Elites, Chiefs and Diversity:
The Political Economy of Deforestation in Africa

DISSERTATION
of the University of St. Gallen,
School of Management,
Economics, Law, Social Sciences,
International Affairs and Computer Science
to obtain the title of
Doctor of Philosophy in International
Affairs and Political Economy

submitted by

Iva Mihaylova

from

Bulgaria

Approved on the application of

Prof. Guido Cozzi, PhD

and

Prof. Dr. Judith Louise Walls

Dissertation No. 5235

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The University of St.Gallen, School of Management, Economics, Law, Social Sciences, International Affairs and Computer Science, hereby consents to the printing of the present dissertation, without hereby expressing any opinion on the views herein expressed.

St. Gallen, May 16, 2022

The President:

Prof. Dr. Bernhard Ehrenzeller

Summary

Deforestation is one of the biggest challenges for humanity in the twenty-first century, and in Africa, its dynamics have become particularly alarming. This dissertation consists of three essays on the political economy of deforestation in Africa. The main connection among them is their contribution to the body of literature that has grown exponentially over the last two decades, highlighting that contemporary life cannot be well-understood without a consideration of its roots in the (distant) past that continue to shape our present day through a process of path dependence. While the enduring importance of the past for current political, economic, and social outcomes has already received considerable academic attention, the ecological legacies of the past, and especially those concerning deforestation, have remained understudied so far. I address this research gap.

Essay 1 shows that the contemporary deforestation in Africa is associated with the evolution of ethno-linguistic cleavages over long periods of time. By using fractionalisation and polarisation indices that have dominated the empirical literature on ethno-linguistic diversity, I find that administrative units with higher ethno-linguistic diversity tend to have more intensive deforestation. Furthermore, I provide evidence that religious diversity partially mediates the association between ethno-linguistic diversity and deforestation. Taken together, these results provide insight into the fact that history can inform policy. Diversity and its historical evolution are factors to consider when the goal is to improve societies' climate mitigation efforts.

Essay 2 focuses on two factors—colonial education and political elites as its frequent consumers—and studies their association with contemporary deforestation. The proxy of political elites are cabinet ministers because they fundamentally influence the distribution of resources in settings where the official institutions are weak. I find that districts in the former British colonies with higher investments in colonial education are less deforested today. Colonial education is detrimental to contemporary forests in the former French colonies. I also show that post-colonial military political elites have consistently accelerated deforestation for lower, intermediate, and higher thresholds of deforestation, and that favouritism is a key mechanism to understand this result. In contrast, post-colonial civilian cabinet ministers, although to a rather limited extent, seem to be beneficial to forests. In this case, favouritism has no significant role in deforestation. I explain the different forest "footprints" of post-colonial civilian versus military elites as a persistent legacy of their unequal colonial-era education. Overall, the results suggest that a better understanding of human capital and of African political elites at the subnational level could be key for the future of African sustainable development.

Essay 3 zooms in on the deforestation challenges of Sierra Leone by highlighting the role of traditional chiefs. While their central influence on contemporary socioeconomic development has become increasingly recognised in the academic literature, little is known about their impact on the natural environment. I study for the first time the role of chiefs' power and trust on these chiefs regarding deforestation. Locations with weaker chiefs experience higher deforestation. In contrast, local communities' trust in chiefs works against deforestation. The study concludes with a discussion on the implications of these results for the democratic decentralisation of forest management in Africa.

Zusammenfassung

Entwaldung ist eine der größten Herausforderungen für die Menschheit. In Afrika ist ihre Dynamik besonders alarmierend geworden. Die vorliegende Dissertation besteht aus drei Aufsätzen zur politischen Ökonomie der Entwaldung in Afrika. Die Hauptverbindung zwischen ihnen besteht in deren Beitrag zur in den letzten zwei Jahrzehnten entstandenen und wachsenden Literatur, die hervorhebt, dass das Verständnis zeitgenössisches Lebens nur beschränkt ist, wenn seine Wurzeln in der (fernen) Vergangenheit, die es bis heute durch einen Prozess der Pfadabhängigkeit prägen, nicht berücksichtigt werden. Während die anhaltende Bedeutung der Vergangenheit für aktuelle politische, wirtschaftliche und soziale Ergebnisse bereits erhebliche wissenschaftliche Aufmerksamkeit erhalten hat, sind die ökologischen Hinterlassenschaften der Vergangenheit, insbesondere in Bezug auf Entwaldung, bisher wenig untersucht worden. Ich spreche diese Forschungslücke an.

Aufsatz 1 zeigt, dass die zeitgenössische Entwaldung in Afrika mit der Entwicklung der ethnolinguistischen Vielfalt über lange Zeiträume verbunden ist. Durch die Verwendung von Fraktionalisierungs -und Polarisierungsindexe finde ich, dass Verwaltungseinheiten mit höherer ethnisch-linguistischer Vielfalt tendenziell intensiver abholzen. Darüber hinaus liefere ich Beweise dafür, dass religiöse Vielfalt teilweise den Zusammenhang zwischen ethnisch-linguistischer Vielfalt und Entwaldung vermittelt. Zusammen betrachtet bieten diese Ergebnisse einen Einblick in die Tatsache, dass Geschichte Politik informieren kann. Vielfalt und ihre historische Entwicklung sind Faktoren, die zu berücksichtigen sind, wenn es darum geht, die Bemühungen der Gesellschaften um den Klimaschutz durch Zusammenarbeit zu verbessern.

Aufsatz 2 konzentriert sich auf zwei Faktoren – koloniale Bildung und politische Eliten als deren häufige Konsumenten – und untersucht deren Zusammenhang mit der zeitgenössischen Entwaldung in sechzehn ehemaligen britischen und französischen Kolonien in Afrika. Die Proxy-Variable für die politischen Eliten sind Kabinettsminister, weil sie die Verteilung der Ressourcen in Gegenden, in denen die offiziellen Institutionen schwach sind, grundlegend beeinflussen. Ich beweise, dass Bezirke in den ehemaligen britischen Kolonien mit höheren Investitionen in koloniale Bildung heute weniger abgeholzt werden. Koloniale Bildung ist schädlich für die zeitgenössischen Wälder in der französischen Stichprobe. Ich zeige auch, dass postkoloniale militärpolitische Eliten die Entwaldung für niedrigere, mittlere und höhere Entwaldungsschwellen konsequent beschleunigt haben und dass Vetternwirtschaft ein Schlüsselmechanismus ist, um dieses Ergebnis zu verstehen. Im Gegensatz dazu scheinen postkoloniale zivile Kabinettsminister, wenn auch in begrenztem Maße, für Wälder von Vorteil zu sein. In diesem Fall hat die Vetternwirtschaft keinen signifikanten Zusammenhang mit der Entwaldung. Ich erkläre die verschiedenen Wald "Fußabdrücke" der postkolonialen zivilen versus militärischen Eliten mit den zurückdatierenden und bis heute anhaltenden Folgen ungleicher Bildung aus der Kolonialzeit. Insgesamt legen die Ergebnisse nahe, dass ein besseres Verständnis des Humankapitals und der afrikanischen politischen Eliten auf subnationaler Ebene der Schlüssel für die Zukunft der nachhaltigen Entwicklung Afrikas sein könnte.

Aufsatz 3 widmet sich der Entwaldung in Sierra Leone, indem die Rolle traditioneller Führer oder Häuptlinge hervorgehoben wird. Während ihr zentraler Einfluss auf die zeitgenössische sozial-ökonomische Entwicklung zunehmend in der wissenschaftlichen Literatur erkannt wird, sind ihre Auswirkungen auf die natürliche Umwelt bis jetzt wenig erforscht. Ich beschäftige mich zum ersten Mal mit der Rolle der Macht und Vertrauenswürdigkeit der Häuptlinge für die Entwaldung. Es stellt sich heraus, dass eine höhere Anzahl von herrschenden Familien als eine Proxy-Variable für die Macht des Chefs die Entwaldung beschleunigt. Im Gegensatz dazu wirkt sich das Vertrauen der lokalen Bevölkerung in Häuptlinge gegen die Abholzung aus. Das Kapitel schließt mit einer Diskussion über die Implikationen dieser Ergebnisse für die demokratische Dezentralisierung der Waldbewirtschaftung Afrikas ab.

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1. Introduction and Motivation

Africa's environmental issues are not a recent phenomenon but they exacerbate at unprecedented rate and take new forms. One of Africa's salient environmental problems is its intensive man-made deforestation (Konteh, 1997; Bare et al., 2015; Ayana et al., 2013; Ongolo et al., 2018; Abman and Lundberg, 2020; Abman and Carney, 2020). According to FAO & UNEP (2020), *"Africa had the highest net loss of forest area in 2010–2020 [...] Since 1990, Africa has reported an increase in the rate of net loss"* (11). Deforestation is a complex issue because it triggers through a domino effect a variety of other environmental problems including but not limited to biodiversity loss, acceleration of climate change, heat-related health threat, disease outbreak, soil erosion and diminished access to clean drinking water (Van der Werf et al., 2009; Hansen et al., 2013; Mapulanga and Naito, 2019; Masuda et al., 2019; Pennisi, 2020; Abman and Lundberg, 2020; Morand and Lajaunie, 2021).

1.1. The argument

This dissertation consists of three essays on the political economy of deforestation in Africa. The main connection among them is their contribution to the body of literature that has grown exponentially over the last two decades, highlighting that contemporary life cannot be well-understood without a consideration of its roots in the (distant) past that continue to shape our present day through a process of path dependence (Açemoğlu et al., 2001; Nunn, 2008; Dell, 2010; Nunn and Wantchekon, 2011; Hariri, 2012; Giuliano and Nunn, 2013; Michalopoulos and Papaioannou, 2013; Gaikwad, 2014; Galor and Özak, 2016; Galor et al., 2016; Cagé and Rueda, 2016; Fenske and Kala, 2017; Bentzen et al., 2017; Beramendi et al., 2019; Paine, 2019; Arbatlı et al., 2020; Dell and Olken, 2020; Lowes and Montero, 2021). However, with the notable exception of Larcom et al. (2016), who focus on pre-colonial institutions in Africa as a key explanatory variable, the influence of the legacies of the past on contemporary deforestation remain out of the scope of this literature. Furthermore, while the literature on the legacies of the past frequently focuses on economic development, institutions, political regimes and conflict, it rarely considers the historical aspects of cultural heterogeneity (Desmet et al., 2012; Gershman and Rivera, 2018), traditional

authorities (Neupert-Wentz and Müller-Crepon, 2021) as well as political elites and investments (Ricart-Huguet, 2021) including in education that is shown to affect contemporary development in Africa (Woodberry, 2012; Cagé and Rueda, 2016). I address these research gaps.

