple regression models for the analysis:

1.5. *De jure forest governance arrangements in Zambia*

Zambia has diverse forest governance arrangements, under the responsibility of different institutions, across different tenure categories and with varying access and use restrictions (Appendix A). 23.7% of forests in Zambia occurs on state land, administered by either the Department of National Parks and Wildlife or Forest Department (GRZ, 2015b). Under the formal law, access and use of forest resources on state forests is restricted except with special permits. 65.7% forest occurs on either individual or communal customary lands, governed by chiefs and their representatives (GRZ, 2015a; Kalinda et al., 2008). Under the formal law, commercial use of forest products without a license on customary lands is restricted although access and subsistence use are not (GRZ, 2015a). Private forests (10.6% of the total forest area) also exist on state lands.These are owned by registered individuals or firms through leasehold tenure (GRZ, 2015a, Kalinda et al., 2008).

2. Conceptual framework

The post-colonial concept of steering decision-making and administration of forests specifically in developing countries focussed on governments that exercised authority through state agencies (Peters and Pierre, 1998; Rhodes, 2007). Starting in the 1980s and due to overexploitation, corruption and policy failure associated with state agencies, there was a transition from an entirely state-driven to multi-actor governance (Arts, 2014). The contemporary governance concept recognizes forest governance as broader than governments, covering many actors in society including civil society, communities and the private sector (Agrawal et al., 2008; Arts, 2014; Mwangi and Wardell, 2012). Taking into account the definition of Giessen and Buttoud (2014), we conceptualize governance as being based on (A) multiple actors and (B) formal and informal rules of forest-related decisions and their implementation (Fig. 1). In addition to these two components, we take into account (C) interactions amongst actors and (D) interactions between actors and rules and (E) the effects of either on forests to compose a comprehensive governance framework (Giessen and Buttoud, 2014; Davis et al., 2013; Kishor and Rosenbaum, 2012). Because it is difficult to cover all these components within the methodology of one study, while simultaneously maintaining scientific rigour, it is recommended to focus on certain components (Giessen and Buttoud, 2014). In this study, we explicitly analyse the effects (E) of institutions, rules and their interactions on deforestation at the local level, where implementation processes occur in practise (de facto).

Governance arrangements (Appendix A) are specific expressions and combinations of these basic governance components and constitute key spatial units of assessment in governance studies.

To assess the quality of rules, and institutions/actors and their interactions we use a set of governance indicators (Section 3.2.4) from the Governance of Forests Initiative (GFI) framework of the World Resource Institute (Davis et al., 2013). Like in other governance assessment frameworks (de Graaf et al., 2017; Kishor and Rosenbaum, 2012; Worldbank, 2006), these indicators reflect compilations of operational aspects that were found to be relevant for forest governance. The GFI framework groups the relevant issues into six thematic areas: 1) forest tenure, 2) land use planning, 3) forest management, 4) forest revenues, 5) crosscutting institutions and 6) crosscutting issues (Davis et al., 2013). The indicators are clustered according to these thematic areas. Although the GFI framework is primarily practise-oriented, the indicators capture the different components of the above described theory-based governance concept (Davis et al., 2013).

Weak forest governance is an underlying driver i.e. a fundamental force that underpins the proximate drivers of deforestation and forest degradation (Geist and Lambin, 2001; Turner et al., 1993; Hosonuma et al., 2012). Therefore, we incorporate the role of proximate drivers of deforestation (Fig. 1). Proximate drivers are human activities that directly affect the forest (Geist and Lambin, 2001, Turner et al., 1993, Hosonuma et al., 2012). They include agricultural expansion, wood extraction and infrastructure extension (Vinya et al., 2011; Armenteras et al., 2017; Geist and Lambin, 2001). We also account for other factors that work as catalytic attributes, leading to changes in human-environment conditions i.e. slope and size of the forest. Other important underlying drivers of deforestation in SSA are also considered i.e. demographic/population density (Mayaux et al., 2013), economic and socio-cultural drivers (Geist and Lambin, 2001; Kissinger et al., 2012).

3. Materials and methods

3.1. *Study area and site selection*

The study was conducted in the Zambian Miombo woodland. Three provinces, Copperbelt, North-Western and Eastern (Fig. 2) were selected to represent different socio-economic and demographic conditions as well as different forest cover and deforestation contexts (Table 1). North-Western is characterized by a low population density, estimated at 8 persons/km^2 in 2017 (WorldPop, 2018), high forest cover (71%) with a tree cover larger than 30% in 2010 (Global Forest Watch, 2019), and unsustainable timber extraction as the main driver of deforestation (Shakacite et al., 2016). Medium to low deforestation rates have been observed, with an annual average tree cover loss of 0.30% between 2013 and 2017 (Global Forest Watch, 2019). According to the same sources, Eastern province has a medium population density, estimated at 38 persons/km^2 in 2017, low tree cover (14%) and a relatively low rate of tree cover loss (0.40% annually) between 2013 and 2017, mostly from small-scale crop agriculture. Copperbelt is characterized by a very high population density, estimated at 76 persons/km^2 in 2017, medium to high tree cover (60%), and high rate of tree cover loss (1.16% annually) between 2013 and 2017, mostly from unsustainable charcoal production.

Within each of the three provinces, four landscapes of approximately 150km^2 each were selected, thus a total of 12 landscapes (Fig. 2). These landscapes corresponded to twelve distinct traditional administration units (chiefdoms), each with typical land-use, socio-economic, demographic and biophysical attributes of their respective province (Fig. 2). Within each landscape, two communities were selected for the study, thus a total of 24 communities. A community, constitutes a group of people living together who share natural resources and are tied together by local traditions, rules and values under the leadership of a section head/sub-chief (Twumasi and Freund, 1985; Madzudzo et al., 2013).

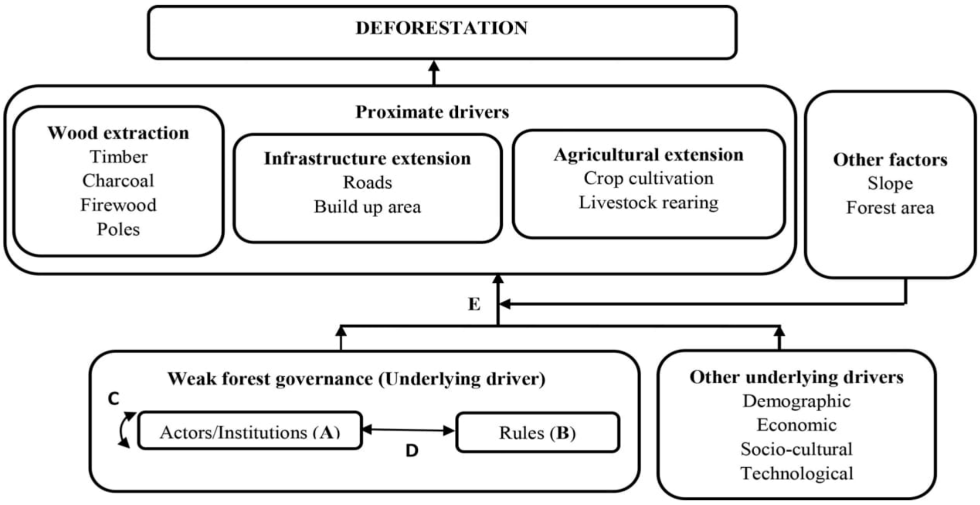

Fig. 1. Conceptual framework underpinning the study analysing the effects of de facto forest governance, proximate and other factors on deforestation in the Zambian Miombo. Adapted from (Geist and Lambin, 2001; Mayaux et al., 2013; Kissinger et al., 2012), with governance components adapted based on (Giessen and Buttoud, 2014; Arts, 2014).

3.2. Data sources and preparation

3.2.1. Participatory mapping exercises and focus group discussions (FGD)

Focus group discussions (FDG) (O. Nyumba et al., 2018) were carried out to conduct governance assessment and participatory mapping exercises aiming to identify the locally perceived, de facto, governance arrangements and land use patterns. Focus group discussions were carried out in all 24 communities, each with 15 key stakeholder representatives including sub-village leaders, customary leaders and forest committee representatives. Participants comprised men, women, youth (18–30 years), and long-term members of the community. This enabled broad representation of decision makers and social groups in the community. Despite the fact that FGDs are perception-based methods, they capture the reality that exists on the ground, which differs from the fact-based notions of laws (Kaufmann et al., 2011). Participatory mapping (Martin et al., 2012) was essential to create awareness on the focus governance arrangements and to ensure that subsequent governance assessment was done in a spatially consistent manner. The participatory mapping exercises were carried out between November 2017 and October 2018, using recent colour print outs of high-resolution Google Earth satellite images of approximately 80*120 cm.

3.2.2. Classification and delineation of governance arrangements

In the participatory mapping exercise, while making reference to the de jure categories of governance arrangements in Zambia, participants were asked to distinguish and delineate the de facto arrangements within their community using the satellite image print outs. Outcomes of these exercises were summarized into five categories, taking into account the local conditions including the institutions with the responsibility for forest control, tenure and access and use restrictions. These are (i) state forests with restrictions to access and use, (ii) communal customary forests with traditional restrictions to access and use, (iii) communal customary forest without restrictions to access and use, (iv) individual customary forests with no restrictions to access and use and (v) private forests with use decided by the registered landowner. The polygons of the mapped governance arrangements within each community were subsequently digitized using QGIS (illustrated in Fig. 3, Map 3).

The participatory mapping exercises from the 24 communities and subsequent digitization resulted in 70 identified de facto governance arrangements. The arrangements specify the institutions with the responsibility to control forests (state, community and private), tenure (customary and state) and access and forest use restrictions (restricted and non-restrcited), at the level of implementation (de facto). They constitute 6 state forests with access and use restrictions, 8 communal customary forests with traditional restrictions to access and use, 22 communal customary forests without restrictions to access and use, 24 individual customary forests with no restrictions to access and use and 10 private forests. As polygons of some governance arrangements were overlapping between neighbouring communities co-existing in the same landscape, we created an additional category of arrangement referred to as "forests with overlapping community claims". This category constituted 21 cases in the 24 communities raising the number of polygons to 91. The forest governance arrangements were used as units of analysis because they represent the lowest level of forest governance in Zambia (Kalinda et al., 2008; GRZ, 2015a).

3.2.3. Classification and delineation of main land use types

FGD participants were asked to delineate land use patterns in their community using a classification based on Di Gregorio and Jansen (2005) as a reference, also taking into account the local conditions. Overall, 11 main land use classes (Appendix B) could be distinguished and spatially delineated during the participatory mapping exercises. These were also digitized using QGIS (Fig. 3, Map 2).

3.2.4. Other governance attributes: governance indicators

In addition to the categories of governance arrangements (Section 3.2.2), the GFI indicators were included as governance attributes. The GFI framework recommends that from the large multitude of governance aspects covered, the indicators should be "adapted based on contextual factors such as scale of assessment, type of forest biome, or ownership regime." After thorough literature analysis coupled with a pre-test workshop in Zambia, we selected at least one indicator from each of the thematic areas (see Section 2), choosing those that reflect pertinent issues in Zambia's forest governance. Altogether we selected 19 quantitative governance indicators covering all thematic areas of the

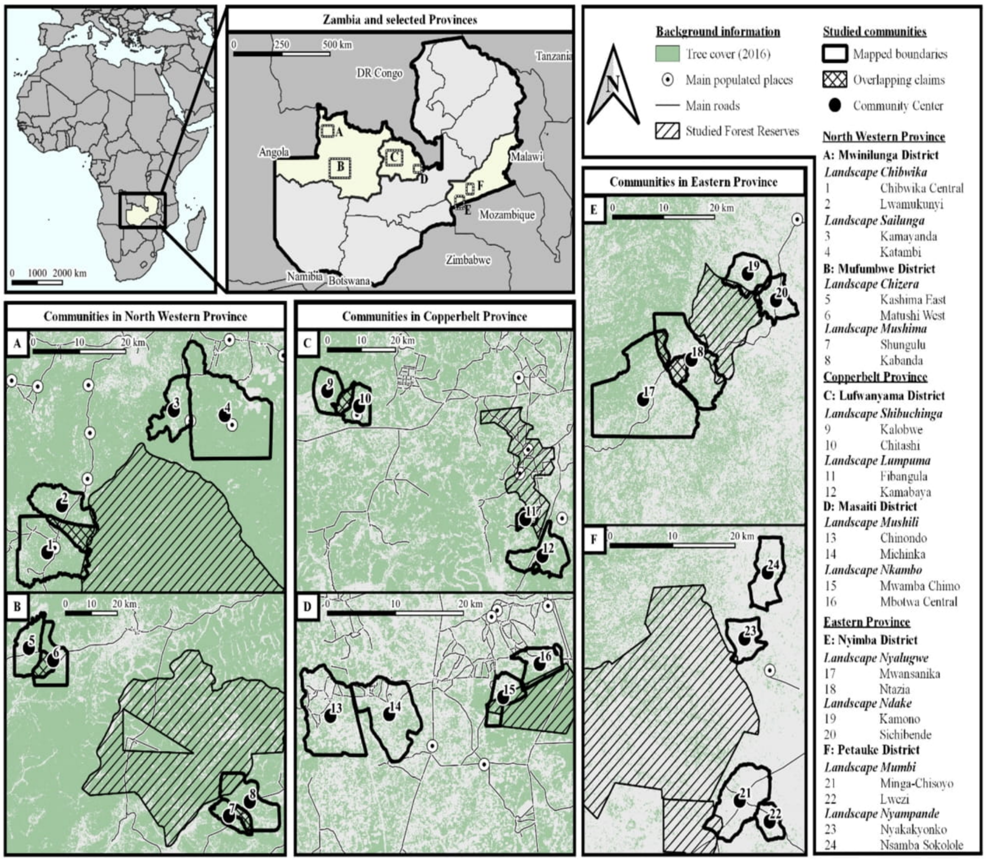

Fig. 2. A Map showing the locations of the study provinces, districts, landscapes and communities in Zambia in the Southern part of Africa. Landscapes are labelled according to the chiefdoms within which they are located. Sources: Tree Areas (ESA, 2017), Main populated places (SERVIR, 2015), Main roads (OpenStreetMap, 2020) and Research Forest Reserves (UNEP-WCMC and IUCN, 2016).

GFI and adapted them to the Zambian context as follows:

- Thematic area “forest tenure”: (1) recognition and protection of tenure rights
- Thematic area “land use”: (2) formal land use planning.
- Thematic area “forest management”: (3) implementation of land use strategies and plans, administration of licences for (4) timber, (5) charcoal and, (6) non-timber forest products, implementation of (7) reforestation, (8) forest protection and conservation, (9) payment for ecosystem services, (10) forest-based livelihood programs/projects and enforcement of (11) formal and (12) customary forest laws.
- Thematic area “revenues”: (13) forest revenue distribution and, (14) implementation of benefit-sharing mechanisms.
- Thematic area “crosscutting institutions” capacities and efficiencies of (15) central, (16) local government, (17) non-government organizations and (18) customary institutions.
- Thematic area “cross-cutting issues”: (19) public participation in policy-making.

Each selected indicator was specified by five elements of quality, rated on a scale of pre-coded statements, from lack of good governance to good practice (Appendix C). In the FGD, participants were asked to discuss

Table 1
Description of the demographic, economic, socio-cultural, forest cover and deforestation attributes of the study provinces. Sources: Forest cover and deforestation rates (Global Forest Watch, 2019), Population density estimates (WorldPop, 2018), Main drivers of deforestation (Shakacite et al., 2016), Poverty incidence (Central Statistical Office, 2018). Dominant ethnicity and share of urbanized population (Central Statistical Office, 2016).

Attributes	Zambia	Copperbelt	North-Western	Eastern
Forest cover (2010) (Tree cover > 30%)	30%	60%	71%	14%
Deforestation rates	High	High	Medium-Low	Medium-Low
(Mean annual tree cover > 30% loss 2013–17)	−0.52%	−1.16%	−0.30%	−0.40%
Population density 2017 (people/km^2)	22	76	8	38
Poverty incidence (%)	–	30.80	66.40	70.00
Urban share of the population (%)	41.80	83.00	27.20	12.20
Dominant ethnicity	–	Bemba	Luvale	Chewa
Main driver of deforestation	–	Charcoal production	Timber extraction	Small-scale farming

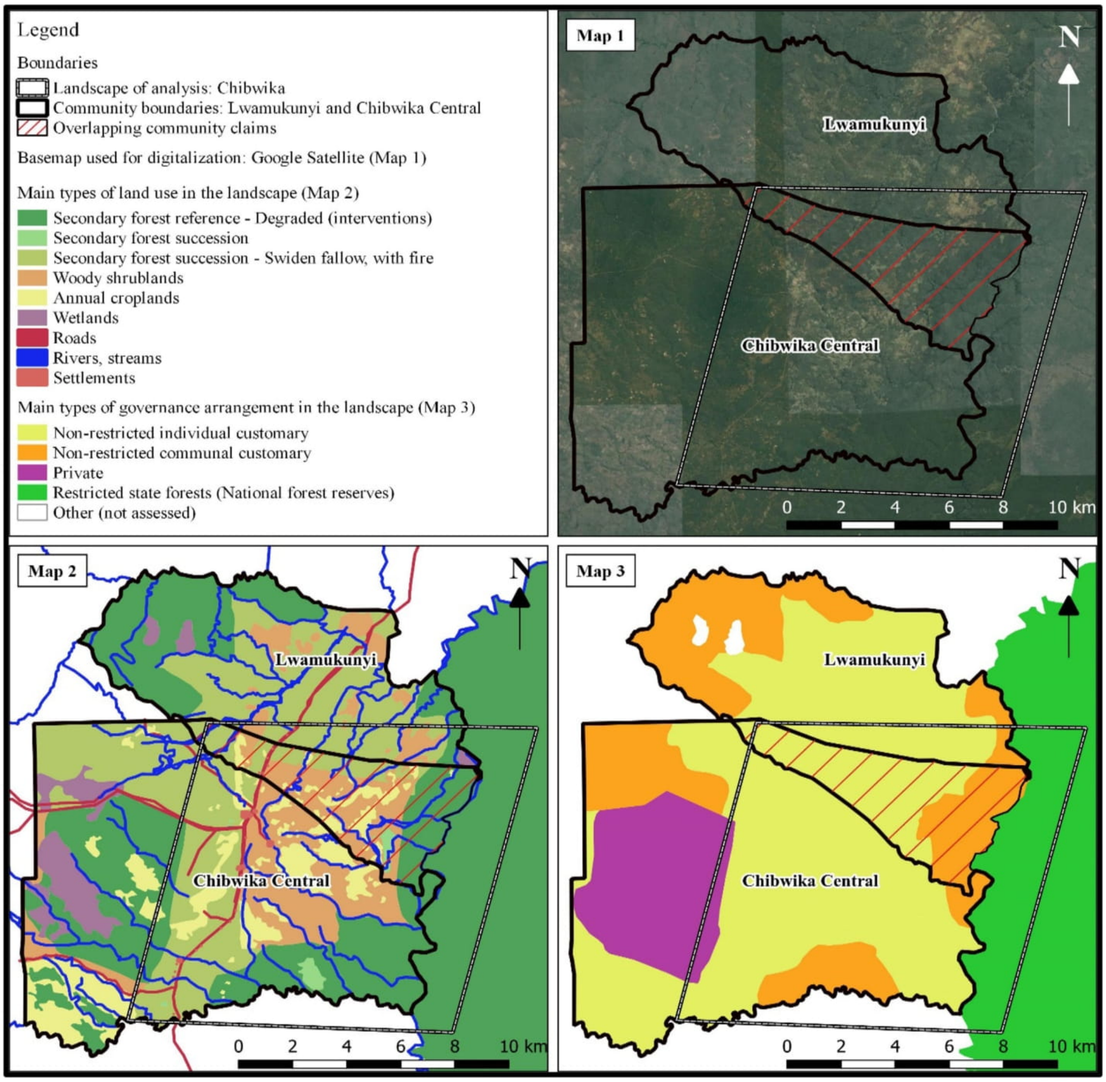

Fig. 3. Results of the participatory mapping exercise for the two communities (Lwamukunyi and Chibwika Central) of the landscape in chiefdom Chibwika (Mwinilunga District, North-Western Province); showing: basemap based on Google Imagery used for digitalization (Map 1), digitized main land use types (Map 2) and digitized governance arrangements (Map 3).

(based on their experiences) and agree on scores for governance performance, which was assigned as a Likert score (Likert, 1932) on a scale from 0 (not present), 1 (very low) to 5 (very high) to each element of quality (Appendix C) within each of the governance arrangements. Likert scales constitute data transformation from qualitative to quantitative form (Flynn et al., 1990). This permits the reliable integration of information across observations or cases (Kirk et al., 1986). Moreover, although criticized for producing ordinal data, Likert scales have been found to provide interval data, suitable for parametric statistical analysis (Parker et al., 2002). Likert scores of all five elements of quality per indicator were aggregated as the arithmetic mean in order to derive indicator values for each of the governance arrangements. The governance scores for the overlapping arrangements were generated as the arithmetic mean of the scores assigned by both communities for the given arrangement category. We further calculated the mean (aggregated) score of all governance indicators for each governance arrangement in addition to the governance scores of the 19 GFI indicators. All qualitative comments that were given for the governance scores were noted. It was not possible to establish contacts to private landowners to a meaningful extent; thus we could not score governance on private forests. Accordingly, the 10 private arrangements and one overlapping arrangement with private claims were excluded from the later analysis where governance indicators were needed.

3.2.5. Deforestation

Deforestation was used as the dependent variable in our statistical analysis. The average annual rate of tree cover loss was used as a proxy for the annual rate of deforestation relying on data from Hansen et al. (2013) as provided by Global Forest Watch (Global Forest Watch, 2018). Similar to related studies in Africa (Potapov et al., 2012; Zabala, 2018; Venter et al., 2018), Hansen et al. (2013) provide tree cover and change estimates for the study period. The data consists of 30 m ground resolution tree cover maps, based on Landsat's satellite imagery for the entire globe, and allows calculating extent and change of tree cover globally. We calculated the average annual rate of tree cover loss (%)

using a 30% tree cover threshold for each individual governance arrangement within our 24 communities for a five-year period previous to the fieldwork (2013–2017). Visual validation using Google Earth and Bing Maps suggested 30% as a reasonable threshold to estimate forest cover in our landscapes. Tree cover does not necessarily correspond to forest cover, and can be also related to plantations or trees outside forest.

3.2.6. Proximate drivers and other underlying drivers and factors

The proximate and other drivers of deforestation were included as control variables to enable a realistic examination of the relationship between the different governance attributes and deforestation. Eight variables represented potential proximate drivers: i) timber, ii) charcoal, iii) pole and iv) firewood use indicated wood extraction; v) livestock grazing and vi) percentage of area under crop agriculture characterized agricultural pressure; vii) distance to the road and viii) percentage of build-up area denoted infrastructure expansion (Table 2). Two variables, slope and area of governance arrangement, represented other factors. Amongst the other underlying drivers, we considered population because it is strongly linked to deforestation in SSA (Mayaux et al., 2013; Rudel, 2013; DeFries et al., 2010). However, the population estimates from WorldPop (2018), the data with the best precision for our study period 2017, are mostly accurate at larger spatial scales and disaggregation would give biased results. For the rough estimation of its influence, we estimated the total population in 2017 per governance arrangement ($N = 91$) and established its correlation with the selected infrastructure variables using the Spearman's correlation (Appendix D). Similar to (Burgess et al., 2007; Shoshany and Goldshleger, 2002; Stamber et al., 2016), population was strongly correlated with distance to roads and percentage of build-up area. Those variables were included in the model. Economic and socio-cultural drivers e.g. poverty incidence, level of urbanization and ethnicity were accounted for in the differences across the provinces (Table 1). Accordingly, we integrated provincial dummies in our analysis.

Data on extraction of charcoal, firewood, timber and poles and livestock grazing were obtained through the same focus group discussions as already described in Section 3.2.1. First, participants were asked to discuss and distribute 100 pebbles between benefits based on their importance to the community. Subsequently, they were tasked to locate the land use classes (generated in Section 3.2.3) from which each benefit is gained on the map. For each governance arrangement, we computed the degree of extraction/use per benefit as a ratio of the community's assigned pebble score, compared to the size (hectares) of the land use polygon that offers the benefit, expressed as a proportion of the size (hectares) of governance arrangement in which the land use polygon is located. Forest use by people other than community members is mainly captured in the arrangements with overlapping community claims.

Data on slope were derived from the SRTM 90 m Digital Elevation Database v4.1(Jarvis et al., 2008). Distances to roads were computed from the nearest point of a delineated and digitized governance polygon using open street map data extracts. Provincial boundaries were computed from the Zambia boundary map for Africa 2007 and percentages of crop and built-up area from the ESA CCI land cover map 2016. The sources of data and units of measurement for each variable are summarized in Table 2.

3.3. Data analysis

3.3.1. Comparative analysis of governance arrangements

To determine whether forest governance quality, the average annual rate of deforestation/tree cover loss and the proximate and other drivers of deforestation differed between the governance arrangements we applied non-parametric Wilcoxon rank tests since the assumption of data normality was violated (Bridge and Sawilowsky, 1999).

3.3.2. Regression models

We applied stepwise multiple regressions to analyse linkages between deforestation, governance attributes, proximate and other drivers. Our stepwise regression model had the form:

$$Y = B_0 + B_1X_1 + B_2X_2 + \ldots + B_kX_k + \varepsilon$$

Here, Y is the dependent variable, average annual rate deforestation between 2013 and 2017; X_1, $X_2 \ldots X_k$ predictors; B's, the parameters estimates or regression coefficients and ε, error. The error, ε is assumed to follow a normal distribution with zero mean and variance σ^2 for any values of predictors.

We used the backward elimination method to determine the set of optimal predictors. Backward elimination is appropriate for selecting those factors that contribute most strongly to the regression model when the number of variables is high (Hocking, 1976), as was the case in this analysis. Akaike Information Criteria (AIC) was used to judge the importance of variables (Motulsky and Christopoulos, 2004). A variation inflation factor set limit < 2.5 was used to confirm the absence of multicollinearity between the predictors in the model (Craney and Surles, 2002).

We specified two models in our analysis, both using the average annual rate of deforestation between 2013 and 2017 as the dependent variable. The models differed in the initial variables that constituted the predictors. In the first model, only the proximate and other drivers constituted the predictors. The second model added governance attributes (governance indicators and arrangements) to the predictors of the first model.

Due to the absence of governance data for the private (10) and overlapping arrangements with private claims (1), only 80 of the 91 observations were included in the regression analyses. A non-parametric Kruskal Wallis test was conducted to compare the annual rate of deforestation between the excluded and considered observations. The test verified the absence of elimination bias from the exclusion of the private and overlapping arrangement with private claims. Results (Appendix E) revealed that the mean annual rate of tree cover loss did not differ significantly between the excluded and considered observations with a p-value of 0.75.

Although we initially selected nineteen governance indicators, we only used nine in our second model, as the rest were not applicable in all study sites and communities (see details in Table 3). The regression model with indicators that are applicable in all sites enabled better comparison across all study sites and communities. Of the nine recurrent indicators, only eight were present in all governance arrangements.

The dependent variable, average annual rate of deforestation was found positively skewed via a Shapiro-Wilk test with a $p\text{-value} < 0.0001$. It was thus transformed with a square root function to ensure normal distribution (Freeman and Tukey, 1950; Thacker and Bromiley, 2001). To ensure comparability of units all observations for the predictors were standardised (Dytham, 2011). All analyses were executed using JMP software (SAS Institute Inc., 2017).

3.3.3. Model validation

Shapiro-Wilk tests were applied to the residuals generated by the models to verify conformity to the assumptions of normality (Dytham, 2011). To verify whether the multiple regression models conform to the assumption of homoscedasticity (Hayes and Cai, 2007), we applied Bartlett's test for homogeneity of variances by comparing the residuals across two categories of predicted values, generated by a median split (Bartlett, 1937).

4. Results

4.1. Governance performance across arrangements

The mean (aggregated) scores of the nine governance indicators applicable for all sites, which were also included in the second regression model, were very low, with values between 1.23 and 1.51 per governance arrangement (Table 3).

As regards to the single indicators, only the indicator of tenure rights recognition scored consistently above the average Likert score of 3 in all arrangements. Tenure rights recognition scored significantly higher in the customary than in state arrangements. Conservation and

Table 2
Description of variables for analysing linkages between deforestation, forest governance, and proximate and other drivers. I indicates that the indicator predominantly represents the governance component on interactions amongst actors or between actors and rules, R, rules and Inst, institutions.

Variable description	Indicator	Measurement unit	Data source
Dependent variable			
Deforestation	Average annual tree cover loss 2013–2017	Percentage	Global Forest Watch (Hansen et al., 2013)
Predictor variables			
Underlying drivers			
Governance attributes			
I	Tenure rights recognition and protection	Likert score	Focus group discussions
I	Land use planning	Likert score	Focus group discussions
I	Implementation of land use strategies and plans	Likert score	Focus group discussions
R	Timber license administration	Likert score	Focus group discussions
R	Charcoal license administration	Likert score	Focus group discussions
R	Non-timber forest products license administration	Likert score	Focus group discussions
R	Protection and conservation	Likert score	Focus group discussions
R	Formal law enforcement	Likert score	Focus group discussions
R	Customary law enforcement	Likert score	Focus group discussions
I	Implementation of benefit-sharing mechanisms	Likert score	Focus group discussions
I	Implementation of forest-based livelihood programs/projects	Likert score	Focus group discussion
I	Forest revenue administration	Likert score	Focus group discussions
Inst	Central government capacities and effectiveness	Likert score	Focus group discussions
Inst	Local government capacities and effectiveness	Likert score	Focus group discussions
Inst	Customary government capacities and effectiveness	Likert score	Focus group discussions
Inst	Non-government organizations capacities and effectiveness	Likert score	Focus group discussions
I	Public policy participation	Likert score	Focus group discussions
	Aggregated governance indicator	Likert score	Focus group discussions
	Type of governance arrangements	Dummies	Focus group discussions
Control variables			
Proximate drivers			
Wood extraction	Timber extraction	Area weighted pebble score	Focus group discussions
	Poles extraction	Area weighted pebble score	Focus group discussions
	Charcoal production	Area weighted pebble score	Focus group discussions
	Firewood extraction	Area weighted pebble score	Focus group discussions
Agriculture expansion	Percentage area under crop agriculture	Percentage	Africa ESA CCI land cover maps
	Livestock grazing	Area weighted pebble score	Focus group discussions
Infrastructure extension (Correlated with estimated total population)	Distance to the road	Metres	Open street maps (https://download.geofabrik.de/).
	Percentage of built-up area	Percentage	Africa ESA CCI land cover map (http://2016africalandcover20m.esrin.esa.int/).
Other factors	Mean slope	Degrees	SRTM for the globe (Jarvis et al., 2008)
	Area of governance arrangement	Hectares	Participatory mapping & digitization
Economic and socio-cultural drivers (differ between provinces)	Region/province	Dummies	Zambia boundary maps for Africa 2007

use restrictions also scored above the average Likert score of 3 in the traditionally restricted communal customary forests. This score differed significantly from that in the arrangements lacking traditional use restrictions, which consistently scored below the average Likert score of 3 (Table 3). The indicators of formal land use planning and formal law enforcement scored significantly higher in the state than in the customary arrangements. Most of the individual indicators did not show significant differences between governance arrangements.

4.2. Variation of proximate drivers and other factors across governance arrangements

The restricted state arrangements and forests with overlapping community claims were located the furthest from roads of all arrangements (Table 4). Charcoal, pole and firewood use was greatest in the forest with overlapping claims, as shown by the high mean scores (Table 4). Mean scores for timber extraction and livestock grazing were highest in the restricted state arrangements (Table 4). Percentages of crop and built-up area were highest in the non-restricted individual customary arrangements (Table 4).

4.3. Average annual rate of deforestation across governance arrangements

The restricted arrangements (state and traditional) showed a considerably lower deforestation rate than the non-restricted arrangements (Table 5). Deforestation rate was lowest in the traditionally restricted communal forests. The forests with overlapping community claims showed a relatively lower deforestation rate than other non-restricted arrangements (Table 5). Deforestation rates were highest in the

Table 3
Mean governance scores by indicators, thematic area and arrangement. Mean 0 = non-existing; 1 = very low; 2 = low; 3 = average, 4 = high, 5 = very high. Arrangements not connected by the same letter are significantly different at $p < 0.05$ with non-parametric Wilcoxon test. S = restricted state forests; CTP = traditionally restricted communal customary forests; CC = non-restricted communal customary forests; CI = non-restricted individual customary forests; OC = forests with overlapping community claims. N = 80. NA implies not applicable at the site. Component *Inst* predominantly captures institutions, *R*, rules and *I*, interactions amongst actors or between actors and rules.

Thematic area	Indicator	Mean score by governance arrangement										
			S		CTP		CC		CI		OC	
		Component assessed	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
Forest tenure	Tenure rights recognition & protection	*I*	6	3.28^{B}	8	4.08^{A}	22	3.85^{AB}	24	4.08^{A}	20	3.91^{AB}
Land use	Formal land use planning	*I*	6	0.58^{A}	8	0.00^{B}	22	0.23^{B}	24	0.21^{B}	20	0.50^{AB}
Forest management	Implementation of land use plans and strategies	*I*	3	1.79	-	NA	-	NA	-	NA	-	NA
	Conservation and use restrictions (includes mean scores of timber, charcoal licences protection and conservation)	*R*	6	1.63^{B}	8	4.23^{A}	22	1.28^{B}	24	1.43^{B}	20	1.43^{B}
	Non-timber forest products licence administration	*R*	1	2.17^{A}	-	NA	1	2.17^{A}	1	2.17^{A}	1	2.17^{A}
	Implementation of reforestation program	*I*	2	2.20^{A}	-	NA	-	NA	2	2.90^{A}	-	NA
	Implementation of forest-based livelihood program/projects	*I*	1	3.00^{A}	-	NA	3	2.28^{A}	6	3.14^{A}	5	2.48^{A}
	Implementation of payment of ecosystem service program	*I*	-	NA	-	NA	-	NA	-	NA	-	NA
	Formal law enforcement	*R*	6	2.03^{A}	8	0.50^{BC}	22	1.04^{ABC}	24	0.49^{C}	20	0.79^{B}
	Customary law enforcement	*R*	6	0.58^{A}	8	1.98^{A}	22	1.59^{A}	24	1.41^{A}	20	1.49^{A}
Revenues	Implementation of benefit sharing mechanisms	*I*	-	NA	-	NA	-	NA	-	NA	-	NA
	Forest revenue administration	*I*	3	2.28^{A}	-	NA	9	1.67^{A}	10	2.08^{A}	8	1.84^{A}
Crosscutting institutions	Central government capacities & effectiveness	*Inst*	6	1.92^{A}	8	1.34^{A}	22	1.65^{A}	24	1.66^{A}	20	1.57^{A}
	Local government capacities & effectiveness	*Inst*	6	0.02^{AB}	8	0.06^{AB}	22	0.07^{B}	24	0.07^{B}	20	0.16^{A}
	Customary institutions` capacities & effectiveness	*Inst*	6	1.54^{A}	8	1.39^{A}	22	2.20^{A}	24	1.76^{A}	20	1.69^{A}
	Non-government organizations capacities and effectiveness	*Inst*	2	3.30^{A}	-	NA	3	3.53^{A}	3	3.53^{A}	4	4.00^{A}
Crosscutting issues	Public policy participation	*I*	6	0.00^{A}	8	0.00^{A}	22	0.00^{A}	24	0.00^{A}	20	0.00^{A}
	Mean Governance score (aggregated for the 9 indicators applicable in all sites)		6	1.29^{A}	8	1.51^{A}	22	1.32^{A}	24	1.23^{A}	20	1.28^{A}
	Final mean governance score (aggregated for all 19 indicators)		6	1.98^{A}	8	1.53^{A}	22	1.47^{A}	24	1.68^{A}	20	1.68^{A}

individualized arrangements (private and customary individual). The private forests exhibited a lower deforestation rate than the individual customary forests (Table 5).

4.4. Proximate and other drivers of deforestation in the Zambian Miombo

In both models, three proximate predictors (distance to the road, percentage of area under crop agriculture and charcoal production) were statistically significant (Table 6).