Why is it important to study contemporary deforestation from the perspective of the literature on the legacies of the past? Moore et al. (2019) demonstrates that human assessment whether the climate is (ab)normal depends on biases and memory limitations. As a consequence, the baseline against which the public opinion about climate change is shaped is not experience over a long time frame but rather in recent years. This may be a reason for blurring the recognition of man-made climate change and may be evidence for the so-called *"boiling frog in a pot"* effect (Moore et al., 2019). According to this well-known experiment in business research, if a frog is put in a pot of boiling water, its reaction is to quickly jump out. However, if the frog is put in a pot of water that is gradually heated on a stove, it stays in it until it literally dies because it does not feel the difference until it is too late. An analogy can be drawn between the human assessment for climate change and deforestation. The perspective that I offer in this book demonstrates that emerged in the past institutions and cultural cleavages should be considered as a factor that like in the experiment with the frog contribute to the heating or the cooling of the pot, in the concrete context by affecting deforestation.

The dissertation aims at analysing the relationship between ethno-linguistic diversity, colonial education, political elites and traditional leaders[1] on the one hand and contemporary deforestation in Africa on the other hand by using formal models and evidence taken from archives, oral history, modern surveys and Geographic Information Systems (GIS).[2] The deforestation data are compiled on the basis of the high-resolution data of Hansen et al. (2013) because their *"coverage is global, the method is accurate, and the data are not susceptible to interference from parties that seek to conceal or misrepresent information"* (Sanford (2020), 14). In what follows, I summarise the research questions, results and contributions of each article.

1.2. Plan of the book

The first article is entitled "Ethno-linguistic diversity: Understanding its significance to contemporary deforestation in Africa". I use for the first time linguistic trees capturing the *non-monotonic historical evolution* of the fractionalisation and polarisation indices that have dominated the em-

[1] Throughout the text, I use "traditional authorities", "traditional leaders" and "traditional chiefs" synonymously for my own statements.

[2] Muhammad Badar Munir and Shaun Astbury have automated part of the GIS calculations in R. Denis Mashin has consulted me on two questions with regard to GIS mapping. Bjarte Aagnes has answered my question in the Statalist forum on how to automate the calculation of Oster's coefficient stability test.

pirical literature on ethno-linguistic diversity in order to analyse its link to contemporary deforestation within the first level sub-national administrative units in 35 African countries. The sub-national geographical focus is relevant because a significant aspect of the literature on the effects of diversity on political economy outcomes is its almost exclusive focus on the country level. However, sub-national administrative units can hold authority to make important forest management decisions (Busch and Amarjargal, 2020), can influence decision-making at the national level (Bechtel, 2012), and can reveal policy relevant information that may remain hidden if countries are considered (Zabala, 2018).

Diversity can influence forest management through various mechanisms. Habyarimana et al. (2007) suggests three channels on how diversity can affect public goods provision as a useful starting point for deriving the most common answers to the question of why ethno-linguistic diversity might also matter for deforestation. The three mechanisms that the authors explain are as follows. First, ethno-linguistic differences can translate into divergent preferences and, as a result, into a failure to provide public goods. Such a divergence of interests could also be salient in other contexts, including forest management, land use, and decisions to clear forest for infrastructural projects. Second, another preferences-based explanation is that people are willing to cooperate when they believe that fellow group members benefit but remain indifferent if out-group members are better off. Third, the social sanctioning mechanism is also a prominent explanation of the failure of collective actions in heterogeneous societies. Concretely, co-ethnics in closely-knit groups can rely on the reciprocity of one another because they have the capacity to detect and punish each other for non-cooperation.

Alesina et al. (2019) is the only existing publication on the link between diversity and deforestation and is closest to my first article. In contrast to it, it does not undertake a historical approach. The authors report evidence that *contemporary* ethno-linguistic cleavages accelerate *contemporary* deforestation in Indonesia through the social sanctioning mechanism: citizens in more ethnically diverse administrative units have a lower capacity to control politicians for their misconduct. Taken together, the several families of mechanisms confirm that ethno-linguistic diversity could have an impact on deforestation. However, whether the total effect of operating through different mechanisms *historically evolving* ethno-linguistic diversity is beneficial or detrimental to contemporary forests in Africa is an empirical puzzle that I address in a novel way by focusing for the first time on the historical evolution of ethno-linguistic diversity via linguistic trees.

I find that administrative units with higher ethno-linguistic diversity tend to have more intensive deforestation for both coarser and finer tiers of the linguistic tree. Since the former tears

signal for a cooperation problem in the related literature and the latter – for a distributive one, a conclusion can be draw that the deforestation in Africa is accelerated by these both sources of conflict. Furthermore, I provide evidence that religious diversity partially mediates the association between ethno-linguistic diversity and deforestation. Taken together, these results provide insight into the fact that history can inform policy. Diversity and its historical evolution are factors to consider when the goal is to improve societies' climate mitigation efforts through cooperation. In addition to contributing to the literature on the legacies of the past, the article adds to the body of work on subnational development, human heterogeneity, public goods provision, natural resource management in low-income and developing countries and on depletion of common resources (Ostrom, 1990; Hardin, 2009; Bernauer and Koubi, 2009; de la Cuesta and Wantchékon, 2016; Gershman and Rivera, 2018; Alesina et al., 2019).

The second article is entitled "Deforestation, political elites and colonial educational investments: Evidence from East and West Africa". This article breaks new ground by undertaking a historical approach and by showing in a comprehensive quantitative manner that colonial-era educational investments in sixteen former British and French colonies in East and West Africa play a durable role for their contemporary deforestation. In the second part of the analysis, I shows that military versus civilian political elites, proxied by cabinet ministers, differ in their forest management performance. Higher district shares of cabinet ministers in post-colonial military cabinets are consistently associated with higher contemporary deforestation. In contrast, higher district shares of cabinet ministers in post-colonial civilian cabinets are moderately associated with less deforestation today.

I argue that a key mechanism for understanding this result is their unequal colonial-era education, which is shown to have long-term persistent effects into the current day and the fact that decision makers' educational background influences their (pro-environmental) policy decisions (Dreher et al., 2009; Lewis et al., 2014). The results of this article can thus inform policy decisions. The study suggests that a natural starting point for addressing Africa's deforestation problem at its roots is to provide more equal access to education, which could reduce the pressure of agriculture on forests as a traditional manner of subsistence in many low-income and developing countries (Dewees, 1995). In the third part of the analysis, I find that although scientific evidence suggests that regional favouritism may have a positive effects on local development (Hodler and Raschky, 2014; De Luca et al., 2018), it is detrimental to forests in the sample of East and West African countries but only if one or more military heads of government are born in the respective region. As the literature with focus on forest management suggests, civilian heads of government are not immune to favouritism but it does not seem to contribute in a meaningful way to unsustainable forest use in the sampled African countries.

The third article is entitled "Deforestation in Sierra Leone: Unpacking the role of traditional chiefs' power and social values". Deforestation is a pressing and multi-faceted environmental challenge in this country and motivates the geographic focus of the study. Given the well-known and enduring weakness of the state's bureaucratic apparatus to implement policies including concerning environmentally sustainable development as well as to deliver public goods and services to rural constituencies, African politicians rely on the cooperation of the local traditional leaders, or chiefs (Baldwin, 2016). Typically hereditary, the status of traditional chiefs originates from their connection to the customs of their local community (Baldwin, 2014). Chiefs have the power to shape multiple facets of socioeconomic development in their communities including the highly relevant in the context of forest management land allocation (Kirst, 2020) because, as noted by Gibbs et al. (2010), transforming forests into agricultural land is a common practice in Africa. Although the central role of traditional leaders for contemporary socioeconomic development becomes increasing recognised, little is know about their impact on the natural environment.

How does chiefs' power relate to deforestation in Sierra Leone? I rely on Açemoğlu et al. (2014) and Van der Windt and Voors (2020) who proxy chiefs' power with the log-transformed number of ruling families per chiefdom. A higher number of ruling families per chiefdom in Sierra Leone weakens chiefs' power because it intensifies their conflict and political competition, including during election periods (Burrows, 1976; Açemoğlu et al., 2014). Conflict can accelerate deforestation (Gonzalez and Miguel, 2015; Kikuta, 2020). In the same direction points the evidence by Klopp (2012) and Sanford (2020) that more contested competitive elections in weakly institutionalised democracies exacerbate deforestation because timber can be used to finance electoral campaigns and forest resources—to win electoral support. Therefore, I hypothesise that weaker traditional chiefs, due to the intensification of political competition among them, could be motivated to use forests for political purposes that accelerate deforestation. The evidence that I find in a regression setting is in line with this expectation for low to intermediate and high deforestation thresholds and remains robust to the inclusion of district fixed effects, controls that influence development and also potentially the natural environment through the well-known Kuznets curve and Oster's coefficient stability test.

Trust is a multi-faceted concept that plays a crucial role in social exchange (Schilke et al., 2015) and is an unconventional determinant of the quality of the natural environment (Carattini et al., 2015) and of deforestation (Murtazashvili et al., 2019). Is higher trust in chiefs associated with lower deforestation? While generalised (Sønderskov, 2008; Carattini et al., 2015; Murtazashvili et al., 2019; Jo, 2021) and political trust (Fairbrother, 2017) as some of the possible dimensions of trust have attracted increasing academic attention, the relevant to be considered trust in chiefs in low-income and developing countries that frequently face environmental challenges has never

been studied. I address this research gap in a contribution to the body of work on the relationship between social values and the quality of the natural environment and report consistent evidence that higher trust leads to less deforestation for low, intermediate and higher deforestation thresholds.

Rather than based on democratic principles, the relationship between communities in Sierra Leone and their chiefs is based on asymmetric power dependence (Açemoğlu et al., 2014). The more powerful the chiefs are, the less powerful is the population in their chiefdom. Variation in power is shown to influence variation in trust (Schilke et al., 2015). Does chiefs' power partially mediate the relationship between trust in chiefs and deforestation? I find that chiefs' power only weakly mediates this relationship. I interpret this result as beneficial to forests because this finding implies that chiefs, due to the consistent trust that they enjoy in their communities, are important partners to win for the introduction of policies that aim at improving local forest management including through the becoming increasingly popular decentralisation strategies. The results of the analysis with focus on trust remain robust to the inclusion of district fixed effects with and without controls and Oster's coefficient stability test. Similarly to article one, article two and three contribute to the body of work on the legacies of the past, subnational development, public goods provision, natural resource management in low-income and developing countries and on depletion of common resources.