As indicated by the magnitude of the regression coefficients, percentage of area under crop agriculture, with the highest magnitude, was the proximate driver with the strongest influence on the annual rate of deforestation. Charcoal production and distance to the road followed respectively.

Percentages of area under crop agriculture and charcoal production were positively related with the rate of deforestation, i.e. the higher the percentage of area under crop agriculture and the higher the production of charcoal, the higher the rate of deforestation. On the other hand, location further from roads was associated with lower rates of deforestation.

Regarding the other factors (Model 2), two regional dummies (Eastern and North-Western) were statistically significant (Table 6). Eastern and North-Western regions, as compared to the reference regional dummy of Copperbelt, were associated with lower rates of deforestation.

4.5. Influence of governance on deforestation and its proximate and other drivers

The regression which includes governance attributes (Model 2), showed a slightly higher adjusted coefficient of determination of 50.0% than the model without governance attributes (Model 1), whose adjusted coefficient of determination was 43.3% (Table 6).

The comparison between the two models (Table 6) indicates that the

Table 4
Comparative results of proximate and other drivers of deforestation across governance arrangements in all 24 communities using unstandardized parameters. Arrangements not connected by the same letter are significantly different at $p < 0.05$ with non-parametric Wilcoxon test. State = restricted state forests; CTP = traditionally restricted communal customary forests; CC = non-restricted communal customary forests; CI = non-restricted individual customary forests; OC = forests with overlapping community claims. N = 80.

Attributes	Mean value by type of governance arrangement				
	State	CTP	CC	CI	OC
Number of observations	6	8	22	24	20
Area (hectares)	$2,933.89^{AB}$	882.83^{C}	3017.13^{B}	$5,158.03^{A}$	706.96^{C}
Distance to road (metres)	$2,095.27^{AB}$	118.84^{B}	549.17^{B}	0.00^{C}	995.12^{A}
Built up-area (%)	0.02^{AB}	0.01^{AB}	0.00^{B}	0.05^{A}	0.00^{B}
Mean slope (degrees)	2.82^{AB}	4.35^{A}	2.69^{AB}	2.30^{B}	3.61^{AB}
Percentage of crop area (%)	8.34^{B}	18.11^{AB}	13.30^{B}	23.31^{A}	11.40^{B}
Charcoal extraction (area weighted pebble score)	2.35^{AB}	0.03^{C}	1.97^{B}	2.04^{B}	4.93^{A}
Timber extraction (area weighted pebble score)	5.28^{A}	0.45^{B}	1.94^{A}	1.25^{A}	3.25^{A}
Pole extraction (area weighted pebble score)	2.68^{BC}	0.15^{C}	3.28^{B}	2.34^{B}	6.83^{A}
Firewood extraction (area weighted pebble score)	5.90^{B}	0.47^{C}	8.16^{B}	8.39^{B}	18.37^{A}
Livestock grazing (area weighted pebble score)	2.00^{A}	$0. 25^{A}$	1.85^{A}	1.71^{A}	1.64^{A}

Table 5
Average annual rate of tree cover loss between 2013 and 2017 across governance arrangement. Arrangements not connected by the same letter are significantly different at $p < 0.05$ when non-parametric Wilcoxon test is applied. $N = 91$ using unstandardized variables.

Governance arrangement	Average annual rate of tree cover loss between 2013 and 2017 (%)	
	Number of observations	Mean
Restricted state forests	6	0.29 [BC]
Traditionally restricted communal customary forests	8	0.04[C]
Non-restricted communal customary forests	22	0.54 [B]
Forests with overlapping community claims	21	0.42 [B]
Non-restricted individual customary forests	24	0.73 [A]
Private forests	10	0.57 [AB]

Table 6
Stepwise multiple regression results showing linkages between annual rates deforestation, de facto forest governance indicators and arrangements, proximate and other drivers. * Implies parameter estimates are significant at 95% confidence interval using standardised variables; n/s, non-significant variables discarded in the backwards selection;— shows variable not included in the model, $N = 70$. Copperbelt is chosen as a reference dummy since it represents the region of highest deforestation (Global Forest Watch, 2019).

Variable type	Predictor	Model 1 No governance attributes; only proximate and other factors	Model 2 Adds governance attributes (indicators & arrangements)
		Coefficients (Standard error)	Coefficients (Standard error)
	Intercept	0.536* (0.037)	0.475* (0.041)
Proximate	Distance to road	−0.131* (0.036)	−0.112*(0.035)
	Percentage of area under crop agriculture	0.167* (0.039)	0.155* (0.040)
	Charcoal production	0.152* (0.036)	0.146* (0.037)
	Timber extraction	n/s	n/s
	Pole extraction	n/s	n/s
	Firewood extraction	n/s	n/s
	Livestock grazing	n/s	n/s
	Percentage of built-up area	n/s	n/s
Other factors	Slope	n/s	n/s
	Area of arrangement	n/s	n/s
	Eastern region (Yes)	−0.270* (0.041)	−0.322* (0.049)
	North-Western region (Yes)	n/s	−0.167* (0.059)
	Copperbelt region (Yes)	Reference dummy	Reference dummy
Governance Indicators	Local government capacity and effectiveness	–	−0.077* (0.037)
	Customary institutions capacity and effectiveness	–	0.092 (0.046)
	Central government capacity and effectiveness	–	n/s
	Tenure rights recognition and protection	–	n/s
	Land use planning	–	n/s
	Conservation and use restrictions	–	n/s
	Formal law enforcement	–	n/s
	Customary law enforcement	–	n/s
	Public policy participation	–	n/s
Governance arrangements	Restricted state forests	–	n/s
	Traditionally restricted communal customary forests	–	Reference dummy
	Non-restricted communal customary forests	–	n/s
	Non-restricted individual customary forests	–	n/s
	Forests with overlapping community claims	–	n/s
	R-squared	0.462	0.544
	Adjusted R-squared	0.433	0.500
	Shapiro-Wilk *p*-values	0.13	0.12
	Bartlett's *P* value	0.69	0.40
	Number of observations	80	80

regression coefficients of the proximate drivers -(i) distance to the road, (ii) percentage of area under crop agriculture and (iii) charcoal production- remained significant when governance attributes were introduced in the analysis. The same coefficients only decreased slightly with the introduction of governance attributes i.e. -0.131 to −0.112 for distance to the road, 0.167 to 0.155 for percentage area under crop agriculture and 0.152 to 0.146 for charcoal production.

The regression coefficient of regional dummy for Eastern increased from −0.270 to-0.322, while that of North-Western became significantly negative with the introduction of governance attributes in the analysis.

Only two governance attributes, (i) local government capacity and effectiveness and (ii) customary institution's capacity and effectiveness, were retained in the model 2, which includes governance (Table 6). Local government capacity and effectiveness showed a significant negative association with the rate of deforestation i.e. effective local government institutions, with adequate capacities were associated with lower rates of deforestation. On the other hand, although not statistically significant, customary institution's capacity and effectiveness were positively related to deforestation i.e. effective customary institutions, with adequate capacities were associated with higher rates of deforestation. Other governance indicators and the arrangements, were not statistically significant and discarded in the backward elimination.

5. Discussion and policy implications

5.1. Deforestation rates and drivers across governance arrangements

The restricted arrangements (state and traditional) exhibited lower deforestation rates than the non-restricted arrangements. Similar to (Nolte et al., 2013; Andam et al., 2008; Ferraro et al., 2013), this result supports the narrative that restrictions on forest access and use lead to lower deforestation than the approaches that permit consumptive use. However, restrictions have been found to increase illegal extraction in the areas with limited livelihood alternatives (Amoah and Wiafe, 2012; Mackenzie et al., 2012; Shova and Hubacek, 2011) and are costly to implement (Pfaff et al., 2017). Thus, augmented support for alternative livelihoods and institutional capacities could improve the enforcement of restrictions in forest-reliant communities.

The very low deforestation rate in the traditionally restricted forests demonstrates the importance of traditional norms and taboos in promoting forest conservation (Li, 2018; Furusawa, 2016; Lingard et al., 2003). The finding also supports the assumption that shared beliefs shape actor behaviour towards forest conservation (Sabatier, 2019; Sabatier, 1999). Together with overlapping claims areas, traditionally restricted communal customary forests, with ancestral burial sites, had the smallest mean areas (Table 4) and also constitute a very small proportion of Zambia's forests. However, even in the absence of effective enforcement mechanisms, given the strong cultural value attached, under the assumption of shared beliefs, there is voluntary compliance with the traditional access and use restrictions (Handavu et al., 2019). Even so, given the upsurge in the marginalization of cultural norms and beliefs following immigration and modernization (Infield et al., 2018), protecting existing traditional norms should be part of the initiatives that promote forest conservation in Zambia.

In the state forests, the low deforestation rates may besides the restrictions, be attributed to remoteness (Table 4), which renders them less attractive for crop agriculture, given the high transport-related transaction costs (Pujiono et al., 2019). Moreover, although still weak, state forests scored better in land use planning, which is associated with sustainable forest use (McDermott et al., 2010; Kaimowitz, 2012). Particular aspects of law enforcement i.e. fining and confiscation of illegal timber and charcoal (Tacconi et al., 2019; Davis et al., 2013) were also reported more prevalent in the state forests. But, whereas crop agriculture was negligible, similar to findings by (Kazungu et al., 2020), forest resource extraction (timber, charcoal and poles) was substantial in state forests, indicating a higher possibility for forest degradation instead.

Compared to other non-restricted arrangements, forests with overlapping community claims showed relatively lower deforestation rates. Although charcoal, poles and firewood extraction was considerable, the forests with overlapping community claims were less subjected to crop agriculture. This is perhaps because of remoteness and the accompanying transport-related transaction costs (Stifel and Minten, 2008). Nonetheless, the prevalence of forest resources makes them attractive for extraction, which when unregulated may cause degradation. Besides, while they presently go unnoticed by the communities involved, overlapping ownership claims reflect unclear resource boundaries. This presents potential conflicts and a challenge to exclude unauthorized users (Ostrom, 2008; Ostrom and Benjamin, 1993). In this regard, land use planning that clarifies community resource boundaries together with joint management strategies and conflict resolution measures would guarantee long-enduring common forest resources of neighbouring communities.

The non-restricted communal forests showed lower deforestation rates than the non-restricted individual forests (customary individual and private). In the communal, contrary to the individualized arrangements, customary leaders and community members have jointly established collective rules to regulate the cutting of trees. According to community members, violators are sometimes punished with monetary or in-kind (goat, chicken, farm labour) fines imposed by the customary leaders. Collective-choice theory predicts a high likelihood for successful common-pool resource management when individuals self-organize and collectively design their own local institutions (Ostrom, 1990; Ostrom et al., 1999). However, certain conditions should be fulfilled to guarantee sustainable outcomes. These include clearly defined boundaries, collective decision-making processes, effective monitoring, graduated sanctions, proportional equivalence between benefits and costs, conflict resolution mechanism, minimal recognition of rights to organize, and nested enterprises (Ostrom, 1990; Ostrom and Benjamin, 1993). In Zambia, owing to limited institutional capacities, these conditions are hardly fulfilled in practice in the communal arrangements. This might explain the considerable rates of deforestation in the communal forests although lower than in the private and customary individual forests.

The individual arrangements (customary individual and private) exhibited higher deforestation rates than the state and communal forests. The result challenges the assumption that individual ownership is more efficient than other forms, given its ability to internalize the externality that would arise from the self-interested behaviour of community members in extracting common pool resources (Kijima et al., 2000; Gordon, 1954). In Zambia, while individualized arrangements permit the exclusion of other community users, forest owner's use decision is barely regulated de facto due to inadequate institutional capacity. In the absence of land use planning and effective institutions, rational choice theory predicts a high likelihood for forest owners to convert forestlands to more potentially profitable alternatives such as agriculture, given their profit maximizing nature (Simon, 1959; Simon, 1955; Zafirovski, 2003). Moreover, unlike in the communal and state forests, the law permits cultivation in the individual arrangements (GRZ, 2015a). The individual arrangements were also the least remote (Table 4) and thus, with lower transport-related transaction costs (Chomwitz and Gray, 1996). In this view, incentivizing forest owners would increase the profitability therefore, the preference for forests over agriculture (March and Olsen, 2010). Actually farmers in Zambia are willing to refrain from forest clearing if incentivized (Vorlaufer et al., 2017).

The titled private forests showed slightly lower deforestation rates than the non-titled individual arrangements. In Zambia, private unlike individual customary forest owners possess legal rights to exclude other community members from using their forests (GRZ, 2015a; Caron and Fenner, 2017). Hypothetically, the ability of landholders to legally exclude competing users is the core mechanism by which tenure affects resource use and land cover (Wong, 2004; Bayley, 2015). Thus, similar to (Xie et al., 2016; Holland et al., 2017), we propose formal support for titling on customary lands. This is likely to improve tenure security therefore, forest conservation. However, as shown by the still high deforestation rates in the private forests, tenure security alone will not guarantee successful forest conservation. It should be accompanied by effective institutions, land use planning, and incentives for avoided deforestation or sustainable use.

5.2. Proximate and other drivers of deforestation in the Zambian Miombo

The results suggest that the percentage of area under crop agriculture is the most important proximate predictor of deforestation in the Zambian Miombo. This is not surprising since scholars in Zambia (Phiri et al., 2019b; Vinya et al., 2011; Mwitwa et al., 2012; Handavu et al., 2019) and elsewhere in the tropics (Acheampong et al., 2019; Hosonuma et al., 2012; Ferrer Velasco et al., 2020) have reported similar findings. According to community members, diminishing soil fertility and the accompanying reduction in crop yield force farmers to abandon their crop fields and open up new forest areas for agriculture. Community members also reported clearing of forest areas for crop agriculture following immigration and high birth rates. Sustainable agriculture intensification practices e.g. crop rotation, conservation tillage and mulching (Wezel et al., 2015) could increase crop yield and reduce forest clearing for agriculture.

Charcoal production also emerged as a significant predictor of deforestation. Differing from (Chomba et al., 2012; Ratnasingam et al., 2014; Vinya et al., 2011), firewood and timber extraction were not significant. In Zambia there is a high market demand for charcoal because it is the major source of energy for cooking in the urban areas (Handavu et al., 2019; Gumbo et al., 2013). Charcoal also generates higher income than firewood (Kazungu et al., 2020). Moreover, unlike timber, which is mostly extracted by external private firms and, predominantly in North-Western, charcoal is produced by the community members in nearly all three provinces (Gumbo et al., 2013; Ngandwe et al., 2015). Besides, although in some cases Miombo woodlands can recover rapidly from the influence of charcoal production (Chidumayo, 1993), a considerable share of forests initially cut for charcoal are subsequently converted to croplands, reducing the possibility for recovery. We propose augmented monitoring of charcoal licences to curb illegal production. This is less likely to adversely impact food security and rural incomes, with many farmers depending on agricultural income and, with charcoal production predominated by the affluent households (Kazungu et al., 2020). Guidelines for sustainable charcoal production systems are also proposed given the high regenerating ability of the Miombo forests (Campbell, 1996).

Our results suggest proximity to roads as another important driver of deforestation. Deforestation rate is higher closer to the roads than in distant forests. Roads open up forests for settlement, agriculture and wood extraction by lowering transport-related transaction costs (Pujiono et al., 2019; Phiri et al., 2019b; Barber et al., 2014; Laurance et al., 2002; Poor et al., 2019). Because roads are inevitable for economic development through enhanced rural connectivity (Gibson and Rozelle, 2003) and for facilitating market access and commercialization of products (Luna et al., 2020), greater control over newly accessible forests through regular patrols is needed.

Similar to our study categorization of deforestation contexts (Table 1), North-Western and Eastern regions showed lower deforestation rates than Copperbelt. Copperbelt is more urbanized (Central Statistical Office, 2016) and has a higher population density than North-Western and Eastern (WorldPop, 2018). High population density and growth implies an increasing demand for food and a corresponding need to convert forests to agriculture (Asongu and Jingwa, 2012). High population density is also associated with high demand for charcoal and firewood therefore, high deforestation (Collins, 1984). Actually, charcoal productions is greatest in Copperbelt (Kalinda et al., 2008). There is need to promote forest restoration in Copperbelt to meet the rising demand for wood thus, reducing pressure on the remnant forests (Fay, 2012). In Eastern province, with deforestation mainly caused by small-scale crop cultivation (Shakacite et al., 2016), we suggest promoting sustainable agriculture intensification. In North-Western, with deforestation attributed to unsustainable timber extraction (Shakacite et al., 2016), we recommend promoting sustainable forest management.

5.3. Influence of governance on deforestation and its proximate and other drivers

There was only a small increase in the explanatory power of the model explaining deforestation (Table 6) when governance attributes were introduced in the analysis. This demonstrates that governance has some effect, but proximate drivers explain most deforestation in the Zambian Miombo. Similar to (Larson and Petkova, 2011; Tacconi, 2007), the results suggest that improvement of forest governance alone does not exclusively guarantee successful forest outcomes. Measures that tackle governance drivers should be complemented with strategies that specifically tackle the proximate and other underlying drivers e.g. sustainable production systems, incentive mechanisms and alternative livelihood and poverty eradication measures. This is relevant for REDD + and climate change adaptation initiatives that propose governance improvement to reduce deforestation and forest degradation.

Additionally and surprisingly, proximate drivers remained at unchanged significance levels when governance attributes were included in the analysis. This is perhaps because governance was hardly varying between arrangements and was in general very low (Table 3). Statistically, it is hard to explain deforestation by a predictor that is mostly the same in all governance arrangements. Actually, the only governance indicator that was significant was amongst those that showed differences between the arrangements (Table 3). Scholars (Hayes and Persha, 2010; Davis et al., 2013; Eklund and Cabeza-Jaimejuan, 2017; Fischer et al., 2020) underline the high quality of forest governance as a prerequisite for regulating human-induced drivers of deforestation.

There are lower deforestation rates where local government institutions are effective and posses adequate capacities. In Zambia, local government institutions are responsible for developing land use plans to guide sustainable forest management in addition to controlling the extraction and transportation of forest products (Mfune, 2013). District local councils occasionally monitor transportation of timber and charcoal contingent on their financial and human capacities. Similar to (Larson, 2002; Kaimowitz et al., 2000), the result emphasizes that strengthened institutional capacities (financial, human, technical) are vital for successful forest conservation. Besides, local government institutions represent a fundamental decentralization structure (Andersson and Gibson, 2004; Andersson, 2006) and thus reveal the potential for curbing deforestation through effective decentralization. Their influence might still be increased by financial and human resources and the state's willingness to cede power over forest management (Kalaba, 2016; Mfune, 2013).