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Chapter 2

Ethno-linguistic diversity: Understanding its significance to contemporary deforestation in Africa

Iva Mihaylova

Deforestation is one of the biggest challenges for humanity in the 21st century, and in Africa, where the focus of this article lies, its dynamics have become particularly alarming. I show that contemporary deforestation in Africa is positively associated with the evolving over long periods of time ethno-linguistic diversity. The results remains stable to a number of robustness and sensitivity checks. Furthermore, I provide evidence that religious diversity partially mediates the association between ethno-linguistic diversity and deforestation. Taken together, these results provide insight into the fact that history can inform policy. Diversity and its historical evolution are factors to consider when the goal is to improve societies' climate mitigation efforts through cooperation and redistribution.

2.1. Introduction

Deforestation is one of today's toughest environmental problems, has far-reaching consequences (Hansen et al., 2013; Abman and Lundberg, 2020), and has become a significant problem in many developing countries. In Africa, where the focus of this article lies, its dynamics have become particularly alarming. Compared to other continents, Africa's deforestation rates have accelerated since 1990 and have ranked first in the world since 2010 (FAO & UNEP, 2020). While research on human heterogeneity, which is frequently defined in terms of measures with ethnic and linguistic

components as a key explanatory variable for understanding political and economic outcomes, is well accepted and enjoys a long tradition (de la Cuesta and Wantchékon, 2016), its effect on deforestation has remained scarcely explored. A notable and recent exception is the contribution of Alesina et al. (2019) who report evidence that contemporary ethno-linguistic fractionalisation as a proxy of human diversity has accelerated contemporary deforestation in Indonesia. The authors reveal that deforestation has been caused by citizens' lower capacity to control politicians' misconduct through legal or electoral punishment in more ethnically diverse administrative units.

In addition to this mechanism, a vast literature without a focus on deforestation reveals evidence for adverse or beneficial effects of diversity that work through a variety of channels on political economy outcomes (Gerring et al., 2015; de la Cuesta and Wantchékon, 2016). On the one hand, higher diversity can impose social costs by increasing the likelihood of mistrust, by inhibiting cooperation, and by disrupting socio-economic order (Ashraf and Galor, 2013). Consequently, the productivity and the capacity of the economy to operate efficiently decrease (Ashraf and Galor, 2013). On the other hand, higher diversity can bring social benefits, originating from diversity-driven innovations and technological progress (Ashraf and Galor, 2013). However, while the effects of human diversity on political economy outcomes have attracted considerable attention, forest commons have remained an understudied empirical puzzle. Furthermore, ethno-linguistic diversity is a dynamic, evolving through history, phenomenon (Ahlerup and Olsson, 2012), and, consequently, can have a non-uniform impact on deforestation. This question, however, has never been studied.

I address these important omissions in the literature by analysing ethno-linguistic diversity with two measures that have dominated the empirical literature – fractionalisation (ELF) and polarisation (ELP) – and via linguistic trees that capture the chronological historical evolution of languages, consisting of their splitting in the course of human history. This research design allows me to analyse the potentially non-monotonic relationship between the evolution of ethno-linguistic diversity through history and contemporary deforestation for the first time. Another significant aspect of the literature on the effects of diversity on political economy outcomes is its almost exclusive focus on the country level. However, sub-national administrative units can hold authority to make important forest management decisions (Busch and Amarjargal, 2020), can influence decision-making at the national level (Bechtel, 2012), and can reveal policy relevant information that may remain hidden if countries are considered (Zabala, 2018). I also address this research gap by focusing on the first level sub-national administrative units within 35 African countries for which high quality ethno-linguistic diversity data can be derived.

2.2. Linkages between ethnic diversity and forest management

In order to analyse the relationship between historically evolving ethno-linguistic diversity and deforestation, I implement cross-sectional regressions for the first level sub-national administrative units (i) within 35 African countries (c). The testable hypothesis is that ethno-linguistic diversity accelerates deforestation in Africa.

While unpacking the variety of mechanisms at work is beyond the scope of this article, the review of broader literature by Habyarimana et al. (2007) on how ethnic diversity could affect public goods provision is a useful starting point for deriving the most common answers to the question of why ethno-linguistic diversity might also matter for deforestation. Ethno-linguistic differences can translate into divergent preferences and, as a result, into a failure to provide public goods (Habyarimana et al., 2007). Such a divergence of interests could also be salient in other contexts, including forest management, land use, and decisions to clear forest for infrastructural projects.

Another preferences-based explanation is that people are willing to cooperate when they believe that fellow group members benefit but remain indifferent if out-group members are better off (Habyarimana et al., 2007). Such a differentiated in-group versus out-group treatment is the reason for positive discrimination and sympathy in the case of the former and negative discrimination and antipathy in the case of the latter situation. Ethnic favouritism, as a representation of this phenomenon, has received special attention in the literature (De Luca et al., 2018). However, with regard to deforestation, the evidence is mixed. Abman and Carney (2020) find that co-ethnics of the president of Malawi received more fertiliser subsidies, which resulted in higher hybrid maize yields and less deforestation. In contrast, Morjaria (2012) reports evidence that forest land allocation has been used to elicit electoral support along ethnic lines in Kenya and accelerated deforestation.

In addition to ethnic favouritism, a differentiated in-group versus out-group treatment can be motivated by the existence of social kinship as a central element of the evolutionary class of theories with a long tradition in the academic literature (Van den Berghe, 1981, 1995; Ahlerup and Olsson, 2012; Habyarimana et al., 2007). Ahlerup and Olsson (2012) have proposed a theoretical model that is able to explain a facet of the historical development of ethno-linguistic diversity that consists of the splitting and chronological formation of new linguistic cleavages. This process can be realistically modelled with linguistic trees (Desmet et al., 2012). Ahlreup and Olsson argue

that social kinship fosters cooperation among closely-knit geographically and ethno-linguistically similar ethnic groups based on in-group sympathy, but gradually deteriorates the effective supply of collective goods of those more dissimilar people displaced in the periphery of the respective geographic community. According to the authors, these marginalised people lose the important ability to communicate with their chief due to their increasing linguistic dissimilarity.

As a result, the increasingly ethno-linguistically diverse people become more likely to leave their community by either forming a new one at a new place or joining another (Ahlerup and Olsson, 2012), which can be successfully proxied by a new tier (cleavage) in a linguistic tree model. In the present setting, the historically emerged ethnicities are linked to their spoken languages and aggregated to the level of major tiers γ, which are 13 in Africa (Desmet et al., 2012; Gershman and Rivera, 2018). The first tier ($\gamma = 1$) that is closest to the root of the tree contains the coarsest measures of diversity and represents the most ancient and major language families in Africa. The lowest tier ($\gamma = 13$) contains the finest and most recently emerged languages in African history.

The social sanctioning mechanism is also a prominent explanation of the failure of collective actions in heterogeneous societies (Habyarimana et al., 2007). Concretely, co-ethnics in closely-knit groups can rely on the reciprocity of one another because they have the capacity to detect and punish each other for non-cooperation. Alesina et al. (2019) report evidence that contemporary ethno-linguistic diversity accelerates contemporary deforestation in Indonesia through this mechanism: citizens in more ethnically diverse administrative units have a lower capacity to control politicians for their misconduct. Taken together, the several families of mechanisms confirm that ethno-linguistic diversity could have an impact on deforestation. Whether the total effect of operating through different mechanisms historically evolving ethno-linguistic diversity is beneficial or detrimental to the forests in Africa is an empirical puzzle. I address it in a novel way by focusing on the historical evolution of ethno-linguistic diversity via linguistic trees for the first time.

2.3. Data and methods

The whole empirical analysis is based on standard regression techniques. The unit of analysis in all model specifications are the first level sub-national administrative units (i) within 35 African countries (c). The dependent variable in all regressions is deforestation. I calculate deforestation rates as percentages based on annually updated geo-spatial data (Version 1.7, covering the period 2001-2019) by Hansen et al. (2013). This deforestation dataset is chosen due to its quality, global geographic coverage, and popularity in the related literature (Hansen et al., 2010; Burgess et al.,

2012; Bare et al., 2015; Larcom et al., 2016; Leblois et al., 2017; Zabala, 2018; Abman, 2018; Alesina et al., 2019; Abman and Lundberg, 2020). The data of Hansen et al. allow deforestation thresholds to be calculated. The motivation for applying them is that the "[a]nalysis of deforestation at different thresholds is important because it demonstrates land use change dynamics in different types of forest environments" (Bare et al. (2015), Appendix, 1).

Based on the related literature (Bare et al., 2015; Leblois et al., 2017), I define these deforestation thresholds as the aggregate percentage of forest cover loss in the period 2001–2019, measured at the 25% and 50% bound for the first level sub-national administrative units within the 35 countries in the sample. The thresholds are illustrated in Figures B.2.1–B.2.2 and indicate whether each pixel with at least 25% or 50% forest cover in 2000 was reduced to 0 within the period of 2001–2019. I implement these particular levels of the thresholds because they are frequently used in the social sciences academic literature (Bare et al., 2015; Leblois et al., 2017). I have also calculated the 30%, 35%, 40%, and 45% deforestation thresholds. Since the insights from the lower additional deforestation thresholds converge to those of the chosen 25% threshold and the upper – to the chosen 50% threshold, I have not provided these additional results due to space considerations.

The measures for both ethno-linguistic diversity and deforestation are continuous. However, unlike the indexes of ethno-linguistic diversity, the measure of deforestation is highly skewed and must be transformed. Consequently, I work with log-transformed values of deforestation that give more weight to the lower segments of the deforestation data that have a higher frequency (Bruederle and Hodler, 2018). Hence, the baseline regression specification in equations 1–2 is of the log-level type. As part of the robustness checks, I re-estimate the main results using the 25% and 50% thresholds of deforestation without any transformations.

The key independent variables are two popular measures of ethno-linguistic diversity (Alesina et al., 2003): fractionalisation, $ELF_{i,c}$ in equation 1, and polarisation, $ELP_{i,c}$ in equation 2. Ethno-linguistic fractionalisation captures the probability of two randomly selected individuals in a region with share s_i of each ethno-linguistic group to belong to a different group and is defined as $ELF_{i,c} = 1 - \sum_1^N s_i^2$ (Gershman and Rivera, 2018). The second measure is ethno-linguistic polarisation. Originally designed to capture conflict in heterogeneous societies, this measure is based on theoretical models of conflict that predict that if a sizeable ethnic minority co-exists alongside the dominant group, the probability of a conflict increases (Horowitz, 1985; Esteban and Ray, 1994; Gershman and Rivera, 2018). Technically, polarisation is defined as $ELP_{i,c} = 4\sum_1^N s_i^2(1 - s_i^2)$ and captures the distance from a perfectly polarised society in which only two equally sized ethno-linguistic groups, a dominant and a minority, co-exist (Gershman and Rivera, 2018). Religious

fractionalisation and polarisation that complement the main analysis are calculated using the same logic as that of ethno-linguistic diversity but ethno-linguistic groups s_i hosted by a region are substituted with their religious counterparts. Similarly to the case of ethno-linguistic diversity, the data on religious diversity are sourced from Gershman and Rivera (2018). They classify religions in Africa into the following categories: Christianity, Islam, traditional or local religion, and none.

The measures of ethno-linguistic diversity ELF and ELP can be either compiled on the basis of survey/census or geo-spatial data. As part of both approaches, ethnicities are linked to their spoken languages and aggregated to the level of the respective unit of analysis. A comparison of both approaches reveals that the geo-spatial approach underestimates ethno-linguistic diversity in Africa (Gershman and Rivera, 2020). Therefore, I work with survey/census data as sourced from Gershman and Rivera (2018). Literature on the effects of ethno-linguistic diversity usually focuses on its contemporary dynamics and ignores the fact that it is the outcome of historic evolution and may have a non-monotonous association with deforestation. To address this omission, I implement an approach that considers the genealogical relationship of languages via the linguistic trees method proposed by Desmet et al. (2012). This method is able to realistically account for languages' historic evolution in the form of splits. Technically, if the linguistic tree with maximally possible 13 major tiers (cleavages) for Africa is considered, the tier that is first and closest to the root contains the coarsest $ELF_{i,c}(\gamma = 1)$, respectively $ELP_{i,c}(\gamma = 1)$ measures, and represents the most ancient and major language families in Africa. In contrast, the lowest tier of the linguistic tree contains the measures $ELF_{i,c}(\gamma = 13)$, respectively $ELP_{i,c}(\gamma = 13)$, with the finest and most recently emerged in African history languages.

Ethno-linguistic fractionalisation ELF and polarisation ELP are both measured at their maximally 13 tiers in Africa. This results in 26 variants of the key independent variable. Therefore, a natural question that arises is whether to stratify or pool the sample by different levels of γ and the type of ethno-linguistic measure. While a pooling of the tiers γ of ethno-linguistic diversity is technically feasible and could be done, for example, by applying a principal component analysis, it is conceptually inappropriate because it will mix deeper/irreconcilable and more recent/milder group differences. Heterogeneous groups could be expected to reach a mutually acceptable agreement more easily in the latter setting as compared to the former, but a pooling together of all the tiers γ will mask between-group differences. Therefore, stratification, which consists of running separate regressions of deforestation on each tier γ of the linguistic tree for each measure of ethno-linguistic diversity, is justified.

Stratification is also preferred in the related literature with an emphasis on linguistic trees

(Desmet et al., 2012; Gershman and Rivera, 2018). These contributions find that different γ matter for different political economy outcomes. Coarser levels of aggregation tend to matter more for civil conflict and redistribution issues where between-groups interests are more divergent, while finer cleavages seem to matter for economic outcomes where cooperation and communication between individuals and groups is essential (Desmet et al., 2012). Deforestation measures have never been analysed in such a setting.

A recent important contribution (Aklin and Mildenberger, 2020) suggests that distributive conflict over material benefits, rather that the dominant for decades collective action and cooperation arguments (Bechtel and Scheve, 2013), is the principal explanation of the observed global failure to mitigate climate change risks including deforestation. Against this background, it is essential to analyse separately all tiers of ethno-linguistic diversity in order to understand whether forest management at different deforestation thresholds in Africa could be described as a distributional problem (if rather coarser tiers are statistically significant), as a cooperation problem (if rather finer tiers are statistically significant), or both (if both coarser and finer tiers are statistically significant).

With respect to the question whether to stratify or to pool the measures of ethno-linguistic diversity (ELF and ELP), it should be noted that fractionalisation is the more general diversity measure, and that polarisation is designed to specifically capture conflict (Gershman and Rivera, 2018). Therefore, the relationship between fractionalisation and polarisation can be described as between a more general and a more specific proxy of ethno-linguistic diversity. Consequently, in order to gain additional insight, it would be of interest to run separate regression analyses with ELF and ELP. Furthermore, pooling them together in the same regression is not appropriate as it will introduce considerable multicollinearity due to the high correlation between the two measures in regard to some tiers γ. Figures C.2.1–C.2.2 in the Appendix contain correlation plots of all variables and illustrate this point.

As part of the controls in the regression specifications in equations 1 and 2, I account for two key groups of variables whose link to deforestation or to the evolution of ethno-linguistic diversity is demonstrated in the existing literature. These controls relate to geographic characteristics or to historical periods with impact on Africa's sustainability and development (Ahlerup and Olsson, 2012; Michalopoulos, 2012; Larcom et al., 2016; Abman, 2018). To the latter category belongs European colonisation that has had a profound ecological impact on African's development (Crosby, 2015; Galor and Özak, 2015, 2016). In order to account for the expansion of the set of available for cultivation crops in the course of the European colonisation, for land quality, agricultural demand, and the opportunity cost of keeping land as a forest more generally, I

implement the post-1500 CE Caloric Suitability Index (CSI), proposed by Galor and Özak (2015, 2016). The attractiveness of using CSI consists in its design. Rather than reflecting actual values, it captures the potential variation in crop yield in calories per hectare and, therefore, can be regarded as exogenous to human intervention (Galor and Özak, 2016). Since CSI successfully explains historical population density (Galor and Özak, 2015), the latter variable is not additionally accounted for. I include data on legal origin from Nunn (2008) because it has been shown to matter for deforestation (Marchand, 2016). These data originate from La Porta et al. (1999) who have coded as dummy variables all countries in their sample as either having British or French legal origin (Nunn, 2008).

I source from Nunn (2008) the constructed measure by Gennaioli and Rainer (2007) for pre-colonial state development that reflects the number of jurisdictional hierarchies beyond the local community because it contributes to the explanation of contemporary deforestation and development (Gennaioli and Rainer, 2007; Nunn, 2008; Larcom et al., 2016). Similarly to Nunn (2008), the empirical analysis includes European coloniser fixed effects (C_c) that alleviate concerns that the results could be driven by unobserved variation across the units of analysis originating from different dynamics of colonial period development (Paine, 2019).

The regression specifications also include the landlocked status of each first level sub-national administrative unit from Gershman and Rivera (2018) because of European colonisation. Concretely, the Scramble for Africa has increased the number of landlocked countries and explains their low contemporary integration in the global markets (Collier, 2008; Michalopoulos and Papaioannou, 2017). I use a measure for ethnic groups that are divided by colonial borders that cut their space of established close interaction in closely-knit societies (Ziltener and Künzler, 2013), as the latter could increase ethno-linguistic fractionalisation and polarisation.

The empirical analysis also accounts for geographical factors that capture climate conditions and the opportunity cost of decisions to keep land as forest cover (Abman, 2018; Sharma et al., 2019): absolute latitude, log-transformed terrain elevation, and ruggedness (Riley et al., 1999) calculated on the basis of the sourced data from the National Geophysical Data Centre (National Geophysical Data Centre, 1999). Ethno-linguistic diversity has also been shown to have the same geographic origins (Michalopoulos, 2012). In addition, I include in the analysis as a measure of historical mobility Özak's Human Mobility Index (HMI) (Özak, 2010, 2018). It reflects the potential minimum travel time in hours on land surface before the introduction of steam power, which was one of the driving forces of industrialisation. The HMI influences economic development (Özak, 2018) that could happen at the expense of forests. Furthermore, the discussed model by Ahlerup and Olsson (2012) demonstrates that ethno-linguistic diversity is associated with human

mobility.

2.3.1. Cross-sectional regressions

I implement a variety of cross-sectional regression models. The motivation for this setting is as follows: although the deforestation data are longitudinal, the data for the key explanatory variables ELF and ELP are cross-sectional. Therefore, I compute an aggregate deforestation percentage for the period 2001–2019 and implement a cross-sectional regression setting that has been adopted in other contributions in the social sciences with a historical focus (Hariri, 2012; Ashraf and Galor, 2013; Michalopoulos and Papaioannou, 2013; Galor and Özak, 2016; Larcom et al., 2016; Paine, 2019; Ricart-Huguet, 2021). Concretely, I estimate variants of the following statistical models:

$$ln(DFO_{\tau\, i,c}) = \alpha_1 + \alpha_2 ELF_{i,c} + X'_{i,c}\alpha_3 + C_c + \epsilon_{i,c} \quad (1)$$

$$ln(DFO_{\tau\, i,c}) = \beta_1 + \beta_2 ELP_{i,c} + X'_{i,c}\beta_3 + C_c + \psi_{i,c} \quad (2)$$

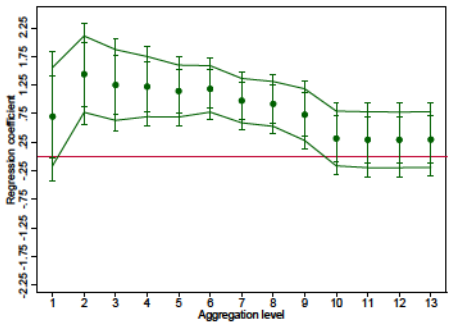
The dependent variable, $ln(DFO_{\tau\, i,c})$, represents the log-transformed deforestation thresholds $\tau = (25\%, 50\%)$ for each first level sub-national administrative unit i in c African countries. The coefficient of interest in this analysis is of ethno-linguistic fractionalisation, α_2, and of ethno-linguistic polarisation, β_2. $X'_{i,c}$ is a vector of control variables, C_c are European coloniser fixed effects, and $\epsilon_{i,c}$, respectively $\psi_{i,c}$, are error terms. The control variables in the regression specifications are the measure of pre- colonial state development, the measure for divided by colonial border ethnic groups, legal origin, the Human Mobility Index, the Caloric Suitability Index, landlocked status, log-transformed ruggedness, log-transformed elevation, and absolute latitude.