Although not significant, there are higher deforestation rates where customary institutions are effective and possess adequate capacities. Zambia's customary institutions are responsible for granting rights of use over customary forests to new immigrants (Mason-Case, 2011) and for mineral exploration (Mwitwa et al., 2011). New immigrants are likely to convert forests to agriculture to protect them from being reallocated (Unruh et al., 2005). Moreover, the results may imply that the customary institutions prioritize agriculture over forest conservation (Lund et al., 2014), with the law permitting agriculture on customary lands. We suggest the need for efficient land use planning and formal mechanisms that hold customary institutions accountable.

None of governance arrangements was retained in the model. This result is surprising given that we found distinct deforestation differences between the governance arrangements (Table 5) and that governance arrangements have been emphasized to influence deforestation patterns owing to the different use restriction and ownership rights attached (Robinson et al., 2014). This could imply that the significant drivers are associated with specific governance arrangements. For example, charcoal is mostly produced in the forests with overlapping community claims, whereas crop agriculture predominates the individualized customary forests (Table 4).

The regression coefficients of the regional dummies for Eastern and North-Western increase, and become significantly negative, respectively, when governance attributes are included in the analysis. This implies that the significant governance attribute, local institutions' capacities and effectiveness, is region-specific. This means that local institutions' capacities and effectiveness are different across regions and certainly related to deforestation in all places. In agreement with (Nansikombi et al., 2020), the result suggest that regional differences ought to be reflected in the strategies for strengthening local-level institutional capacities and effectiveness.

6. Conclusions

In the context of persistent deforestation posing a substantial threat to the existence and functioning of the dry forest Miombo biome in sub-Saharan Africa, we challenge the notion that improved forest governance alone will successfully halt deforestation. Our data show that governance has some effect, but proximate drivers, particularly crop agriculture, charcoal production and road proximity explain most deforestation in the Zambian Miombo. We recommend complementing governance measures with strategies to specifically address the proximate and other underlying drivers including sustainable production systems, incentive mechanisms and alternative livelihood and poverty eradication measures. This is particularly relevant for REDD+ and climate change adaptation initiatives that propose governance improvement to reduce deforestation and forest degradation. On the other hand, de facto governance in our data set was consistently weak, with hardly any variation and thus with limited statistical effects on deforestation and related proximate drivers. Across all analysed governance arrangements, scores for governance performance were mostly very low. This highlights the need for strengthening the implementation of forest laws and regulations as well as administrative reforms in Zambia. Our data shows noticeably high rates of deforestation, especially in the individualized arrangements (private and customary individual) that on the other hand exhibit higher tenure security. Although these are the arrangements with legal agricultural land use and thus explainable forest conversion into croplands, it challenges the notion that tenure security will guarantee successful forest conservation. Rather it should be accompanied by incentive mechanisms, effective institutions and land use planning to guide sustainable use and production systems. Restricted arrangements (state and traditional) exhibited lower deforestation rates than the non-restricted ones. But, while crop agriculture is negligible, forest resource extraction is substantial in the state forests. This implies that state forests are instead more susceptible to degradation. The regression results show that local government institutions seem to play an important role in reducing deforestation, particularly when they are functioning and with adequate capacity. On the other hand, while not significant, the customary institutions appear to exacerbate deforestation, probably because of their legal mandate, which permits them to allocate forest land for agriculture and mineral exploration. Also, this might imply that traditional institutions prioritize agriculture production over forest conservation. We point to the need for effective participatory land use planning and formal mechanisms that hold customary institutions accountable. However, because land use planning has been linked to inequitable land allocation and the accompanying displacement and migration of the marginalized people into forestlands (Bluwstein et al., 2018), it should be complemented by social safeguard policies to protect the local people's land rights.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendices

Appendix A: Zambia's forest governance arrangements with differing tenure and restrictions to forest access and use (Kalinda et al., 2008; GRZ, 2015a; GRZ, 2015b)

Arrangement	Access and use restrictions	Tenure	Administration Institutions	IUCN Category	% total forest area
National Parks	Access and use of timber and NTFPs: restricted	State	Department of National Parks and Wildlife	IUCN II	23.7
National Forest Reserves	Access and NTFPs use: restricted; Use of timber: regulated by license	State	Forest Department	IUCN II	
Local Forest Reserves	Access: restricted; Use of timber and NTFPs: regulated by license	State	Forest Department Traditional institutions	IUCN VI	
Game Management Areas	Access: restricted; Use of timber and NTFPs: regulated by license	State	Department of National Parks and Wildlife Traditional institutions	IUCN VI	
Traditional/ cultural forests	Access: restricted; Use of Timber and NTFPs: restricted	Customary	Traditional institutions	IUCN III	65.7
Individually owned customary forests	Access: Non-restricted; Commercial Timber and NTFPs use: regulated by license; Subsistence use of timber and NTFPs: non-restricted	Customary	Traditional institutions Forest Department	None	
Communal customary forests	Access: Non-restricted; Commercial timber and NTFPs use: regulated by license; Subsistence use of timber and NTFPs: non-restricted	Customary	Traditional institutions Forest Department	None	
Private forests	Access and use: restricted by owner	State/ leasehold	Registered individual/ company	None	10.6

Appendix B: Description of major land use classes from the community participatory mapping exercises

Land use type	Description	Area (ha)
Secondary forest reference-Degraded (interventions)	Forest with anthropogenic disturbance from extraction followed by natural regeneration.	133,737.67
Secondary forest succession	Forest once completely deforested for crop agriculture and abandoned. With natural regeneration greater than or equal to five meters height.	37,509.97
Plantation forest	Forest once completely deforested followed by anthropogenic regeneration	29.02
Woody shrubland	Forest once completely deforested for crop agriculture and abandoned. With natural regeneration, less than five meters height.	50,035.42
Annual croplands	Land used for growing annual crops	53,672.94
Wetlands	Land consisting of marshes or swamps	13,774.13
Roads	Hard ground that is built to facilitate movement from one place to the other.	256.77
Water bodies	Rivers and lakes	9705.94
Bare surfaces	Land covered by only soil	232.67
Settlements	Land where people have established buildings	1509.06
Grasslands	Land that mostly contains grasses	3112.60

Appendix C: Description of the governance indicators and the elements of quality by thematic areas of the GFI framework. Component Inst predominantly captures institutions, R, rules and I, interactions amongst actors/ between actors and rules

Thematic area	Indicator	Component	Elements of quality
Forest tenure	1.Tenure rights recognition and protection	*I*	Recognition. Most individual and communal rights-holders have their rights recognized and recorded
			Demarcation. Most individual and communal forestlands have boundaries demarcated
			Enforcement. Infringements (violation) of rights are quickly and fairly addressed
			Gender equity. Rights registered to individuals or households are often registered in the names of women, jointly or individually
			Customary tenure. Minimal conflict exists between customary forest tenure systems and statutory systems on the ground
Land use	2. Land use planning	*I*	Procedure. Land use decisions are taken in a formally established process
			Transparency. Planning process is transparent and procedures are clearly defined
			Opportunities for participation. Communities or entitled individuals have the possibility for participation in land use planning processes
			Representation. Representatives to land use-planning processes reflect a range of community perspectives, including women and different socioeconomic classes
			Capacity to engage. Representatives in land-use planning have information and skills to effectively engage and participate in land use planning processes
Forest management	3.Strategies and plans	*I*	Coordination. Implementing agencies/persons/enterprise effectively coordinate in carrying out their roles and responsibilities
			Timeliness. Implementation happens according to the timeline specified by the plan/strategy
			Monitoring. Implementation is subject to regular monitoring of impacts and effectiveness
			Transparency. Land use plans and monitoring reports are publicly disclosed on a regular basis
			Review. Plans and strategies are reviewed and updated regularly
	Licences:	*R*	Procedural clarity. Clear administrative procedures regulate the obtaining of licences and permits
	4. Timber		Transparency. Application status can be tracked
	5. Charcoal		Accessibility. The process for acquiring a license or permit is not prohibitively complicated and expensive
	6. Non-timber forest products		Timeliness. Licences and permits can be obtained in a reasonable time and within the time prescribed
			Implementation. Licences and permits are honoured during harvesting and transport of forest products
	7. Reforestation programs	*I*	Procedures. Stakeholders understand the procedures and terms of the program, including planting sites and species, duration, and associated benefits and responsibilities
			Coordination. The implementing agency coordinates implementation by establishing clear agreements with people and organizations
			Capacities. Communities have been capacitated to implement the program
			Benefits. Participants have received compensation as agreed
		R	Monitoring. Implementation is subject to regular monitoring to ensure compliance and effectivity
	7. Protection and conservation		Demarcation. Boundaries of protected or conservation forests areas are clearly demarcated.
			Use restrictions. Stakeholders clearly understand the timeframe and what activities are allowed and not allowed within the protection or conservation area
			Enforcement. Implementing agencies are aware and effectively coordinate to carry out their roles and responsibilities
			Penalties. Stakeholders understand penalties for failing to comply with the rules of the arrangement
			Monitoring. Implementation is subject to regular monitoring of impacts and effectiveness
	9. Payment for Ecosystem Services programs	*I*	Procedures. The procedures for establishing PES have been made clear to the stakeholders
			Coverage. PES schemes have been established on the ground.
			Benefit-sharing. The schemes for benefit sharing have been jointly decided, understood and acceptable to the stakeholders
			Protection. The protection of the forests providing these ecosystem services has been put in place
			Monitoring. Implementation is subject to regular monitoring
	10. Forest-based livelihood programs/projects	*I*	Procedures. Stakeholders clearly understand the procedures for setting up sustainable livelihood projects.
			Coordination. Government agencies coordinate and provide support in implementing and sustaining projects
			Resources. Forest resources are adequate to sustain livelihoods

			Facilities. Credit facilities and capacity building were made available to local communities
			Benefits. Community members receive shares and benefits equitably
	Law enforcement:	*R*	Apprehension. Violators are apprehended and brought to trial by concerned authorities
	11. Formal law		Consistency. Assigned penalties are generally consistent with the law and appropriate given the nature of the offence
	12. Customary law		Compliance. Penalties are served or are paid in full in a timely manner
			Monitoring of compliance. Compliance with penalties is monitored and further legal action is taken in cases of non-compliance
			Transparency. Information about penalties and their state of compliance is publicly disclosed
Revenues	13. Revenues	*I*	Fairness. Fees collected are reasonable and basis of computation are understood.
			Transparency. Field staff generate comprehensive and accurate records of all fees collected and are made available to the public.
			Awareness. The government takes action to ensure that non-governmental "payers" are aware of their obligations.
			Timeliness. Fees are collected in a timely manner.
			Monitoring. Regular monitoring evaluates whether appropriate fees are collected as agreed
	14. Benefit-sharing mechanisms	*I*	Participation. The community has participated in the design of local benefit-sharing arrangements.
			Compliance. Benefits are delivered in accordance with the agreed terms set out in relevant legal or project documents
			Awareness. Community members are aware of the benefits received and obligations associated with those benefits
			Fairness. The type and magnitude of benefits are fair and appropriate
			Monitoring. Regular monitoring evaluates whether benefits, as agreed, have reached intended recipients
Crosscutting Institutions	Capacities and effectiveness	*Inst*	Knowledge and skills. Institutions capacitated with up to date knowledge and skills to take an active role in forest management
	15. Central government		Human resources. Institutions capacitated with an adequate number of staff personnel to take an active role in forest management
	16. Local government		Financial resources. Institutions capacitated with sufficient financial resources to take an active role in forest management
	17. Non-government organizations		Scientific and technical information. Institutions capacitated with relevant scientific and technical information to take an active role in forest management
	17. Customary institutions		Effective. Institutions are effective in implementing forest management objectives
Crosscutting issues	19. Participatory policymaking	*I*	Awareness. Community members are aware in a timely manner of policies to be developed, reviewed and revised that are relevant for land use in their community
			Platforms. Platforms are provided for multi-stakeholder participation in policymaking
			Representation. Policymaking platforms allowed participation of key representatives from the different forestry sector
			Effectivity. Facilitation methods allowed key stakeholders to participate actively in the process
			Transparency. The stakeholders are informed of the results of policy engagements

Appendix D: Correlation between estimated population and variables on infrastructure development at 95% confidence interval using standardised variables. Coefficients (ρ) range between +1 and − 1, where 1 is the total positive linear correlation, 0 is no linear correlation and − 1 is total negative linear correlation. Low p-values below the significance level of 0.05 indicate that relationships are statistically significant (Bewick et al., 2003), Number of observations = 91

Infratructure Variable	Number of people	
	Spearman (ρ)	P-value
Built up area (%)	0.4125	< 0.0001
Distance to roads (Meters)	−0.504	< 0.0001

Appendix E: Average annual rate of deforestation 2013–2017 for the observed and included observations in the regression models. The same letter implies means are significantly similar at 95% significance level when non-parametric Kruskal Wallis test is applied. N = 91 using unstandardized variables

Consideration status	Number of observations	Mean	Standard deviation
Included	80	0.534 [A]	0.644
Excluded	11	0.520 [A]	0.507

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Appendix K: Publication III

Land Use Policy

How are governance and socioeconomic factors linked to the forest transition dynamics at the local scale in the tropics? Empirical evidence from Ecuador, Philippines and Zambia

--Manuscript Draft--

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Abstract:	Forest transition (FT) in the form of deforestation and reforestation has shaped the landscapes of most tropical countries. Studies, mostly conducted at the national scale, have linked the FT dynamics to governance, socioeconomic and biophysical factors. However, transition dynamics depend on implementation of forest legislation, socioeconomic processes and even on household decision-making at the local scale. We examine the linkages of governance and socioeconomic factors to the FT dynamics on the local level, while accounting for biophysical factors. We further distinguish these links to the deforestation (pre, early and late transition) and forest recovery phase (post-transition). We base our study on empirical data from an extensive field study in 34 landscapes across different tropical contexts in Ecuador, Philippines, and Zambia covering approx. 500,000 ha and apply factor analysis as a basis for ordered logistic regression. The results show that both, governance factors (i.e. institutional capacities and effectiveness and access to forest resources) and socioeconomic factors (i.e. human pressure and non-forest income) explain the FT dynamics of landscapes. This mostly confirms previous findings at the national level, for the local scale considering completely different tropical contexts. Astonishingly, a high non-forest income is associated with the pre-transition phase whereas a low non-forest income is associated with the early and late transition phases. Together with increasing population this indicates a marginalization of the population during the deforestation process. Because forest transition obviously deprives small-holder farmers of their livelihood and pushes them further into forestlands, the challenge is to avoid the agriculture-dependent deforestation trap. Our findings neither clearly confirm nor clearly falsify the hypothesis that forest recovery and deforestation are distinct processes. However, the explanatory factors clearly distinguish the pre-transition phase from the rest of the phases. We interpret this as indication that the underlying development pathway already changes at the transition between the pre- and early phases. This suggests that initiatives for reducing deforestation and forest degradation e.g. REDD+ and other conservation programs ought to establish alternatives to the usual agriculture-based development pathway already in the pre-transition phase. Alternative off-farm income opportunities and sustainable forest-based value chains but with strict controls should be promoted as substitutes for agriculture already in the pre-transition phase.

Title Page (with Author Details)

How are governance and socioeconomic factors linked to the forest transition dynamics at the local scale in the tropics? Empirical evidence from Ecuador, Philippines and Zambia

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Abstract

Forest transition (FT) in the form of deforestation and reforestation has shaped the landscapes of most tropical countries. Studies, mostly conducted at the national scale, have linked the FT dynamics to governance, socioeconomic and biophysical factors. However, transition dynamics depend on implementation of forest legislation, socioeconomic processes and even on household decision-making at the local scale. We examine the linkages of governance and socioeconomic factors to the FT dynamics on the local level, while accounting for biophysical factors. We further distinguish these links to the deforestation (pre, early and late transition) and forest recovery phase (post-transition). We base our study on empirical data from an extensive field study in 34 landscapes across different tropical contexts in Ecuador, Philippines, and Zambia covering approx. 500,000 ha and apply factor analysis as a basis for ordered logistic regression. The results show that both, governance factors (i.e. institutional capacities and effectiveness and access to forest resources) and socioeconomic factors (i.e. human pressure and non-forest income) explain the FT dynamics of landscapes. This mostly confirms previous findings at the national level, for the local scale considering completely different tropical contexts. Astonishingly, a high non-forest income is associated with the pre-transition phase whereas a low non-forest income is associated with the early and late transition phases. Together with increasing population this indicates a marginalization of the population during the deforestation process. Because forest transition obviously deprives small-holder farmers of their livelihood and pushes them further into forestlands, the challenge is to avoid the agriculture-dependent deforestation trap. Our findings neither clearly confirm nor clearly falsify the hypothesis that forest recovery and deforestation are distinct processes. However, the explanatory factors clearly distinguish the pre-transition phase from the rest of the phases. We interpret this as indication that the underlying development pathway already changes at the transition between the pre- and early phases. This suggests that initiatives for reducing deforestation and forest degradation e.g. REDD+ and other conservation programs ought to establish alternatives to the usual agriculture-based development pathway already in the pre-transition phase. Alternative off-farm income opportunities and sustainable forest-based value chains but with strict controls should be promoted as substitutes for agriculture already in the pre-transition phase.

Key words: Forest transition, governance, socioeconomic, local scale, tropics

1 Introduction

1.1 Forest transitions in the tropics

Tropical forests provide a variety of goods and services including timber, non-timber products, watershed protection and carbon storage, which are essential for human wellbeing (Millennium Ecosystem Assessment, 2005). Despite this, tropical forests continue to experience deforestation and forest degradation. According to FAO (2020), about 9.28 million hectares of tropical forests were lost annually between 2015 and 2020 with a recovery on 4.58 million hectares. Net forest recovery has been observed in some tropical countries (Costa et al., 2017, Rudel et al., 2002, Ashraf et al., 2017) but only 13 tropical countries had shifted from experiencing net deforestation to net gain in forest cover between 1990 and 2015 (Keenan et al., 2015). Because forest cover change is known to affect the range of goods and services that forests can provide (Sean et al., 2017), it is essential to understand the mechanisms and processes that underlie it.

The forest transition (FT) theory provides a useful framework for analysing the mechanisms and processes that underlie forest cover change across large spatial and temporal scales (Mather, 1992, Rudel et al., 2005). The theory proposes that a country or region begins with a long period of decline in forest cover followed by a subsequent period of sustained forest recovery (Mather, 1992). Four phases characterise the FT of a country or region: (1) an initial phase characterised by high forest cover and low deforestation rates, (2) a phase of forest cover loss at an increasingly rapid rate, (3) a phase of decelerating rate of deforestation from the small fraction of remnant forests, and finally (4) a phase, where the forest cover increases through reforestation (Angelsen and Rudel, 2013, Hosonuma et al., 2012, Angelsen, 2007).

The changes in the phases of FT, here FT dynamics, in most developed countries are mainly accredited to socioeconomic development (Rudel et al., 2005). In the early phases, low-income levels, rural population growth and rising commodity demand increase the rate of forest conversion to agriculture. In the late phase, owing to improved economic conditions through urbanization and industrialization, non-farm jobs compel rural populations to migrate to urban areas and abandon marginal agricultural lands that revert to forests (Rudel, 1998, Rudel et al., 2005, Wolfersberger et al., 2015). Studies also attribute the change in the FT phase to the scarcity of forest resources and declining forest ecosystem services that prompt governments and land managers to commence reforestation or afforestation (Rudel et al., 2005). Additionally, a broader range of processes are recognised to influence FTs in tropical developing countries. They comprise smallholders who promote reforestation through land-use intensification and agroforestry activities, governance instruments e.g. state policies that restrict land use activities on forestlands and promote restoration and globalization processes that result into pressures, incentives and investments in forest protection and reforestation in a country (Lambin and Meyfroidt, 2010).

1.2 The role of forest governance in FTs

Classical theory posits socioeconomic development as the principal determinant of change in FT phase (Rudel, 1998, Rudel et al., 2005, Wolfersberger et al., 2015). However, long-term trends indicate that socioeconomic development can only influence forest cover positively if there are supportive governance structures i.e. institutions, rules and their implementation (Liu et al., 2017). This implies that governance is an important factor, which influences the socioeconomic effects on FTs (Bhattarai and Hammig, 2004). Improved forest governance, by limiting illegal activities, permits efficient, sustainable and equitable use of forest resources, which in turn induces inclusive socioeconomic growth and an accompanied decrease in natural resource dependence (PROFOR, 2011, Davis et al., 2013, van Bodegom et al., 2012, Wolfersberger et al., 2015). Conversely, evidence suggests that poor forest governance fosters inequitable socioeconomic growth, which frequently pushes disadvantaged farmers to migrate further into forestlands that they convert to agricultural lands (Riggs et al., 2018, Riggs et al., 2020, Buys, 2007). Moreover, because forest governance involves restrictions on human exploitation of forest resources, it may have substantial impacts on FTs (Fischer et al., 2020, Nansikombi et al., 2020b) even where the economic preconditions for turning point are unmet (Barbier and Tesfaw, 2015, Bebber and Butt, 2017).

The indicators of forest governance that have been linked to forest conservation and accompanying forest recovery include credible and strong institutions (Paudel et al., 2014, Ametepeh, 2019, Bhattarai and Hammig, 2004) that effectively enforce good quality forest policy and support sustainable forest management (Barbier and Tesfaw, 2015). Furthermore included are the governance arrangements which provide for participatory planning (Buys, 2007) and forest management (Ametepeh, 2019) and those that recognise and protect individual and communal rights to forest resources (Youn et al., 2017, Porter-Bolland et al., 2012). Those arrangements foster tenure security and local legitimacy of forest rules and minimise land use conflicts (Buys, 2007, Mather, 2007). Other governance attributes that are associated with lower deforestation and increased forest recovery are the interventions that incentivise landowners to retain or increase forests (Angelsen and Rudel, 2013) and those that restrict the clearing of forest even in weak economic settings e.g. protected areas (Gizachew et al., 2020, Buys, 2007, Singh et al., 2017).

1.3 Research gap

Several studies link the change in FT phase (FT dynamics) to governance and socioeconomic factors (Riggs et al., 2018, Wolfersberger et al., 2015, Youn et al., 2017, Ametepeh, 2019, Barbier and Tesfaw, 2015). However, those studies largely comprise national scale analyses. There is hardly any evidence of local scale that explicitly link governance and socioeconomic factors to FT dynamics (He et al., 2014), considering different tropical contexts, which are highly diverse and the biophysical factors that are posited to play a role (Yackulic et al., 2011). This is mostly because reliable data are seldom available at the local scale (Secco et al., 2014). And even more, if they are available, they are hardly comparable due to different methodological approaches. Additionally, FT dynamics are conceived for larger spatial scales i.e. national scale, where policy design occurs, or regional and global scales, owing to globalization effects (Meyfroidt et al., 2010, Ametepeh, 2019). National scale or global studies generate insights on the appropriate socioeconomic and legal (de jure) conditions for controlling deforestation and promoting forest recovery that are specific to a country's FT phase (Angelsen and Rudel, 2013) e.g. higher GDP per capita, presence of forest policy (Barbier and Tesfaw, 2015), robust legal framework, and improved institutional quality (Riggs et al., 2018, Wolfersberger et al., 2015). However, they conceal the important transition dynamics from differential implementation of forest legislation and institutional reforms, that mainly occur at the local scale, de facto (Secco et al., 2014). They also risk to neglect essential local scale socioeconomic processes relating to household decision-making, which are highly diverse and crucial to understand forest cover dynamics (Perz and Walker, 2002). Accordingly, it is necessary to complement the exclusively national focus with studies of FT that emphasize governance and socioeconomic effects at the local scale (Ametepeh, 2019, Angelsen and Rudel, 2013). Besides, the hypothesis that deforestation and forest recovery are two distinct processes of FT and thus, shaped by differing socioeconomic and governance mechanisms (Grainger, 1995, Barbier et al., 2010) ought to be substantiated at the local scale. This is particularly important because the local scale drivers have strong influence on national-level processes especially in the situations where macroeconomic adjustments do not play a significant role (Oliveira et al., 2017). Local level insights may moreover strengthen the efficiency and effectiveness of national and global policy and landscape interventions that aim to control deforestation and promote forest recovery (Riggs et al., 2018).

1.4 Aims and research questions

Given the current gaps in knowledge, we examine the linkages between governance and socioeconomic factors and the FT dynamics at the local scale, accounting for biophysical factors as well. We use a landscape as our local scale unit of analysis because it permits simultaneous framing of social and ecological aspects (Sayer et al., 2013, Sayer, 2009). We generate empirical evidence from 34 landscapes spanning three tropical countries Zambia, Ecuador and Philippines accounting for different tropical contexts. With this novel methodological approach we address local level effects accounting for variability within and between countries. Two key questions are addressed. (i) How are governance and socioeconomic factors linked to the FT dynamics at the local scale in tropics? (ii) How do governance and socioeconomic linkages to the FT change during deforestation and forest recovery, addressing the hypothesis that deforestation and forest recovery are two distinct processes with differing underlying mechanisms? The study aims to generate knowledge for tailoring policy interventions e.g. REDD+ and Bonn Challenge to the specific forest cover context (Angelsen and Rudel, 2013).

We employ a methodological approach that combines participatory mapping, focus group discussions, geographical information systems (GIS) and household surveys to collect data and use regression models for the analysis.

2 Conceptual framework

Our study is based on four FT phases, based on the FT theory as described by Angelsen and Rudel (2013), Hosonuma et al. (2012) and Angelsen (2007). In this theory, forest cover and deforestation are hypothesized to vary across the FT phases contingent on the governance, socioeconomic and biophysical conditions (Yackulic et al., 2011, Rudel et al., 2002, Buys, 2007).

The first phase describes core forest areas, where deforestation rates are low, and the forests are relatively undisturbed i.e. >50% forest cover. Poor infrastructure and market access, low population density, low demand for agriculture and forest products, high poverty, low non-farm opportunities and low opportunity costs of avoided deforestation represent the socioeconomic conditions. Because these forests are often remote, outside the reach of state or governments, government agencies have limited capacity to enforce and monitor regulations/restrictions and implement other management measures. Accordingly, formal forest governance is often weak, with customary structures existing in some areas. Formally insecure land tenure predominates most of those areas especially since the cost of defending property rises with distance from towns (Hosonuma et al., 2012, Culas, 2012, Angelsen, 2007, Angelsen and Rudel, 2013, Buys, 2007).

The second phase refers to the areas within forest frontiers (15–50% forest cover), where deforestation rates are high. Medium infrastructure and market access, mixed poverty, low to medium population density, low non-farm opportunities, low to medium demand for agriculture and forest products and medium to high opportunity costs for avoided deforestation characterise the socioeconomic conditions. Forest governance is weak, and the land tenure is insecure in those areas.

The third phase refers to areas within forest/agricultural mosaics (<15% forest cover) with low levels of forest loss. High infrastructure and market access, medium to low poverty and medium to high population density, increasing non-farm income opportunities, and high avoided deforestation characterize the socioeconomic conditions. Forest governance and forest management are both well-established (stable) and the land tenure is also reasonably secure.

The fourth phase comprises the areas with forest restorations and reforestations through plantations, and agrarian mosaics (<50% forest cover). Improved infrastructure and reasonable market access, medium to low poverty levels, medium to high population density, high non-farm income opportunities, high farm labour costs, scarcity of forest products, high opportunity costs for avoided deforestation and abandonment of agriculture on marginal lands e.g., steep slopes and further from markets, characterize the socioeconomic environment. Because such areas are easily accessible by government institutions to enforce regulations, forest governance is well-established and stable. Moreover, given that forest scarcity is likely to increase the demand and value of forest products, there is increased incentive for protecting remnant forests e.g., through establishment of national parks and measures to restrict human access to environmentally valuable areas (Angelsen, 2010). The land tenure is considered secure, mainly among larger landowners.

However, the aforementioned variations of socioeconomic and governance factors across the FT phases are only indicative of broad tendencies and not necessarily definitive to any particular phase (Buys, 2007). The link between specific factors of forest governance and the FT phases is also still unclear (Angelsen and Rudel, 2013). This underscores the necessity to explore the linkages between governance and socioeconomic factors and the FT phases. Moreover, deforestation and forest recovery are theorised as two distinct processes with potentially different predictors (Grainger, 1995).

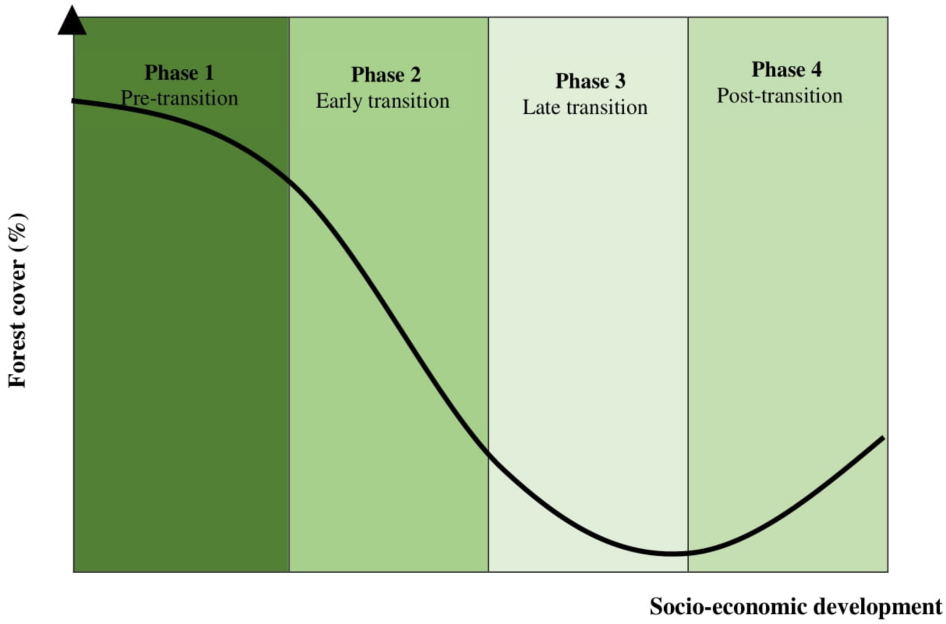


Figure 1: A curve showing the four FT phases (pre-transition, early transition, late transition and post-transition). Adapted from (Angelsen and Rudel, 2013, Hosonuma et al., 2012, Buys, 2007)

3 Methods

3.1 Selection and categorization of study sites

Three countries (Ecuador, Philippines and Zambia) were selected for the study (Figure 2). The countries present a diverse array of dynamics of tropical forest cover change that enabled capturing the different

FT phases at the local scale (landscape). The countries also provide a variant but methodologically comparable set of socioeconomic and governance attributes across the geographical regions.

The Philippines is an archipelago country of Southeast Asia in the western Pacific Ocean. As shown in Table 1, Philippines recorded a net forest cover increase of 0.8%, annually between 1990 and 2015, with less than 30% of the forest cover left in 2015 (FAO, 2015). At the start of our study in 2016, the Philippines were densely populated i.e. 348 persons/km^2, exhibited the highest road density among the three countries and had 41.72% of its land under agricultural production (FRA, 2015). At 0.00, on a scale ranging from -2.5 to +2.5, Philippines had better-quality regulations than Zambia at -0.48 and Ecuador at -1.02 in 2016 (World Bank Group, 2016a). Forest cover loss in the Philippines is mainly attributed to commodity-driven agriculture expansion (Curtis et al., 2018). Forestry practices and urbanization also play a more significant role in the Philippines as compared to Zambia and Ecuador (Curtis et al., 2018).

Ecuador is located at the Pacific side of North-Western South America. The country is a mega-biodiversity hot spot that covers the Andes and Amazon basin. At the start of our study in 2016, Ecuador had reduced its forest cover to 50.2% and the deforestation rate was still relatively high i.e. -0.6% yr^{-1} (FAO, 2015). Ecuador had more than twice the population density of Zambia i.e. 66 persons/km^2, with a share of 63.99 % of the urban population and a high GDP per capita, purchasing power parity i.e. 11551.62 USD (World Bank Group, 2016b). The main driver of deforestation in Ecuador is shifting agriculture. Small-scale ranching and more locally, commodity production e.g. palm oil are also important drivers of deforestation in Ecuador (Piotrowski, 2019).

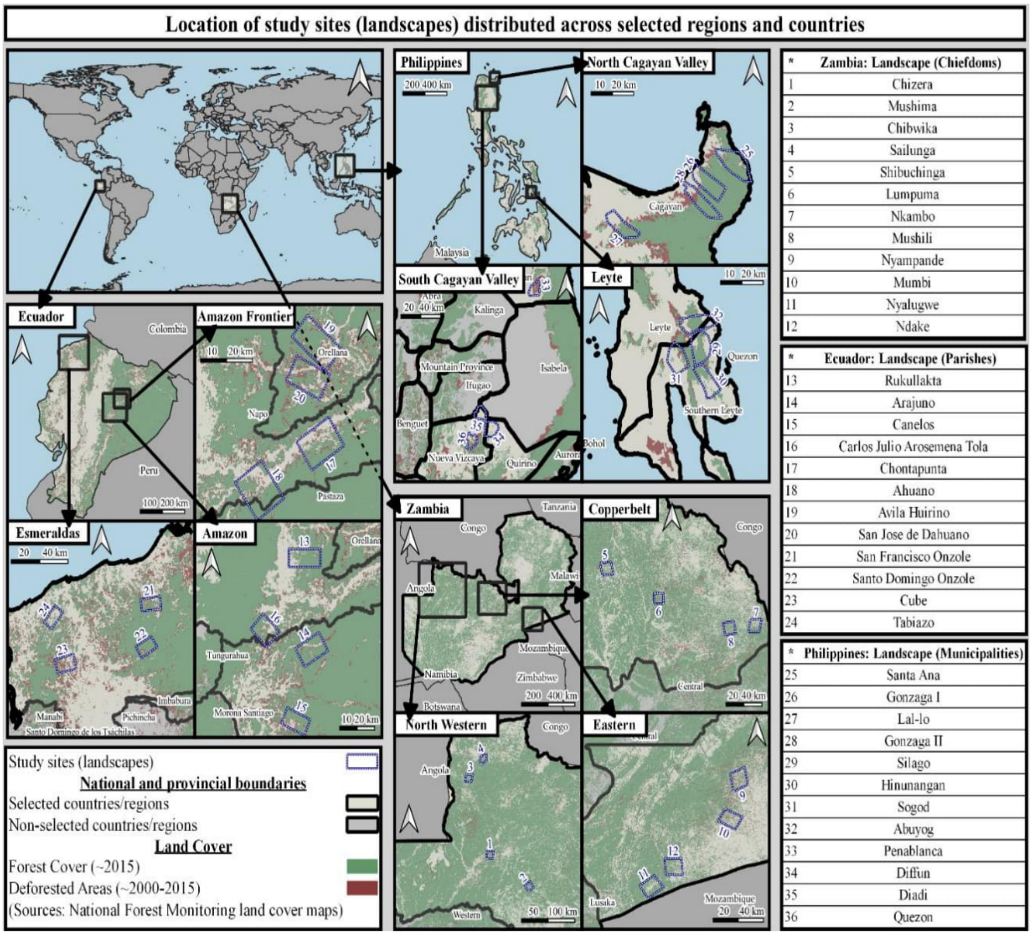
Zambia is a landlocked country located between Southern and Central Africa. As shown in Table 1, at the start of our study in 2016, the country had a high forest cover (65.2%) and a moderate deforestation rate i.e. about -0.3% yr^{-1} (FAO, 2015). The population density (22 persons/km^2) and GDP per capita, purchasing power parity (3467.87 USD) were relatively low (World Bank Group, 2016b). The globalization index, which reflects the effect of globalization on the economic growth was quite low in Zambia as compared to Ecuador and Philippines (Gygli et al., 2019). Like in the Philippines, the main driver of deforestation in Zambia is shifting agriculture (Vinya et al., 2011). According to the same source, other important drivers of forest loss in Zambia are timber logging, infrastructure extension, charcoal production, firewood collection, and livestock grazing.