2.4. Results

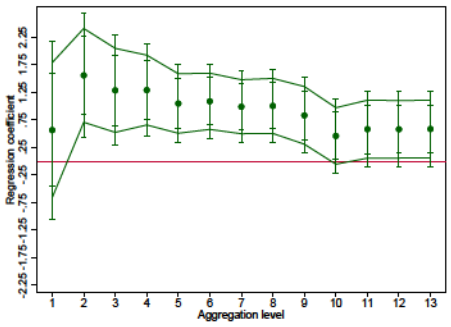
The regression analysis compares the performance of various regression specifications for the 25% and 50% deforestation thresholds without controls and European coloniser fixed effects in Panels (a) and (c) in Figures 2.1–A.2.6 and with a full set of controls and European coloniser fixed effects in Panels (b) and (d) in the same figures. The rationale and data sources of all variables are explained in section "Data and methods".

Figure 2.1 reports the main regression results for the 25% and 50% deforestation thresholds on ethno-linguistic fractionalisation ELF(γ). The comparison of the specifications without controls and coloniser fixed effects in Panels (a) and (c) with the ones with a full set of controls

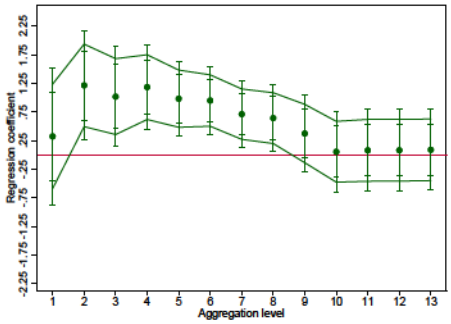
and coloniser fixed effects in Panels (b) and (d) reveals a similar pattern: the estimates of the regression coefficient α_2 of ELF from equation 1 is statistically significant predominantly at the 1% level, from tier $\gamma = 2$ up to tiers 8 or 9 of the linguistic tree. As predicted by the hypothesis, ethno-linguistic fractionalisation accelerates deforestation. A similar pattern can be noted for the estimates of the regression coefficient β_2 of ELP from equation 2 that are plotted in Figure 2.2.



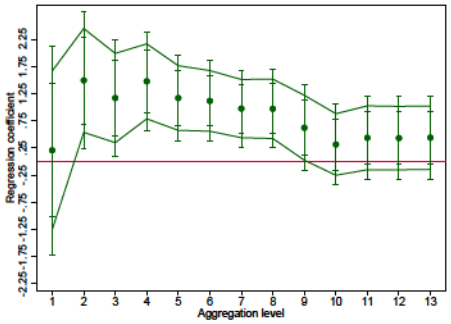
(a) $ln(DFO_{25\%})$ on ELF_γ without controls and fixed effects



(b) $ln(DFO_{25\%})$ on ELF_γ with controls and fixed effects



(c) $ln(DFO_{50\%})$ on ELF_γ without controls and fixed effects

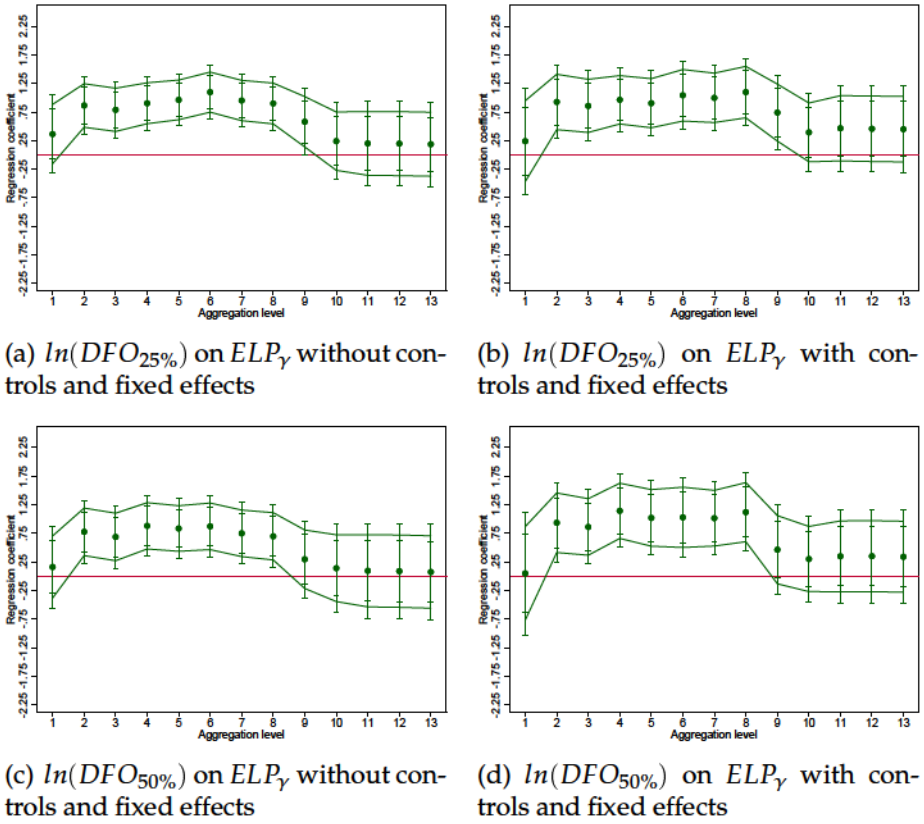


(d) $ln(DFO_{50\%})$ on ELF_γ with controls and fixed effects

Figure 2.1: Panels (a) and (c) represent results for the 25% and 50% log-transformed deforestation thresholds, respectively, on all tiers γ of ethno-linguistic fractionalisation ELF. These regression specifications do not include control variables and European coloniser fixed effects. Panels (b) and (d) represent results for the same deforestation thresholds and tiers of ELF but with added control variables and European coloniser fixed effects. The control variables are a measure of precolonial state development, a measure for ethnic groups divided by colonial borders, legal origin, an index of human mobility, an index of caloric suitability, landlocked status, log-transformed ruggedness, log-transformed elevation, and absolute latitude. See "Data and methods" section for the rationale and data sources of the variables. All point estimates are represented with their 90%, 95%, and 99% confident intervals respectively, based on robust standard errors.

The results for both ethno-linguistic diversity measures can be interpreted in connection with the findings in the empirical literature that indicate how different tiers γ of the implemented linguistic tree model matter for different political economy outcomes: coarser levels of γ seem to matter more for civil conflict and redistribution requests where between-groups' interests are more divergent, while finer γ levels matter more for economic outcomes where cooperation and communication between individuals and groups is essential (Desmet et al., 2012). Against this background, the overall statistical significance of ethno-linguistic diversity for both coarser and

finer tiers γ of the linguistic tree for Africa suggest that forest management can be regarded simultaneously as a distributive and cooperation problem that aggravates deforestation.



(a) $ln(DFO_{25\%})$ on ELP_γ without controls and fixed effects

(b) $ln(DFO_{25\%})$ on ELP_γ with controls and fixed effects

(c) $ln(DFO_{50\%})$ on ELP_γ without controls and fixed effects

(d) $ln(DFO_{50\%})$ on ELP_γ with controls and fixed effects

Figure 2.2: Panels (a) and (c) represent results for the 25% and 50% log-transformed deforestation thresholds, respectively, on all tiers γ of ethno-linguistic polarisation ELP. These regression specifications do not include control variables and European coloniser fixed effects. Panels (b) and (d) represent results for the same deforestation thresholds and tiers of ELP but with added control variables and European coloniser fixed effects. The control variables are a measure of precolonial state development, a measure for ethnic groups divided by colonial borders, legal origin, an index of human mobility, an index of caloric suitability, landlocked status, log-transformed ruggedness, log-transformed elevation, and absolute latitude. See "Data and methods" section for the rationale and data sources of the variables. All point estimates are represented with their 90%, 95%, and 99% confident intervals respectively, based on robust standard errors.

These results could also be interpreted in light of findings from a recent important contribution by Aklin and Mildenberger (2020). The authors suggest that distributive conflict about material benefits, rather that the dominant collective action and cooperation arguments (Bechtel and Scheve, 2013), is the principal explanation of the observed global failure to mitigate climate change risks including deforestation. In addition, Bates (2015) emphasises that ethnicity, which in this article is captured by ELF and ELP, is responsible for the distributive conflict in Africa: *"given that in most African countries some regions are better endowed than others and that ethnic groups tend to occupy distinct territories, demands for regional redistribution take on an ethnic colouring and regional conflicts assume the guise of ethnic discord. Ethnic conflict is not a "clash of cultures," then, but rather a struggle over the regional allocation of resources"* (133).

Given the possibility for within-group correlations of the residuals, I implement various OLS specifications with clustered standard errors (Figure A.2.3 for *ELF* and Figure A.2.4 for *ELP*). One-way clustering at the country level or two-way clustering at the country and district levels renders similar confidence intervals of the coefficients of ethno-linguistic diversity. In both cases, the confidence intervals are compared to the baseline specifications with robust standard errors. Another robustness check consists of re-running the main regression specifications from Figures 2.1–2.2 but excluding capital cities that could drive the results due to their higher economic development that might occur at the expense of the natural environment. These additional results are presented in Figure A.2.1 for *ELF* and in Figure A.2.2 for *ELP*. All robustness checks reveal that no qualitative changes of the estimates occur in comparison with the baseline.

One legitimate concern that may arise from the empirical evidence presented so far is the possible sensitivity of the results with respect to single, influential cases. To address these concerns, I implement robustness checks that leave one country out. Specifically, I re-estimate the same OLS regressions as in Figures 2.1–2.2 by leaving one country out for the 25% and 50% deforestation thresholds and for tier $\gamma = 6$ as a value approximately in the middle of the tiers of the linguistic tree of *ELF* and *ELP*. Figures A.2.7 through A.2.10 demonstrate that the plotted 90% confidence intervals of the measures of ethno-linguistic diversity exclude 0, so the results remain statistically significant.

As an additional robustness check, I re-run the regression specifications from Figures 2.1–2.2 but replace $ln(DFO_{25\%})$ and $ln(DFO_{50\%})$ with their non-transformed and highly skewed equivalents $DFO_{25\%}$ and $DFO_{50\%}$. These results, which are presented in Figures A.2.5 and A.2.6, do not qualitatively differ from the log-linear specifications. Furthermore, to alleviate endogeneity concerns, I implement the coefficient stability test of Oster (2019). It consists of calculating the bounds of the coefficient α_2 of *ELF* in equation 1 and of β_2 of *ELP* in equation 2 for both deforestation thresholds. Table C.2.1 in the Appendix presents these results. It can be noted that the bounds exclude 0, meaning that unobservables are less important than observables unless R^2 increases by 220% or more in some of the cases, which is unlikely to happen.