Table 1: Description of the general socioeconomic, governance and forest cover dynamics of the study countries at the start of our study in 2016. PPP implies purchasing power parity. Regulatory quality score -2.5 implies weak and 2.5 strong. Source: Forest cover (FRA, 2015), population density (22 persons/km^2) and GDP per capita, purchasing power parity (World Bank Group, 2016b), regulatory quality score (World Bank Group, 2016a) and globalization index (Gygli et al., 2019)

Attributes	Philippines	Ecuador	Zambia
Forest cover in 2016 (%)	27.8	50.2	65.2
Forest cover change (%)	0.8	-0.6	-0.30
GDP per capita, PPP in 2016 (US $)	7705.05	11551.62	3467.87
Population density 2016 (Person/ km^2)	348	66	22
Urban population in 2016 (%)	47.15	63.99	44.07
Globalization index in 2016 (0-100)	59.86	66.05	57.42
Regulatory quality score in 2016 (-2.5-+2.5)	0.00	-1.02	-0.48

Within each country, three regions were selected to capture the different FT phases, totalling up to nine regions. Within each of the nine regions, four landscapes each of approximately 100-150km^2 were selected, thus resulting in 36 landscapes (Figure 2). The 36 landscapes correspond to distinct country-specific administration units (i.e., chiefdoms, parroquias and municipalities in Zambia, Ecuador and Philippines, respectively), which were selected to ensure homogenous formal administration across landscapes. The landscapes were selected to represent typical land-use, socioeconomic, demographic, and biophysical attributes of their respective regions.

Figure 2: A map showing the location of study landscapes within the selected countries. Source illustrated by authors based on national forest monitoring land cover maps



Following the methodology described by Hosonuma et al. (2012) and (Da Fonseca et al., 2007), the 36 landscapes were grouped into four FT phases i.e. pre-transition, early transition, late transition and post-transition, based on two factors: percentage forest cover and rate of forest area change. The FT phases constituted the outcome variable in the analysis. A decision tree (Figure 3) was developed for categorizing the 36 landscapes into four FT phases and is based on the most recently available data sets for forest cover per country (Table 2). The percentage forest cover of 2016 was used for Zambia and Ecuador while that of 2015 was used for Philippines, contingent on data availability. Forest cover change rates were calculated based on the amount of annual forest change relative to forest cover in 2000 for Zambia and Ecuador and 2003 for Philippines for two time periods using national level map information derived from government authorities or related project archives (Table 2). An annual forest area loss rate of - 0.35% was used to separate between pre-and early transition landscapes. A forest cover of 60% was used as the minimum threshold for high forest cover and 25% as the maximum threshold for low forest cover. A forest area change rate of 0% was selected as an additional threshold (Figure 3). The limitation of this approach is that the FT phase of landscapes can change depending on

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the thresholds of forest cover and forest cover loss.

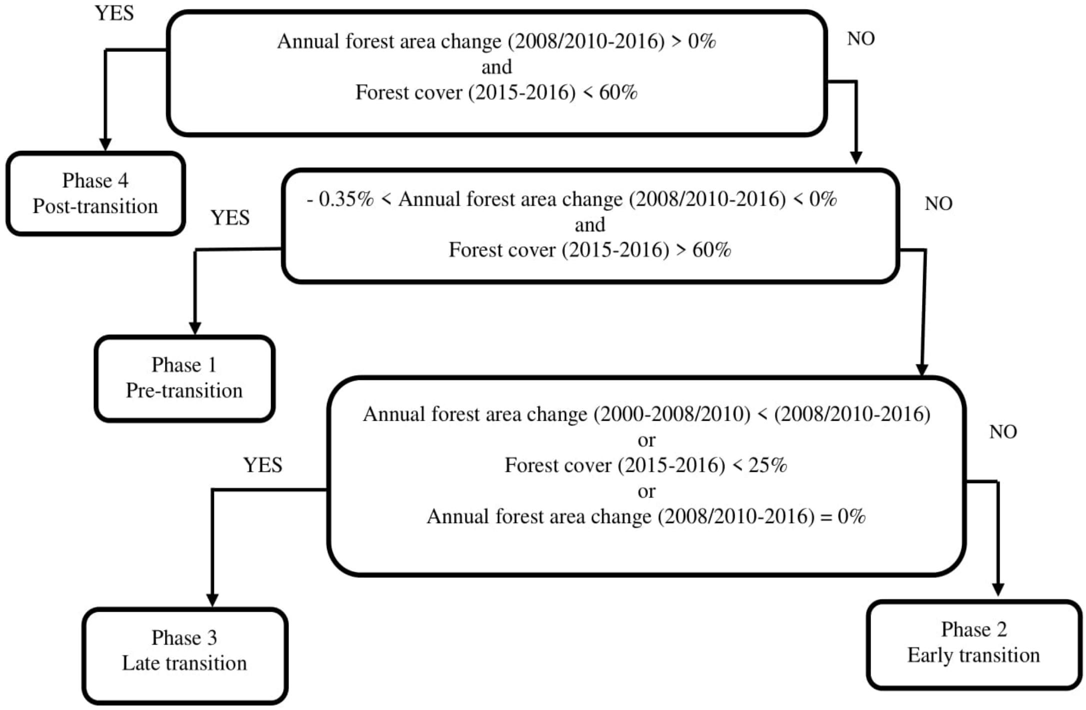

Figure 3: Decision tree for FT categorization. Adapted from Hosonuma et al. (2012)

Table 2: The two periods used to calculate the amount of annual rate of forest area change for the landscapes in each country: Source (NAMRIA, 2013, ESA, 2017, MAE, 2015, RCMRD, 2010)

Landscape country of location	Annual forest area change			
	Period 1	Source	Period 2	Source
Zambia	2000-2010	RCMRD Maps	2010-2016	ESA maps
Ecuador	2000-2008	MAE Maps	2008-2016	MAE Maps
Philippines	2003-2010	NAMRIA Maps	2010-2015	NAMRIA Maps

Of the 36 tropical landscapes, 11 were in the pre-transition phase, 14 in early transition, 4 in late transition and 7 in post-transition.

3.2 Governance, socioeconomic and biophysical data preparation

3.2.1 Scoping visits

Scoping visits were conducted in each of the 36 landscapes as a preliminary step. In these visits, it was ensured that the landscapes and communities fitted within the objectives of the study and the willingness of the communities to participate and cooperate with the research project was confirmed. The visits also enabled the identification of relevant de jure governance arrangements, representing different tenure and restrictions to forest access and use within each landscape. Contacts to representatives from all communities and major stakeholder groups within each landscape were also established during these visits.

3.2.2 Governance variables

Focus group discussions (FGDs) (O. Nyumba et al., 2018) were carried out to conduct governance assessment and participatory mapping exercises aiming to identify the locally perceived, de facto governance arrangements and land use patterns. Focus group discussions were carried out in all 36 landscapes, each with about 15-20 key stakeholder representatives including community leaders, customary leaders and forest committee representatives. Participants comprised men, women, and youth (18–30 years), and long-term members from the communities in the landscape. This enabled broad representation of decision makers and social groups in the landscape. Despite the fact that FGDs are perception-based methods, they capture the reality that exists on the ground, which differs from the fact-based notions of laws (Kaufmann et al., 2011). Participatory mapping (Martin et al., 2012) was essential to create awareness on the focus governance arrangements and to ensure that subsequent governance assessment was done in a spatially consistent manner. The participatory mapping exercises were carried out between August 2016 and October 2018, using recent colour print outs of high-resolution Google Earth satellite images of approximately 80*120 cm (Nansikombi et al., 2020a, Fischer et al., Submitted).

3.2.2.1 Classification and delineation of governance arrangements

In the participatory mapping exercise, while referring to the de jure categories of governance arrangements in each country, participants were asked to distinguish and delineate the de facto arrangements within the different communities in the landscape using the satellite image print outs. The de facto arrangements were differentiated based on tenure, ownership status, and access and use restrictions in the respective countries (Fischer, 2020, Nansikombi et al., 2020a). Eight major categories of de facto governance arrangements were summarised from the participatory mapping exercise, depending on the country and region of context. They are: (i) restricted state forests, (ii) restricted customary forests with title, (iii) restricted customary forests without title, (iv) communal forests with title, (v) communal forests without title, (vi) individual forests with title, (vii) individual forests without title, and (viii) private forests. The polygons of the mapped governance arrangements within each landscape were digitized using QGIS. The arrangements were the unit of governance assessment in each landscape because they represent a comparable governance structure across the three countries. Their area extent was used for weighting the governance scores (Section 3.2.2.2), to derive mean governance per landscape.

3.2.2.2 Governance assessment

Governance variables constituted a key component of the predictors in the analyses. The study relies on the Governance of Forests Initiatives framework (GFI) of the World Resource Institute as to generate information on the indicators of forest governance. The GFI framework provides a comprehensive diagnostic tool that covers six core governance issues in forestry. These are: 1) forest tenure, 2) land use planning, 3) forest management, 4) forest revenues, 5) cross-cutting institutions, and 6) cross-cutting issues, denoted as thematic areas (Davis et al., 2013). The framework assesses these governance areas through a set of detailed indicators. The GFI framework recommends that the indicators should be "adapted based on contextual factors such as scale of assessment, type of forest biome, or ownership regime" from the large multitude of governance aspects covered.

Initially, we selected only the indicators that are relevant for the local scale. After a thorough literature analysis, these were refined to capture at least one indicator from each of the thematic areas, choosing those that reflect pertinent issues of forest governance in our three study countries (Appendix A). After a pre-selection of 21 indicators (Fischer, 2020, Nansikombi et al., 2020a), we reduced the set to those that were applicable in all landscapes (Table 3). The analyses with indicators that are applicable in all sites enabled better comparison across all study landscapes. Each selected indicator was specified by five elements of quality, rated on a scale of pre-coded statements, from lack of good governance to good practice (Appendix A). In the FGD, participants were asked to discuss (based on their experiences) and agree on scores for governance performance, which was assigned as a Likert score (Likert, 1932) on a scale from 0 (not present), 1 (very low) to 5 (very high) to each element of quality within each of the governance arrangements. Likert scales constitute data transformation from qualitative to quantitative form (Flynn et al., 1990). This permits the reliable integration of information across observations or cases (Kirk et al., 1986). Moreover, although criticized for producing ordinal data, Likert scales have been found to provide interval data, suitable for parametric statistical analysis (Parker et al., 2002).

Likert scores of all five elements of quality per indicator were aggregated as the arithmetic mean to derive indicator score for each of the governance arrangements. All qualitative comments that were given for the governance scores were noted. It was not possible to establish contacts to private landowners to a meaningful extent; thus, we could not score governance on private forests. Accordingly, the private arrangements were excluded from the later analysis where governance indicators were needed.

The indicator on forest law enforcement combines the indicators on enforcing customary and formal laws both representing the thematic area "forest management" (Appendix A). The separate indicators were only applicable in specific governance arrangements. However, at least one of the indicators could be measured for each arrangement. This was as well the case with the indicator on forest management, which combines all indicators on managing forests i.e. administration of timber and charcoal licences, protection and conservation and implementation of PES programs, from the thematic area "forest management" (Appendix A). We also included the percentage of restricted area as a potential factor associated with FTs (Yackulic et al., 2011). As restricted, we considered restricted state forests and restricted customary forests in Ecuador, restricted state forests in Zambia and restricted state forests in the Philippines. This summed up to 8 governance variables (Table 3). Based on governance assessments per arrangements we calculated mean governance values per landscape as means weighted by the area of the governance arrangements.

Table 3: Summary of the eight governance indicators that were used in the analysis

Thematic area	Governance indicator
Forest tenure	Tenure rights recognition and protection
Forest management	Forest management
	Forest law enforcement
Crosscutting institutions	Government institutions capacities and effectiveness
	Local institutions capacities and effectiveness
	Non-government organizations capacities and effectiveness
Crosscutting issues	Public policy participation
Other governance variables	Percentage of restricted area

3.2.3 Socioeconomic variables

Socioeconomic variables also constituted a key component of the predictors in the analyses. Six socioeconomic variables were considered in the analysis: (i) population density, (ii) road density, (iii) crop income, (iv) livestock income, (v) non-farm income and (vi) forest income. Population density reflects the demand for forest and agricultural products (Rademaekers et al., 2010). Road density reveals the level of urbanization (Zhao et al., 2017) and market access (Ulimwengu et al., 2009). Crop income indicates the smallholder households` dependence on crop farming for consumption and commercial purposes. Livestock income reveals smallholder households` dependence on livestock farming for consumption and commercial purposes. Non-farm income represents the presence of alternatives opportunities to agriculture and as well the opportunity cost of farm labour (Vedeld et al., 2007, Angelsen et al., 2011). Forest income represents smallholder households` dependence on forest extraction for consumption and commercial purposes.

Data on population density and road density were obtained through GIS. We calculated the population density in 2016 using data from worldpop.org by Sorichetta et al. (2015) for Ecuador, Linard et al. (2012) for Zambia and Gaughan et al. (2013) for the Philippines. For the individual countries, the data on population density were UN adjusted at 100m resolution. Data on road density were obtained from OpenStreetMap. We used the latest dataset downloaded on 22.06.2020. To represent roads, we included paths, primary roads, residential, secondary roads, service road, tertiary roads, tracks, bridleways, footways, trunk roads and unclassified roads. Data on the different income categories were obtained through a household survey. The data set relies on a transnationally harmonized survey of 1123 households in Zambia (Kazungu et al., 2020), 1294 households in Ecuador (Luna et al., 2020) and 1005 households in the Philippines (Wiebe, Submitted). Household income categorization and computation methods are based on (Vedeld et al., 2007, Angelsen et al., 2011). For inter-household income comparisons we used adult equivalent units (AEU), precisely the OECD-modified scale (Chanfreau and Burchardt, 2008). We compared national currency values using purchasing power parity (PPP) rates (OECD and Eurostat, 2012); thus all income figures are reported as PPP adjusted US $ per AEU. To derive the landscape level value, for each socioeconomic variable, we computed the average value of all the sampled households in the landscape.

3.2.4 Biophysical variables

The biophysical factors constituted the control variables in the analysis to permit a realistic examination of the relationships between governance and socioeconomic factors and the FT phases. Five biophysical factors that are posited to influence the FT (Yackulic et al., 2011, Bennett and Barton, 2018) were included: slope, elevation, soil nutrient availability, precipitation, and temperature. Data on slope and elevation were derived from the SRTM 90m Digital Elevation Database v4.1 (Jarvis et al., 2008). Soil nutrient value data were computed from the harmonised world soil databases (Fischer et al., 2008) and precipitation and temperature data from climatologies at high resolution for the earth's land surface areas (Karger et al., 2017). All biophysical variables were computed as mean values for each landscape.

We also include country dummy variables in our analysis to account for the possibility that unobserved factors within a particular country affect the outcome independent of the primary variables of interest. A summary of all variables is presented in Table 4.

Table 4: Description of variables for analysing associations between governance, socioeconomic and biophysical factors the FT phase in tropical landscapes.

Variable category	Indicator	Measurement unit	Data source
Outcome variable	FT stage: (i) pre (ii) early (iii) late (iv) and post transition	Categories of FT stages	ZMB ESA 2016, RCMRD, 2010, ECU MAE 2016, PHL NAMRIA 2015
Explanatory variables			
Governance	Tenure rights recognition and protection	Likert score	Focus group discussions
	Forest management	Likert score	Focus group discussions
	Forest law enforcement	Likert score	Focus group discussions
	Central government capacities and effectiveness	Likert score	Focus group discussions
	Non-Government Organization capacities and effectiveness	Likert score	Focus group discussions
	Local level institutions` capacities and effectiveness	Likert score	Focus group discussions
	Public policy participation	Likert score	Focus group discussions
	Percentage of restricted area	Percentage	Land cover maps
Socioeconomic	Population density 2016	Persons/km^2	www.worldpop.org (Gaughan et al., 2013, Linard et al., 2012, Sorichetta et al., 2015)
	Road density	Km/Km^2	OpenStreetMap (www.geofabrik.de)
	Livestock income	$US PPP/AEU	HH survey
	Crop income	$US PPP/AEU	HH survey
	Forest income	$US PPP/AEU	HH survey
	Non-farm income	$US PPP/AEU	HH survey
Control variables			
Biophysical	Slope	Degrees	Jarvis et al. (2008)
	Soil nutrient availability	Numeric value	FAO world soil database 2016 (Fischer et al., 2008)
	Elevation	Meters above sea level	Jarvis et al. (2008)
	Precipitation (1979-2013)	mm	Karger et al. (2017)
	Temperature (1979-2013)	Degrees Celsius	Karger et al. (2017)
Other variables	Country variables	Country dummies	Boundary maps

3.3 Data analysis

We applied the ordered logit (ologit) model by McCullagh (1980) to analyse the linkages between governance and socioeconomic factors and the FT phases. Because our outcome variable, the categories of FT phases, have a natural sequential order i.e. (i) pre-transition followed by (ii) early transition, (iii) late transition and finally, (iv) post-transition, the ordered logit (ologit) model provides the best theoretical fit for our data (Agresti, 2010).

We estimated two ordered logit models to distinguish the factors which are relevant for deforestation and forest recovery. In both models we used governance, socioeconomic and biophysical factors as the explanatory variables. Only the categories of the outcome variable differed between the models to understand the implication of segregating deforestation and forest recovery in FT analysis. The categories of the outcome variable in the first model constituted all the four FT phases to reflect deforestation and forest recovery. In the second model, the categories of the outcome variable comprised only the three phases of deforestation. An assumption of this model is that regression parameters are the same for different FT phases, known as the parallel line or proportional odds assumption (Fullerton, 2009). Hence the slope coefficient does not vary over different alternatives. A Brant test (Brant, 1990), however, revealed that in both ologit models not all the explanatory variables fulfilled the proportional odds assumption. Accordingly, ordinal generalized linear models (oglm) were estimated because they relax the proportional odds assumption for the explanatory variables (Fu, 1998, Williams, 2010). For an ordered variable y with m categories, the probability of being in the FT phase j is written as (Long, 1997):

$$\Pr(y_i > j) = g(x_i\beta') = \frac{\exp\left(x_i\beta' - \tau_j\right)}{1 + \exp(x_i\beta' - \tau_j)}, j = 1, \ldots . m - 1$$

Where x_i is a (k x 1) vector of observed non-random explanatory variables, β' is (k x 1) vector of unknown parameters to be estimated. The parameters of the model (β') and the cut-points (τ_1 and τ_2) are estimated by the method of maximum likelihood (Long, 1997). β' is not fixed across equations and the parallel-lines constraint is relaxed for all variables.