Up to this point, the presented evidence consistently confirms the positive relationship between the historically evolving ethno-linguistic diversity and contemporary deforestation. However, other social cleavages might be important for explaining deforestation and may mediate the role of ethno-linguistic diversity. Against this background, I complement the analysis with data on religious fractionalisation (RF) and polarisation (RP) that are compiled in the same way as their ethno-linguistic counterparts, but replace ethnic groups with religious ones for the same baseline of countries. OLS estimates of RF and RP with and without controls and European coloniser fixed

effects are presented in Figure A.2.11 for $ln(DFO_{25\%})$ and in Figure A.2.12 for $ln(DFO_{50\%})$.

These figures reveal an interesting new insight: while RF is only statistically significant for the 25% deforestation threshold after the estimation precision is improved by adding controls and coloniser fixed effects, both RF and RP become statistically significant for the 50% deforestation threshold for the same specifications with controls and coloniser fixed effects, thus indicating that more intensive deforestation in Africa also has religious antagonism origins. It is worth analysing further the association between ethno-linguistic and religion diversity on the one hand and deforestation measures on the other. Figure A.2.13 contains the results for $ln(DFO_{25\%})$ and $ln(DFO_{50\%})$ on ELF and RF, and Figure A.2.14 – for $ln(DFO_{25\%})$ and $ln(DFO_{50\%})$ on ELP and RP, respectively. These regressions reveal that religious fractionalisation at the higher 50% deforestation threshold consistently co-facilitates deforestation, together with ethno-linguistic fractionalisation at both coarser tiers of the linguistic tree, starting from $\gamma = 2$ to finer tiers and up to $\gamma = 8$.

Although the indexes of fractionalisation and polarisation are commonly used in the empirical literature on human diversity that frequently focuses on language and ethnicity, other types of social cleavages, their position in the social hierarchy and geographic segregation may be potentially relevant for explaining aggregate deforestation in Africa. I leave the analysis of these questions for future research. Since the regression results confirm the existence of a positive correlation between ethno-linguistic diversity and deforestation, both factors are therefore likely to be useful for generating hypotheses for causal relationships in future research when a plausible counterfactual to ethno-linguistic diversity could be identified. Such studies could retain their focus on the sub-national level of analysis but should address the methodological problem of which units to compare in a counterfactual setting (Kikuta, 2020).

2.5. Conclusion

Rapidly growing empirical research over the last two decades has confirmed that the substantial variation and persistence of modern political and economic differences has its roots in the past and has important context-specific policy implications (Nunn, 2020). However, with the notable exception of Larcom et al. (2016), the historical origins of contemporary deforestation, which is one of today's toughest environmental problems, have attracted little academic attention. This article contributes to literature on the legacies and persistence of the past by highlighting the fact that ethno-linguistic divisions and antagonism in societies, when conditioned on their historic dimension, aggravate current deforestation.

How can these findings inform public policy in heterogeneous societies? The relevant evolu-

tionary literature on such societies assumes that ethnic identity is a successful behaviour through history that fosters cooperation based on social kinship and helps to solve collection action problems (Van den Berghe, 1981, 1995; Ahlerup and Olsson, 2012). As an analogy to the language trees approach of Desmet et al. (2012), the theoretical model of Ahlerup and Olsson (2012) suggests that human diversity evolves historically but also finds that diversity inevitably increases over time because resources in a community are distributed unevenly based on kinship, which creates disbalance. However, "[t]o function, large collectivities need to foster solidarity and cooperation among their members" (Baldassarri and Abascal (2020), 1), which is also particularly relevant for climate change actions.

How can prosocial behaviour and solidarity extend and remain sustainable over the long run beyond the confines of close-knit homogenous communities? When answering this question in the context of Africa, the strong attachment of African citizens both to their nation and to their ethnic group (Michalopoulos and Papaioannou, 2015) must be considered. What public policy could work beneficially in such a situation? An inclusive policy that decreases the politicisation of ethnic identity could be an option (de la Cuesta and Wantchékon, 2016). A central element of such a policy could be to build a national educational system (de la Cuesta and Wantchékon, 2016) that is equally accessible to all communities (Baldassarri and Abascal, 2020). The logic is as follows: a regional, decentralised schooling system could foster political and economic development but ethnic divisions and the use of several different languages could also limit the ability of each community to participate in diverse environments or have multiple identities in different life situations that are not defined by characteristics such as race, ethnicity, or class (de la Cuesta and Wantchékon, 2016; Baldassarri and Abascal, 2020).

Having multiple identities is a key to promoting broader prosocial behaviour and establishing a sense of collective identity and cooperation in heterogeneous societies beyond the in-group confines because greater individualisation decreases identification with in-group characteristics (Baldassarri and Abascal, 2020). Dating back to the colonial era, regional education inequality has been a reality in Africa even after independence (Ricart-Huguet, 2021). The introduction of a national schooling system would address this problem and is a viable solution because it can foster cooperation on the basis of a shared history and experience as well as a positive strategic interaction (de la Cuesta and Wantchékon, 2016; Baldassarri and Abascal, 2020). Effective climate mitigation requires cooperation and broad support that is sustainable over the long run (Bechtel and Scheve, 2013). The introduction of a national schooling system can serve as a building block to create out-group prosociality and conditions for durable cooperation for supporting climate change actions.

The finding of this article that the historically evolving human heterogeneity aggravates deforestation indicates an important direction for future research. Concretely, in Africa exists extensive evidence of a pronounced legal pluralism both historically and contemporarily (Michalopoulos and Papaioannou, 2015; Larcom et al., 2016; Unruh, 2008; Marfo et al., 2012). This concept can be defined as "a situation where at least two legal orders assert jurisdiction over the same geographical space and persons within that space and a legal order is defined as a set of rules and practices that are oriented toward ordering relations between persons with its own source of authority" (Larcom (2014), 194).

With respect to Africa, a key characteristic of legal pluralism is that "non-state legal orders can be complex systems and that they often aim to regulate a broad scope of behaviours; which means they have the potential to simultaneously support, undermine, and be inconsequential to the state" (Larcom (2014), 197). In addition, there is context-specific isolated evidence that legal pluralism can lead to deforestation (Mutolib and Ismono, 2017). Therefore, a venue for future, more nuanced, research could be to conduct a large-scale study on the mechanisms of how, why, and when the conditioned on human diversity legal pluralism is problematic and accelerates deforestation in Africa. Depending on the gravity of the case, policy makers could either resort to social engineering "to create and perpetuate norms through the communicative role of the law in changing internalised beliefs within society" (196) or to solving conflicts (Larcom, 2014).

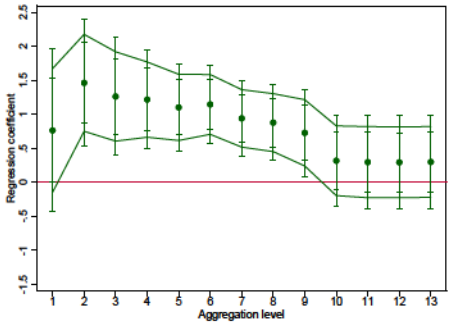
Individuals overexploiting forests to their own advantage without considering the collective interest is captured by Garet Hardin's (1968) famous article, "The Tragedy of the commons". Perfect rationality, understood as the individual behaviour model on which the tragedy of the commons is based, has been challenged because it assumes that individuals have perfect information, flawlessly interpret it, and always choose to act to their own advantage rather than cooperate (Schlager, 2002). Bounded rationality models in which individuals learn by applying common norms such as reciprocity that help explain cooperation is a possible solution (Ostrom, 1998; Schlager, 2002; Fehr and Schurtenberger, 2018). Building on this basis, a new perspective from political economy literature regarding an individual's decision-making with respect to public policies on climate change has begun to emerge.

As part of this literature, the survey article of Drews and Van den Bergh (2016) summarises the most frequent drivers of public support for climate policies in three categories: (1) social-psychological factors and climate change perceptions, such as political orientation, values, climate change knowledge, risk perception, and emotions; (2) perceptions of climate policy and its design, including costs, policy effectiveness, and fairness; and (3) contextual factors, such as social trust, norms, media communication, and economic, political, and geographical conditions.

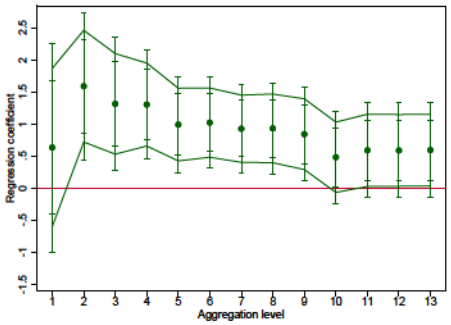
While this literature is likely to be a major frontier over the coming years, its current limitation is that it overlooks to a considerable extent that "[e]nvironmental behaviour varies significantly between ethnic groups" (Medina et al. (2019), 1). Consequently, "there is an inadequate amount of studies conducted with ethnic minority groups" (Medina et al. (2019), 2). Considering the fact that the literature reports "significant ethnic asymmetries in the pattern of norm enforcement" (Winter and Zhang (2018), 2722) as well as that effective climate mitigation requires global co-operation (Bechtel and Scheve, 2013) and redistribution (Aklin and Mildenberger, 2020), which is based on norms (Fehr and Schurtenberger, 2018), a more pronounced future scholarly focus on the forest management effects of environmental beliefs and actions among ethnic lines and in cultural environments away from the dominant focus on Western cultures (Medina et al., 2019) is needed.