Prior to each regression analysis, factor analyses using principal component method were conducted for each category of explanatory variables i.e. governance, socioeconomic and biophysical variables separately, to reduce the likelihood of multicollinearity within each category. Factor analysis entails the reduction of a large set of correlated predictor variables to a smaller, less correlated set called factors, that still contains most of the information in the larger set (Perez, 2017).

The first factor analysis reduced the 8 governance variables into 2 principal factors that together explained 68.8 % of the variations in governance conditions for the three-phase model and 68.5 % for the four-phase model (Appendix B). For both models, the first governance factor was positively correlated with the capacities and efficiencies of (i) government, (ii) non-government organizations and (iii) local institutions and (iv) public policy participation and (v) formal law enforcement. It was interpreted as representing institutional capacities and effectiveness (Appendix B). The second factor was positively correlated with (i) tenure rights recognition and protection, (ii) forest law enforcement and (iii) forest management and negatively correlated with (iv) percentage of restricted area. The second factor was interpreted as representing access to forest resources.

The second factor analysis reduced the 6 socioeconomic variables into 3 principal factors that together explained 86.2% of the variations in socioeconomic conditions for the three-phase model and 87.2% for the four-phase model (Appendix C). For both models, the first socioeconomic factor, was positively correlated with (i) crop income (ii) livestock income and (iii) non-farm income (Appendix C). It was interpreted as representing non-forest income. The second factor was positively correlated with (i) population density and (ii) road density (Appendix C). It was interpreted as representing human pressure. The third factor was strongly correlated with forest income and thus, interpreted as representing forest income.

The third factor analysis reduced the 5 biophysical factors into 2 principal factors that together explained 84.8% of the total variations in biophysical conditions for the three-phase model and 85.0% for the four-phase model (Appendix D). For both models, the first biophysical factor was positively correlated with (i) temperature (ii) slope and (iii) precipitation and negatively correlated with elevation (Appendix D). It was interpreted as mostly representing elevation. The second factor was positively correlated with (i) soil nutrients and (ii) precipitation (Appendix D). It was interpreted as representing soil fertility.

After the factor analysis, correlation analyses were conducted between the resultant principal factors that were to be included in each model. Correlation statistics (Appendices E and F) indicate that multicollinearity is less likely to be a significant constraint in the subsequent regression analyses. The correlation coefficients between the different factors are less than 0.8, the threshold for multicollinearity (Midi et al., 2010).

Because the processes by which FT occurs can affect the socioeconomic and governance conditions (Meyfroidt and Lambin, 2011), there is potential for endogeneity in our regression models. In absence of suitable instrumental variables to account for the endogeneity problem, we restrict our deductions to associations.

Since socioeconomic data could not be obtained for 2 landscapes in the Philippines, they were excluded from the regression analyses.

Given that the estimated coefficients from an ordinal generalized linear models are difficult to interpret as they are in log-odds units, we additionally estimated the average marginal effects. Marginal effects are interpreted relative to the category and sign. A positive coefficient for a category indicates that an increase in the respective variable increases the probability of being in that category, whereas a negative coefficient indicates a decrease in probability of being in the respective category (Agresti, 2010, O'Connell, 2006). All variables were standardised prior to the regression analysis. All analyses were conducted using STATA 16 (StataCorp, 2019).

4 Results

4.1 Percentage of forest cover for each FT phase between 2015 and 2016

As determined within the methodology (Figure 3), with a mean of 73%, the landscapes assigned to the pre-transition phase record the highest forest cover which successively decreases through the early (56%) and late transition (11%) phases and then increases in the post-transition phase (34%) (Figure 4).

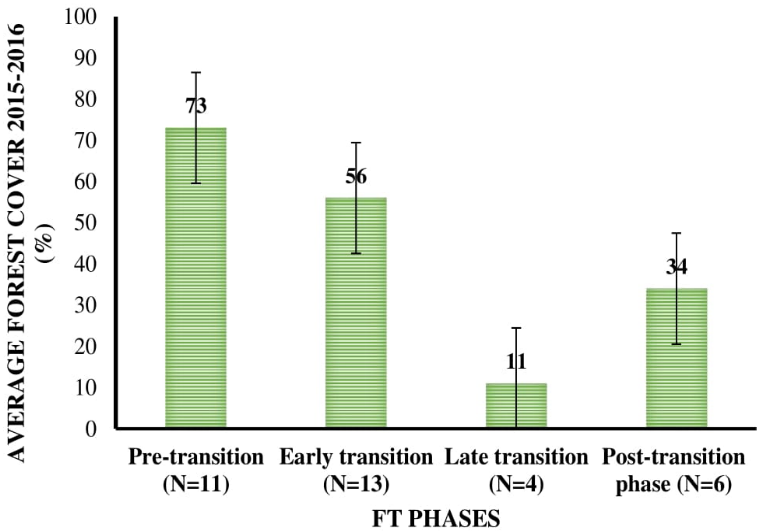

Figure 4: Percentage of forest cover by FT phase between 2015 and 2016

4.2 Governance and socioeconomic factors in the deforestation and forest recovery FT phases

As shown by the chi-squared test statistics, in both models, the combined effect of all the variables is different from zero, and the models are statistically significant compared to the null models with no predictors (Table 5).

The governance factor on institutional capacity and effectiveness and the socioeconomic factors on human pressure and non-forest income are significantly associated with FT dynamics in the four-phase model (Table 5) and expressed by the marginal effects (Table 6).

Surprisingly, the signs of the factors change for the pre-transition phase and not as expected for the post-transition phase (Table 6).

The governance factors on institutional capacities and effectiveness and access to forest resources have a significant marginal effect in the four-phase model, which captures both deforestation and forest recovery (Table 6). Increasing institutional capacity and effectiveness and increasing access to forest resources increase the landscapes' probability of being in the pre-transition phase and decrease the probability of being in either the early or late or post-transition phases.

The socioeconomic factors on non-forest income and human pressure have a significant marginal effect in the four-phase model (Table 6). Surprisingly, increasing non-forest income (including crop, livestock, and non-farm income) increases the landscapes' probability of being in the pre-transition phase and decreases the probability of being in either the early or late or post-transition phases. Increasing human pressure, reflected by increasing road and population densities, has an opposing effect, decreasing the landscapes' probability of being in the pre-transition phase and increasing the probability of being either in the early or late or post-transition phases.

Although non-significant, the landscapes in Ecuador and Philippines have a lower probability of being in the pre-transition phase and a higher probability of being in the early, late and post-transition phases than those in Zambia our reference category.

Table 5: Results of ordered generalized linear regression models (oglm) showing the relationships between governance and socioeconomic factors and the FT phases. *implies significant factor at a 95% confidence interval; R is the reference country dummy and, na implies non-applicable, AIC is the Akaike Information Criterion. Cut-point 1, Cut-point 2 and Cut-point 3 are the estimated cut-points on the latent variable, Y*, used to differentiate the adjacent levels of categories of FT Phases. The + sign on the biophysical factor on elevation is interpreted in the opposite direction (-) because elevation is negatively correlated with this factor.

Explanatory variables	**Four FT phases (deforestation and recovery)**		**First three FT phases (deforestation)**	
	Coefficient	**Standard error**	**Coefficient**	**Standard error**
Governance				
Institutional capacity and effectiveness	**-4.3909***	1.4885	**-6.4656***	2.7188
Access to forest resources	-1.6306	0.8916	-0.8652	1.1507
Socioeconomic				
Non-forest income	**-1.8811***	0.8719	**-2.9138***	1.3582
Human pressure	**2.5063***	0.748	**3.5820***	1.3089
Forest income	-0.737	0.4336	**-1.5257***	0.7355
Biophysical				
Elevation	1.6952	1.6425	4.1883	2.3934
Soil fertility	0.6684	0.6587	0.6309	0.9986
Country dummies				
Ecuador	4.4948	4.0518	2.8331	5.114
Philippines	5.5807	5.0584	1.0071	6.9547

Zambia	R	-	R	-
Cut-point 1	0.996	2.8924	-0.5611	3.3561
Cut-point 2	5.1343	3.0815	5.2377	3.6607
Cut-point 3	6.96	3.2599	na	na
Number of observations	34		28	
Likelihood Ratio $chi^2(9)$	35.93		26.17	
Prob > chi^2	0.0000		0.0019	
Pseudo R-squared	**0.41***		**0.47***	
Log likelihood	-25.92		-14.95	
AIC	75.83		51.90	

4.3 Differences in the linkages of governance and socioeconomic factors to deforestation and forest recovery

The model that omits the phase of forest recovery (post-transition) from the categories of outcome variable yields a better fit (lower AIC, and higher Pseudo R-squared) than the model that integrates both the deforestation and forest recovery in a single analysis (Table 6).

The marginal effect of the governance factor on access to forest resources becomes insignificant when the phase of forest recovery (post-transition) is excluded from the analysis in the three-phase model (Table 6).

The marginal effect of the socioeconomic factor on forest income becomes significant. It increases the landscapes' probability of being in the pre-transition phase but decreases the probability of being in either the early or late transition phase when forest recovery (post-transition) is excluded from the analysis in the three-phase model (Table 6).

The marginal effect of the biophysical factor that is negatively linked to elevation and positively linked to temperature becomes significant when the phase of forest recovery (post-transition) is excluded from the analysis in the three-phase model. Because elevation is negatively linked to this factor and temperature positively linked, increasing elevation, and decreasing temperature, increases the landscapes' probability of being in the pre-transition phase and decreases the probability of being in either the early or late transition phases (Table 6).

The marginal effects of the governance factors on institutional capacities and effectiveness, non-forest income and socioeconomic factors on human pressure, which also explain most of the variations in FT phases, remain significant and retain their signs across all FT phases when forest recovery (post-transition) is excluded from the analysis in the three-phase model (Table 6).

Table 6: Average marginal effects of the explanatory factors on the specific FT phases. The - sign on the biophysical factor on elevation is interpreted in the opposite direction (+) because elevation is negatively correlated with this factor.

Explanatory variables	Four FT phase model (N= 34)				Three FT phase model (N=28)		
	Pre-transition	Early transition	Late transition	Post-transition	Pre-transition	Early transition	Late transition
Governance							
Institutional capacity and effectiveness	**0.594***	**-0.305***	-0.049	**-0.240***	**0.896***	**-0.673***	**-0.223***
Access to forest resources	**0.221***	**-0.113**	-0.018	**-0.089***	0.120	-0.090	-0.030
Socioeconomic							
Non-forest income	**0.255***	**-0.131***	-0.021	**-0.103***	**0.404***	**-0.303***	**-0.101***
Human pressure	**-0.339***	**0.174***	0.028	**0.137***	**-0.496***	**0.373***	**0.124***
Forest income	0.100	-0.051	-0.008	-0.040	**0.211***	**-0.159***	**-0.053***
Biophysical							
Elevation	-0.229	0.118	0.019	0.093	**-0.580***	0.436	**0.145***
Soil fertility	-0.090	0.046	0.007	0.037	-0.087	0.066	0.022
Country dummies							
Ecuador	-0.608	0.313	0.050	0.246	-0.393	0.295	0.098
Philippines	-0.755	0.388	0.062	0.305	-0.140	0.105	0.035

5 Discussion and methodological and policy implications

5.1 Governance and socioeconomic factors in the deforestation and forest recovery FT phases

In both models the combined effect of all the variables is different from zero, and both models are significant compared to the null models with no predictors. Analogous to (Mather, 1992, Yackulic et al., 2011), this result confirms our hypothesis that underlying governance, socioeconomic and biophysical conditions are related to FT dynamics. This is valid across different tropical contexts.

Our results reveal that the signs of all factors change between the pre-transition phase and the early-transition phase for both models and not as expected at the post-transition phase. This indicates that the processes which distinguish the pre-transition phase from the rest of the phases are more clearly pronounced than those that differentiate the post-transition phase from the early and late transition phases. Accordingly, the development pathway changes at the transition between pre- and early FT phases and not as expected between late and post-transition phases. Similar to (Angelsen and Rudel, 2013), the result suggests that initiatives for controlling deforestation and forest degradation e.g. REDD+ and other conservation programs ought to establish alternatives to the usual agriculture-based development pathway already in the pre-transition phase. This is because once ongoing, the destructive processes relating to deforestation are hard to reverse in the later FT stages.

We found that a higher institutional capacity and effectiveness is associated with the pre-transition phase whereas a lower institutional capacity and effectiveness is linked to the early, late, and post-transition phases. The model does not allow to establish cause effect relationships and thus implies that either low governance in the form of low institutional capacities and effectiveness can lead to advanced deforestation or that during advancing deforestation governance quality is decreasing. The presence of customary/local institutions in the pre-transition landscapes, also reported by Nansikombi et al. (2020a) and Fischer et al. (Submitted) may elucidate the registered institutional effectiveness unlike in the early, late and post-transition landscapes, in which customary institutions have been degraded following immigration (Angelsen and Rudel, 2013). The results emphasize the necessity for strengthening local and customary institutions to curb forest loss. Effective institutions may impose additional costs on the economic agents and reduce their potential to convert forests to agriculture (Buys, 2007).

Our results show that higher individual and communal access to forestlands /lower restrictions on forestlands is associated with the pre-transition phase whereas low individual and communal access to forestlands/high restrictions on forestlands is associated with the post-transition phases. In the pre-transition landscapes, the relatively low restrictions to forest access and use may be accredited to a low demand for forest resources given the low population density (Rademaekers et al., 2010) and limited market access due to remoteness. A low demand implies low forest exploitation and a minimal requirement for governments to restrict individual and communal access to forestlands. In the post-transition landscapes, forest products scarcity from continuous deforestation could propel governments to implement policies that restrict forest exploitation and reduce individual and communal access to forestlands (Nelson and Chomitz, 2011). Nevertheless, restrictions have been found to negatively affect rural livelihoods since they deprive the rural poor of income from forests (Kaimowitz, 2003). Collaborative forest management would enable sustainable use of forest resources (Kant, 2004).

We found that lower human pressure, reflected by a low population density is linked to the pre-transition phase while higher human pressure, reflected by a higher population density is linked to the early, late, and post-transition phases. This finding confirms standard FT predictions that population density is lower in the pre-transition phases and increases with in the early, late, and post-transition phases. The low population density implies less demand for forest products and alternative land uses e.g. agriculture and settlements (Angelsen and Rudel, 2013, Culas, 2012) and therefore, a higher forest cover as reflected by the pre-transition landscapes. Conversely, a higher population density implies a greater land use intensity and consequently, a shift towards the early, late and post-transition FT phases (Rademaekers et al., 2010, Ferrer Velasco et al., 2020).

Moreover, similar to Glover and Simon (1975) road density was also strongly positively correlated to the factor on human pressure. This implies that increased road density has similar effects as population density, reducing the probability of being in pre-transition and increasing the probability of either early, late, or post-transition phases. A poor road network renders forests inaccessible for external commercial exploitation. This preserves the forest cover and prolongs the pre-transition period. Increased road density on the other hand facilities deforestation through improved forest and market access (Nansikombi et al., 2020b, Ulimwengu et al., 2009). This lowers the forest cover and triggers the shift towards the early, late, and post-transition phases. Because roads are inevitable for economic development, effective institutions would minimise unsustainable forest exploitation in the easily accessible and densely populated areas. Besides, roads have been demonstrated to provide more diversified income opportunities that can relieve pressure on forests (Angelsen, 2010).

Our results show that higher non-forest income (crop, livestock and non-farm) is surprisingly associated with the pre-transition phase whereas lower non-forest income is linked to the early, late or post-transition phases. Similar to (Trædal and Angelsen, 2020) this implies that non-forest income (agriculture and non-farm), which also reflects the welfare of most tropical rural households (Brück, 2004), decreases with subsequent shift in FT phase (Angelsen and Rudel, 2013, Angelsen, 2007). Because population density has an opposite relation (Table 6), the result might imply that whereas population increases during deforestation, non-forest income per household decreases. This might indicate a marginalisation in the context of agricultural expansion, which occurs in the early, late and in some cases post-transition phases and is mainly driven by external actors, in-migrants, and resource exploitation companies, with limited benefits to residents. The removal of forest cover and forest degradation deprives forest dwellers of their livelihoods and aggravates their poverty levels (Angelsen, 2007). In-migration and or population growth also provide a steady supply of labour, which dampens local wages (Angelsen, 2007). This reduces the non-farm income in the early and late FT phases, with in-migration and high population densities. In the pre-transition phase, poor infrastructure makes the forest area inaccessible by immigrants and external commercial users (Angelsen and Rudel, 2013). Thus, the challenge is to avoid the agriculture-dependent deforestation trap. Alternative off-farm livelihood opportunities and land-use independent development strategies on one side as well as sustainable forest-based value chains, but with strict controls on the other side should be promoted as a substitute for deforesting agricultural practices already in the pre-transition phase.

Although non-significant, the landscapes in Ecuador and Philippines have a lower probability of being in the pre-transition phase and a higher probability of being in the early, late and post-transition phases as compared to those in Zambia, our reference category. The results might reflect the forest cover dynamics of the respective countries. According to (Hosonuma et al., 2012, Ferrer Velasco et al., 2020), Zambia is still in the pre-/ early stage of the forest transition, Ecuador in the early-/late stage of forest transition and Philippines in the late/post-transition stage of forest transition.

5.2 Differences in the linkages of governance and socioeconomic factors to deforestation and forest recovery

Although only marginally, the model yields a better fit and explains the variations in FT phases better when forest recovery (post-transition) is excluded from the categories of the outcome variable. This on one side implies that the patterns of forest transition are better examined by separating deforestation from forest recovery. On the other side the marginal effects of the factors that explain most of the variations in FT phases i.e. institutional capacities and effectiveness, population density and non-forest income, remain significant and retain their signs across all FT phases when forest recovery is excluded from the analysis. Coupled with the rather identical structure of factors in the factor analysis (Appendices B, C and D) for the two models this is a strong indication that recovery and deforestation are driven by similar processes. According to (Grainger, 1995), the factors that drive deforestation and forest recovery are partly overlapping, given that the two processes largely mirror each other. Because the arguments are pro and contra, we can neither clearly confirm nor clearly falsify the hypothesis that deforestation and forest recovery are distinct processes that are also associated with different factors (Rudel et al., 2005, Lambin et al., 2006, Grainger, 1995). Besides, the difference in the significant predictors in the two models may be accredited to a small sample size that is also unequally distributed i.e. 6 landscapes undergoing recovery against 28 landscapes undergoing deforestation. The sample sizes of the two models are also different. Because the post-stratification approach of categorizing landscapes into the FT Phases may partly explain this, future studies would benefit from a pre-stratification.