Appendix to Chapter 2

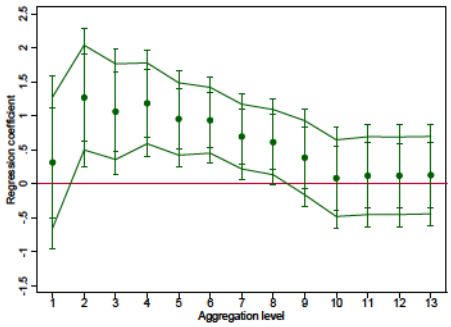
A. Additional results



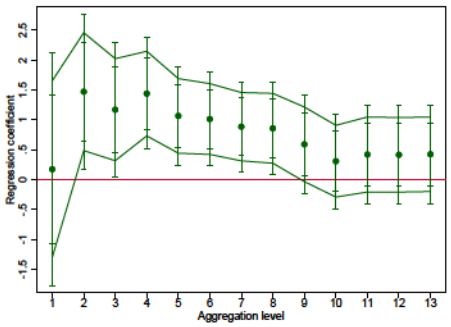
(a) $ln(DFO_{25\%})$ on ELF_γ without controls and fixed effects



(b) $ln(DFO_{25\%})$ on ELF_γ with controls and fixed effects

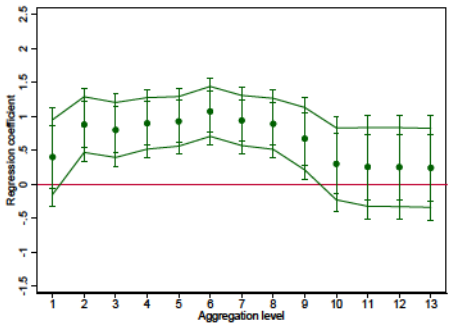


(c) $ln(DFO_{50\%})$ on ELF_γ without controls and fixed effects

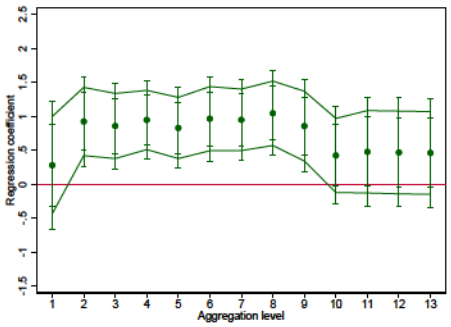


(d) $ln(DFO_{50\%})$ on ELF_γ with controls and fixed effects

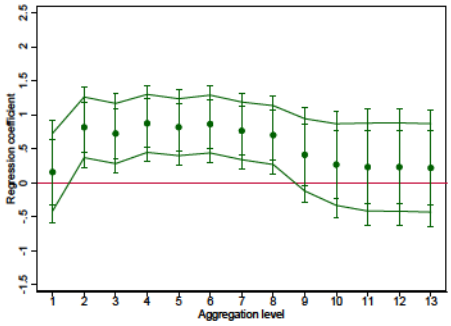
Figure A.2.1: Panels (a) and (c) represent results for the 25% and the 50% log-transformed deforestation thresholds, respectively, on all tiers γ of ethno-linguistic fractionalisation ELF. These regression specifications do not include control variables and European coloniser fixed effects. Panels (b) and (d) represent results for the same deforestation thresholds and tiers of ELF but with added control variables and European coloniser fixed effects. The control variables are a measure of precolonial state development, a measure for ethnic groups divided by colonial borders, legal origin, an index of human mobility, an index of caloric suitability, landlocked status, log-transformed ruggedness, log-transformed elevation, and absolute latitude. See section "Data and methods" for the rationale and data sources of the variables. All point estimates are represented with their 90%, 95% and 99% confidence intervals, based on robust standard errors. All regression specifications exclude the capital cities.



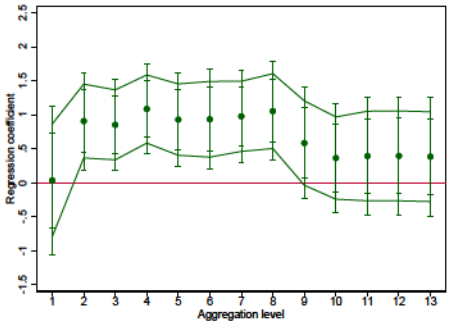
(a) $ln(DFO_{25\%})$ on ELP_γ without controls and fixed effects



(b) $ln(DFO_{25\%})$ on ELP_γ with controls and fixed effects

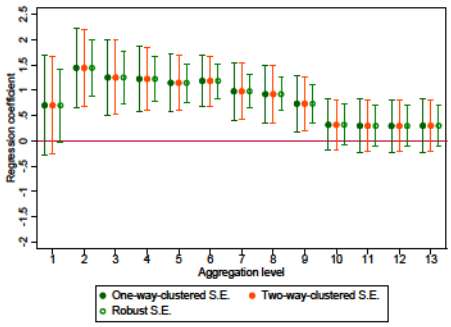


(c) $ln(DFO_{50\%})$ on ELP_γ without controls and fixed effects

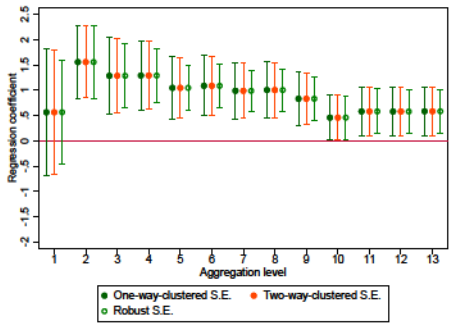


(d) $ln(DFO_{50\%})$ on ELP_γ with controls and fixed effects

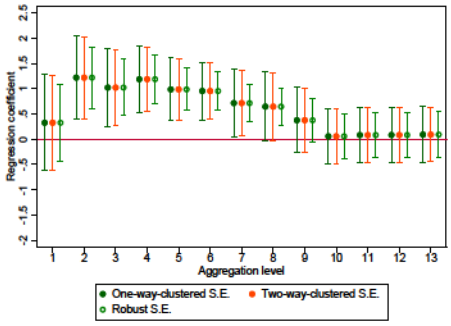
Figure A.2.2: Panels (a) and (c) represent results for the 25% and the 50% log-transformed deforestation thresholds, respectively, on all tiers γ of ethno-linguistic polarisation ELP. These regression specifications do not include control variables and European coloniser fixed effects. Panels (b) and (d) represent results for the same deforestation thresholds and tiers of ELP but with added control variables and European coloniser fixed effects. The control variables are a measure of precolonial state development, a measure for ethnic groups divided by colonial borders, legal origin, an index of human mobility, an index of caloric suitability, landlocked status, log-transformed ruggedness, log-transformed elevation, and absolute latitude. See section "Data and methods" for the rationale and data sources of the variables. All point estimates are represented with their 90%, 95% and 99% confidence intervals, based on robust standard errors. All regression specifications exclude the capital cities.



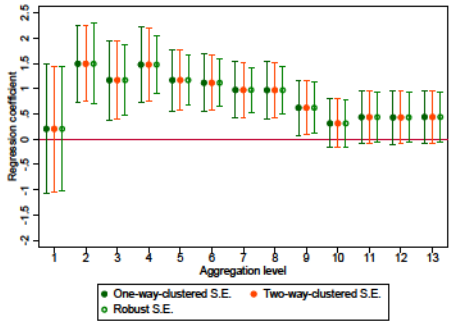
(a) $ln(DFO_{25\%})$ on ELF_γ without controls and fixed effects



(b) $ln(DFO_{25\%})$ on ELF_γ with controls and fixed effects

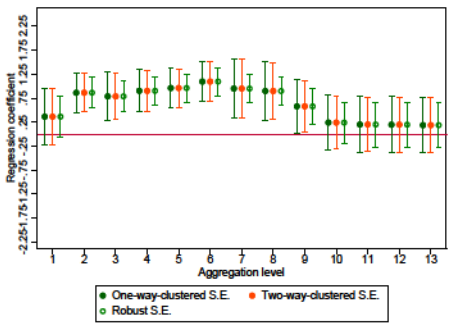


(c) $ln(DFO_{50\%})$ on ELF_γ without controls and fixed effects

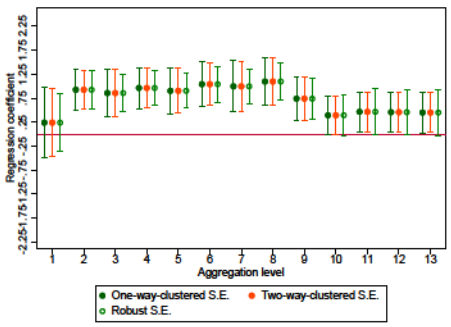


(d) $ln(DFO_{50\%})$ on ELF_γ with controls and fixed effects

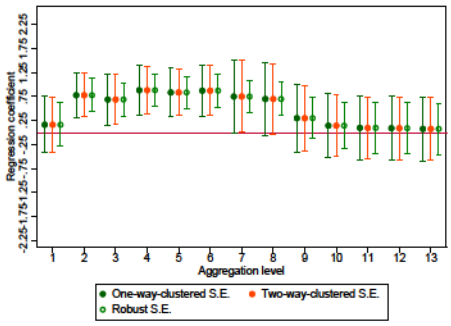
Figure A.2.3: Panels (a) and (c) represent results for the 25% and the 50% log-transformed deforestation thresholds, respectively, on all tiers γ of ethno-linguistic fractionalisation ELF. These regression specifications do not include control variables and European coloniser fixed effects. Panels (b) and (d) represent results for the same deforestation thresholds and tiers of ELF but with added control variables and European coloniser fixed effects. All point estimates are represented with their 90% confidence intervals, based on robust, one-way-clustered at the country level and two-way-clustered at the country and district levels (Cameron et al., 2006) standard errors. It can be noted from the figure that the one-way clustered standard errors have a similar performance to the robust ones, and that two-way clustering decreases the confidence intervals.