The marginal effects that remain significant and retain their signs across all FT phases indicate that institutional capacities and effectiveness, population density and non-forest income, also revealing household welfare, are important predictors of both deforestation and forest recovery.

The marginal effect of the governance factor on access and restrictions to forestlands becomes insignificant when the phase of forest recovery (post-transition) is excluded from the analysis. This implies that restrictions and limiting individual and communal access to forests is more connected to forest recovery than deforestation. This could be attributed to the fact that restrictions are mostly implemented as a policy measure to facilitate forest recovery following prolonged deforestation and accompanying forest products scarcity (Angelsen and Rudel, 2013, Angelsen, 2007, Meyfroidt et al., 2010). The effects of purely restricting forest use are discussed controversially. Restrictions have been found to reduce deforestation in the tropics by limiting unsustainable forest resource extraction (Spracklen et al., 2015, Busch and Ferretti-Gallon, 2017). On the other hand, it has been argued that restrictions alone are hard to enforce (Porter-Bolland et al., 2012, Bae et al., 2012). Whatever the effects might be, they obviously have a specific relevance in the later FT phases and need to be considered within forest recovery in the tropics.

When forest recovery (post-transition) is excluded from the analysis the marginal effect of the socioeconomic factor on forest income becomes significant, increasing probability of landscapes with higher forest income to be in the pre-transition phase and decreasing the probability of being in either the early or late transition phase. The result shows that forest income is more connected to deforestation than to forest recovery. This means that forest income contributes to deforestation or deforestation contributes to forest income, but forest recovery does not or not yet contribute to forest income or forest income is not yet sufficient to promote forest recovery. Forest income reveals the degree to which households extract timber and non-timber forest products for subsistence and commercial purposes (Heubach et al., 2011, Vedeld et al., 2007, Kamanga et al., 2009). Forest resource extraction is dependent on the resource availability (Pandey et al., 2014). Therefore, it is most likely to be associated with the pre-transition landscapes, with a considerable forest cover. The post-transition phase, with a comparatively low forest cover and forest resource scarcity resulting from continuous deforestation, is likely to register a low rate of forest resource extraction (Angelsen, 2007) and thus, a negligible forest income. The result indicates that there is potential to reduce the pressure on natural forests if forest income could be generated from planted or naturally regenerated forests because in the moment the income from plantations/succession is not significantly related to the FT phases. Moreover, if wood resources are needed e.g. for construction or energy purposes but cannot be imported, then higher income without accompanying reforestation would bear the risk of deforestation and leakage elsewhere.

The marginal effect of the biophysical factor for elevation becomes significant when the phase of forest recovery (post-transition) is excluded from the analysis. This indicates that elevation is a more important predictor of deforestation than forest recovery. Because elevation is negatively associated with the factor, our results show that higher elevations are associated with pre-transition landscapes while lower elevations are linked to either early or late or post-transition landscapes. This is probably because most of the pre-transition landscapes are located in Zambia (above 2000masl) in contrast to the landscapes from Ecuador and Philippines (under 1000masl), which predominate the later FT stages. However, because we control for country effects in our models, the results might reflect the fact that forest landscapes at higher elevations are less accessible and therefore, with higher costs of forest resource extraction and land clearing (Southworth and Tucker, 2001). For that reason, they retain a considerable forest cover and rather remain in the pre-transition phase. At lower elevations, improved accessibility lessens the cost of transporting forest products and clearing for agriculture (Gaveau et al., 2009). This facilitates the shift towards the early or late FT phases. Although mostly associated with a low deforestation rate, higher elevations have also been linked to forest recovery in the tropics given the milder temperatures at higher altitudes that favour tree growth (Lippok et al., 2013, Beck et al., 2008). Forest recovery might be specifically challenging at lower elevations with their higher temperatures.

6 Conclusion

There is a widespread agreement that understanding the factors that explain the FT dynamics at the local scale provides a good basis for fitting policy measures to specific forest cover contexts thereby increasing their success. Accordingly, we examine the linkages of governance and socioeconomic factors to the FT phases, accounting for the biophysical factors that are hypothesised to play a role. Different from previous studies, we conduct our analysis at the local scale, where policy implementation and the socioeconomic processes of household decision-making occur in practice. We generate empirical evidence from 34 landscapes spanning three tropical countries Ecuador, Philippines and Zambia, accounting for different tropical contexts. With this novel methodological approach, we address the local level effects considering the variability within and between countries.

The results show that both governance factors (i.e. institutional capacities and effectiveness and access to forest resources) and socioeconomic factors (i.e. human pressure and non-forest income) explain the FT dynamics. Although previous studies have shown similar findings at the national level, we now can confirm that this also holds true at the local scale considering completely different tropical contexts. However, all factors distinguish the pre-transition phase from the rest of the phases more clearly than that they differentiate between the post-transition phase and the early and late transition phases. This implies that the development pathway changes at the transition between the pre- and early phases and not as expected between late and post transition. The result suggests that initiatives for reducing deforestation and forest degradation e.g. REDD+ and other conservation programs ought to establish alternatives to the usual agriculture-based development pathway already in the pre-transition phase. Opportunity costs, market forces and population trends are likely to develop strong dynamics in the early and late transition and in doing so make policy interventions expensive and less effective. Our results further show that an increase in non-forest income, which combines agricultural and non-farm income, is surprisingly associated with the pre-transition phase whereas a decrease is associated with the early and late transition phases. Together with increasing population this indicates a marginalization of the population during the deforestation process. This also indicates a dampening in local wages perhaps due to a steady supply of labor resulting from in-migration and or population growth. The challenge is to avoid the agriculture-dependent deforestation trap. Alternative off-farm livelihood opportunities and sustainable forest-based value chains but with strict controls should be promoted as a substitute for agriculture already in the pre-transition phase. Our results suggest that forest income is linked to deforestation, but forest recovery does not yet link to forest income. This implies that there is potential to reduce the pressure on natural forests if forest income could be generated from planted or naturally regenerated forests because currently income from plantations/succession is not significant. Additionally, if wood resources are needed e.g. for construction or energy purposes but cannot be imported, then higher income without accompanying reforestation would bear the risk of deforestation and leakage elsewhere since consumption and thus ecological footprint usually increases with income.

Our findings neither clearly confirm nor clearly falsify the hypothesis that forest recovery and deforestation are distinct processes. There are statistical arguments pro and contra.

Appendix A: Description of the governance indicators and the elements of quality by thematic areas of the GFI framework

Thematic area	Indicator	Philippines	Ecuador	Zambia	Elements of quality
Forest tenure	1.Tenure recognition	✓	✓	✓	Recognition. Most individual and communal rights-holders have their rights recognized and recorded
					Demarcation. Most individual and communal forestlands have boundaries demarcated
					Enforcement. Infringements (violation) of rights are quickly and fairly addressed
					Gender equity. Rights registered to individuals or households are often registered in the names of women, jointly or individually
					Customary tenure. Minimal conflict exists between customary forest tenure systems and statutory systems on the ground
Land use	2. Land use planning	✓	✓	✓	Procedure. Land use decisions are taken in a formally established process
					Transparency. Planning process is transparent, and procedures are clearly defined
					Opportunities for participation. Communities or entitled individuals have the possibility for participation in land use planning processes
					Representation. Representatives to land use-planning processes reflect a range of community perspectives, including women and different socioeconomic classes
					Capacity to engage. Representatives in land-use planning have information and skills to effectively engage and participate in land use planning processes
Forest management	3.Strategies and plans	✓	✓	✓	Coordination. Implementing agencies/persons/enterprise effectively coordinate in carrying out their roles and responsibilities
					Timeliness. Implementation happens according to the timeline specified by the plan/strategy
					Monitoring. Implementation is subject to regular monitoring of impacts and effectiveness
					Transparency. Land use plans and monitoring reports are publicly disclosed on a regular basis
					Review. Plans and strategies are reviewed and updated regularly
	Licences:				Procedural clarity. Clear administrative procedures regulate the obtaining of licenses and permits
					Transparency. Application status can be tracked
	4. Timber	✓	✓	✓	Accessibility. The process for acquiring a license or permit is not prohibitively complicated and expensive

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	5. Charcoal			✓	Timeliness. Licenses and permits can be obtained in a reasonable time and within the time prescribed
	6. Non-timber forest products	✓	✓	✓	Implementation. Licenses and permits are honoured during harvesting and transport of forest products
	7. Reforestation programs	✓	✓	✓	Procedures. Stakeholders understand the procedures and terms of the program, including planting sites and species, duration, and associated benefits and responsibilities
	8. National Greening program (NGP)	✓	X	X	Coordination. The implementing agency coordinates implementation by establishing clear agreements with people and organizations
					Monitoring. Implementation is subject to regular monitoring to ensure compliance and effectivity
	9. Protection and conservation	✓	✓	✓	Demarcation. Boundaries of protected or conservation forests areas are clearly demarcated. Use restrictions. Stakeholders clearly understand the timeframe and what activities are allowed and not allowed within the protection or conservation area Enforcement. Implementing agencies are aware and effectively coordinate to carry out their roles and responsibilities Penalties. Stakeholders understand penalties for failing to comply with the rules of the arrangement Monitoring. Implementation is subject to regular monitoring of impacts and effectiveness
	10. Protection and logging moratorium	✓	X	X	Demarcation. There is no demarcation and people are unaware on the location of their natural forest
					Use restrictions. Participants know that it is not allowed to cut trees as informed by the DENR
					Respect of rights. They think that the law has an advantage since it restrict commercial logging. However, they also think that the law did not respect their rights since they need timber for personal use
					Transparency. The DENR coordinates with them if there are reported logging in the area
					Accountability. The participants said that those caught were penalized
	11. Payment for Ecosystem Services programs	✓	✓	✓	Procedures. The procedures for establishing PES have been made clear to the stakeholders Coverage. PES schemes have been established on the ground. Benefit-sharing. The schemes for benefit sharing have been jointly decided, understood and acceptable to the stakeholders
					Protection. The protection of the forests providing these ecosystem services has been put in place

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					Monitoring. Implementation is subject to regular monitoring
	12. Forest-base livelihood programs				Procedures. Stakeholders clearly understand the procedures for setting up sustainable livelihood projects.
					Coordination. Government agencies coordinate and provide support in implementing and sustaining projects
		✓	✓	✓	Resources. Forest resources are adequate to sustain livelihoods
					Facilities. Credit facilities and capacity building were made available to local communities
					Benefits. Community members receive shares and benefits equitably
	Law enforcement:				Apprehension. Violators are apprehended and brought to trial by concerned authorities
	13. Formal law	✓	✓	✓	Consistency. Assigned penalties are generally consistent with the law and appropriate given the nature of the offence
	14. Customary law	✓	✓	✓	Compliance. Penalties are served or are paid in full in a timely manner
	15. Revenues				Fairness. Fees collected are reasonable and basis of computation are understood.
					Transparency. Field staff generate comprehensive and accurate records of all fees collected and are made available to the public.
		✓	✓	✓	Awareness. The government takes action to ensure that non-governmental "payers" are aware of their obligations.
					Timeliness. Fees are collected in a timely manner.
					Monitoring. Regular monitoring evaluates whether appropriate fees are collected as agreed
Revenues	16 Benefit-sharing mechanisms				Participation. The community has participated in the design of local benefit-sharing arrangements.
					Compliance. Benefits are delivered in accordance with the agreed terms set out in relevant legal or project documents
		✓	✓	✓	Awareness. Community members are aware of the benefits received and obligations associated with those benefits
					Fairness. The type and magnitude of benefits are fair and appropriate
					Monitoring. Regular monitoring evaluates whether benefits, as agreed, have reached intended recipients
Crosscutting Institutions	Capacities and effectiveness				Knowledge and skills. Institutions capacitated with up-to-date knowledge and skills to take an active role in forest management
	17. Central government	✓	✓	✓	Human resources. Institutions capacitated with an adequate number of staff personnel to take an active role in forest management

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	18. Local government	✓	✓	✓	Financial resources. Institutions capacitated with sufficient financial resources to take an active role in forest management
	19. Non-government organizations	✓	✓	✓	Scientific and technical information. Institutions capacitated with relevant scientific and technical information to take an active role in forest management
	20. Customary institutions	X	X	✓	Effective. Institutions are effective in implementing forest management objectives
Crosscutting issues	21. Participatory policymaking	✓	✓	✓	Awareness. Community members are aware in a timely manner of policies to be developed, reviewed and revised that are relevant for land use in their community
					Platforms. Platforms are provided for multi-stakeholder participation in policymaking
					Representation. Policymaking platforms allowed participation of key representatives from the different forestry sector
					Effectivity. Facilitation methods allowed key stakeholders to participate actively in the process
					Transparency. The stakeholders are informed of the results of policy engagements

Appendix B: Principal factors of governance variables

Governance variable	**Assigned meaning of principal factors**			
	Three FT phases (deforestation) N= 29		**Four FT phases (deforestation and recovery) N= 36**	
	Factor 1	**Factor 2**	**Factor 1**	**Factor 2**
	Institutional capacity and effectiveness	**Access to forest resources**	**Institutional capacity and effectiveness**	**Access to forest resources**
Tenure rights recognition and protection	0.41	**0.64**	0.09	**0.77**
Forest management	-0.47	**0.63**	**-0.59**	**0.57**
Forest law enforcement	**0.67**	**0.58**	**0.52**	**0.68**
Government institutions capacities and effectiveness	**0.85**	0.09	**0.85**	0.17
Non-Government Organizations capacities and effectiveness	**0.84**	-0.35	**0.86**	-0.12
Local institutions capacities and effectiveness	**0.81**	-0.19	**0.85**	-0.05
Public policy participation	**0.70**	0.38	**0.61**	0.42
Percentage of restricted area	0.33	**-0.73**	**0.51**	**-0.66**
Eigen value	3.52	1.98	3.46	2.02
Variance explained (%)	43.99	24.79	43.19	25.28
Cumulative variance (%)	43.99	68.78	43.19	68.47

In both scenarios, two principal component factors resulted that together explained 70.16% of the variations. The first component, accounting for 46.78% of the variance was significantly positively correlated with the non-government organizations (NGOs), local institutions and government institutions capacities and effectiveness, respectively (Annex 1). The component was as well considerably negatively correlated with forest management (Annex 1). The first component was interpreted as representing institutional capacities and effectiveness. The second component, accounting for 23.38% of the variance was most strongly correlated with tenure rights recognition and protection.

Appendix C: Principal factors of socioeconomic variables

Socioeconomic variable	**Assigned meaning of principal factor**					
	Three FT phases (deforestation) N= 28			**Four FT phases (deforestation and recovery) N= 34**		
	Factor 1	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**
	Non-forest income	**Human pressure**	**Forest income**	**Non-forest income**	**Human pressure**	**Forest income**
Crop income	**0.97**	0.02	0.00	**0.94**	0.10	0.07
Livestock income	**0.90**	0.06	-0.17	**0.90**	0.15	-0.16

Forest income	0.38	0.10	**0.86**	0.34	-0.13	**0.89**
Non-farm income	**0.82**	0.34	-0.17	**0.80**	0.45	-0.09
Population density	-0.21	**0.83**	-0.38	-0.33	**0.86**	-0.17
Road density	-0.30	**0.75**	0.40	-0.41	**0.64**	**0.50**
Eigen value	2.69	1.39	1.10	2.74	1.39	1.10
Variance explained (%)	44.81	23.08	18.34	45.64	23.24	18.35
Cumulative variance (%)	44.81	67.89	86.23	45.64	68.88	87.23

Appendix D: Principal factors of biophysical variables

Biophysical variables	**Assigned meaning of principal component factor**			
	Three FT phases (deforestation) N= 29		**Four FT phases (deforestation and recovery) N= 36**	
	Factor 1	**Factor 2**	**Factor 1**	**Factor 2**
	Elevation	**Soil fertility**	**Elevation**	**Soil fertility**
Precipitation (1979-2013)	**0.67**	**0.61**	**0.59**	**0.69**
Temperature (1979-2013)	**0.95**	-0.09	**0.96**	-0.04
Slope	**0.79**	-0.31	**0.81**	-0.28
Elevation	**-0.94**	0.16	**-0.94**	0.15
Soil nutrients	0.09	**0.93**	0.01	**0.93**
Eigen value	2.87	1.37	2.80	1.46
Variance explained (%)	57.32	27.43	56.00	29.00
Cumulative variance (%)	57.32	84.75	56.00	85.00

Appendix E: Correlation analysis of between factors that were included in the regression model with three FT phases in the outcome variable

Principal component factors	Institutional capacity and effectiveness	Access to forest resources	Non-forest income	Human pressure	Forest income	Elevation	Soil fertility
Institutional capacity and effectiveness	1.000						
Access to forest resources	0.000	1.000					
Non-forest income	0.280	0.431	1.000				
Human pressure	0.469	-0.176	0.000	1.000			
Forest income	-0.415	0.119	0.000	0.000	1.000		
Elevation	0.779	0.073	0.644	0.214	-0.381	1.000	
Soil fertility	0.218	0.683	0.177	-0.184	0.011	0.026	1.000

Appendix F: Correlation analysis of between factors that were included in the regression model with four FT phases in the outcome variable

Principal component factors	Institutional capacity and effectiveness	Access to forest resources	Non-forest income		Forest income	Elevation	Soil fertility
Institutional capacity and effectiveness	1.000						
Access to forest resources	0.041	1.000					
Non-forest income	0.005	0.508	1.000				
Human pressure	0.611	-0.052	0.000	1.000			

Forest income	-0.252	0.076	0.000	0.000	1.000		
Elevation	0.751	0.064	0.440	0.447	-0.299	1.000	
Soil fertility	0.171	0.667	0.114	-0.180	0.039	-0.006	1.000

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