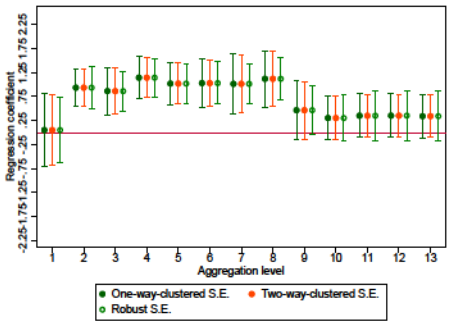
(a) $ln(DFO_{25\%})$ on ELP_γ without controls and fixed effects



(b) $ln(DFO_{25\%})$ on ELP_γ with controls and fixed effects

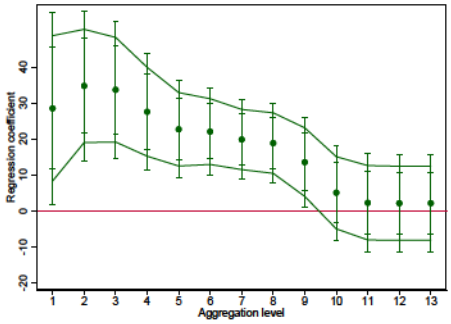


(c) $ln(DFO_{50\%})$ on ELP_γ without controls and fixed effects

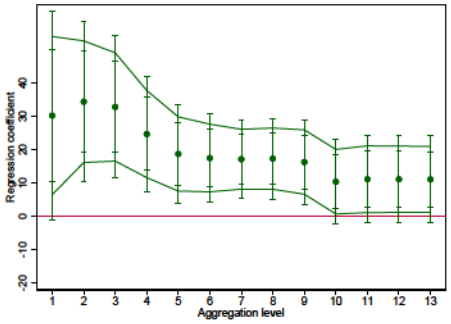


(d) $ln(DFO_{50\%})$ on ELP_γ with controls and fixed effects

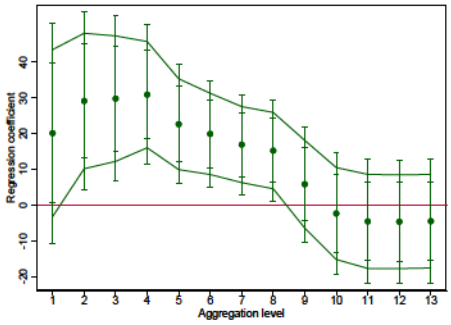
Figure A.2.4: Panels (a) and (c) represent results for the 25% and the 50% log-transformed deforestation thresholds, respectively, on all tiers γ of ethno-linguistic polarisation ELP. These regression specifications do not include control variables and European coloniser fixed effects. Panels (b) and (d) represent results for the same deforestation thresholds and tiers of ELP but with added control variables and European coloniser fixed effects. All point estimates are represented with their 90% confidence intervals, based on robust, one-way-clustered at the country level and two-way-clustered at the country and district levels (Cameron et al., 2006) standard errors. It can be noted from the figure that the one-way clustered standard errors have a similar performance to the robust ones, and that two-way clustering decreases the confidence intervals.



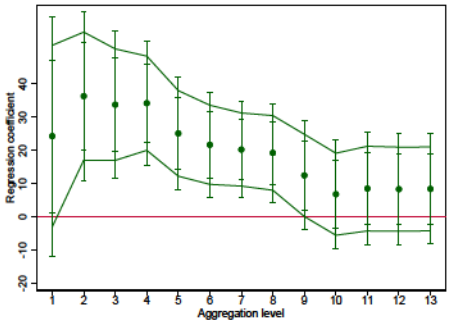
(a) $DFO_{25\%}$ on ELF_γ without controls and fixed effects



(b) $DFO_{25\%}$ on ELF_γ with controls and fixed effects

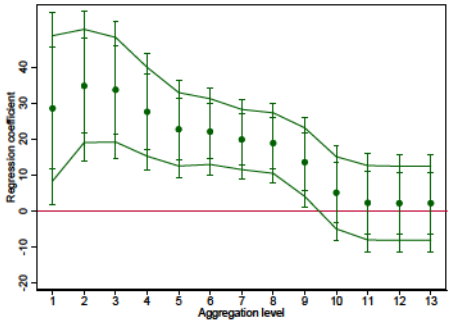


(c) $DFO_{50\%}$ on ELF_γ without controls and fixed effects

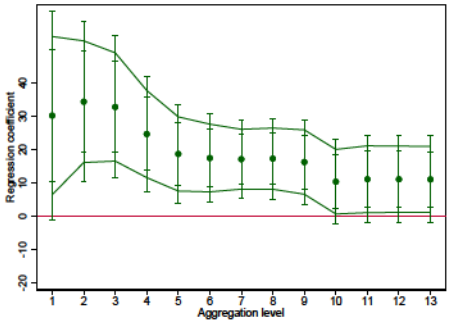


(d) $DFO_{50\%}$ on ELF_γ with controls and fixed effects

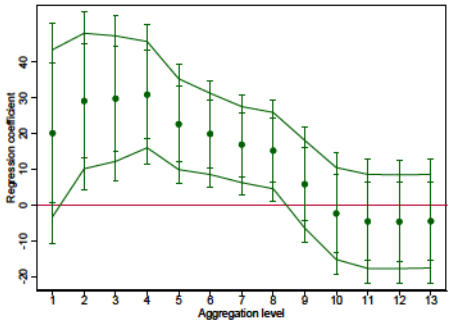
Figure A.2.5: Panels (a) and (c) represent results for the 25% and the 50% non-transformed deforestation thresholds, respectively, on all tiers γ of ethno-linguistic fractionalisation ELF. These regression specifications do not include control variables and European coloniser fixed effects. Panels (b) and (d) represent results for the same deforestation thresholds and tiers of ELF but with added control variables and European coloniser fixed effects. The control variables are a measure of precolonial state development, a measure for ethnic groups divided by colonial borders, legal origin, an index of human mobility, an index of caloric suitability, landlocked status, log-transformed ruggedness, log-transformed elevation, and absolute latitude. See section "Data and methods" for the rationale and data sources of the variables. All point estimates are represented with their 90%, 95% and 99% confidence intervals, based on robust standard errors.



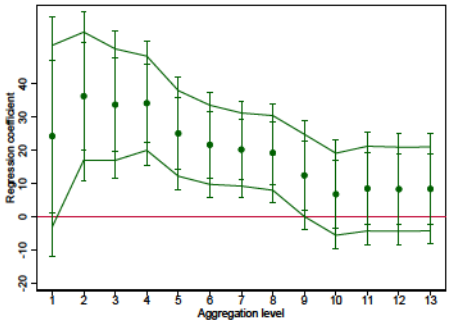
(a) $DFO_{25\%}$ on ELP_γ without controls and fixed effects



(b) $DFO_{25\%}$ on ELP_γ with controls and fixed effects



(c) $DFO_{50\%}$ on ELP_γ without controls and fixed effects



(d) $DFO_{50\%}$ on ELP_γ with controls and fixed effects

Figure A.2.6: Panels (a) and (c) represent results for the 25% and the 50% non-transformed deforestation thresholds, respectively, on all tiers γ of ethno-linguistic polarisation ELP. These regression specifications do not include control variables and European coloniser fixed effects. Panels (b) and (d) represent results for the same deforestation thresholds and tiers of ELP but with added control variables and European coloniser fixed effects. The control variables are a measure of precolonial state development, a measure for ethnic groups divided by colonial borders, legal origin, an index of human mobility, an index of caloric suitability, landlocked status, log-transformed ruggedness, log-transformed elevation, and absolute latitude. See section "Data and methods" for the rationale and data sources of the variables. All point estimates are represented with their 90%, 95% and 99% confidence intervals, based on robust standard errors.

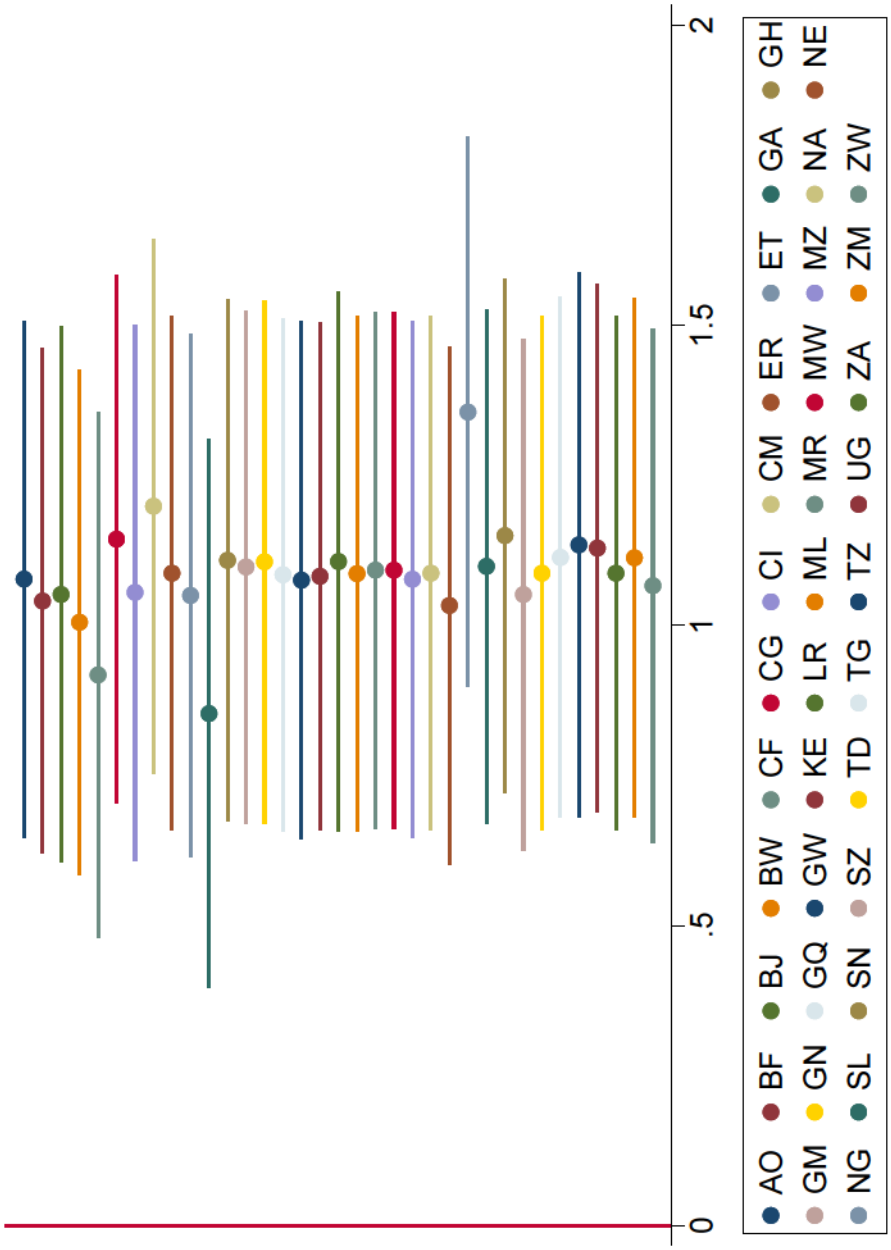


Figure A.2.7: This figure presents a leave-one-country-out robustness check for $ln(DFO_{25\%})$ on $ELF_{\gamma=6}$. The labels with the ISO2 codes of the 35 countries in the sample indicate which country is left out of the regression. All models include the full set of controls and coloniser fixed effects. See section "Methods" for the rationale and data sources of the variables. It can be noted from the graph, that the plotted 90% confidence intervals do not include 0. This means that the results remain statistically significant.

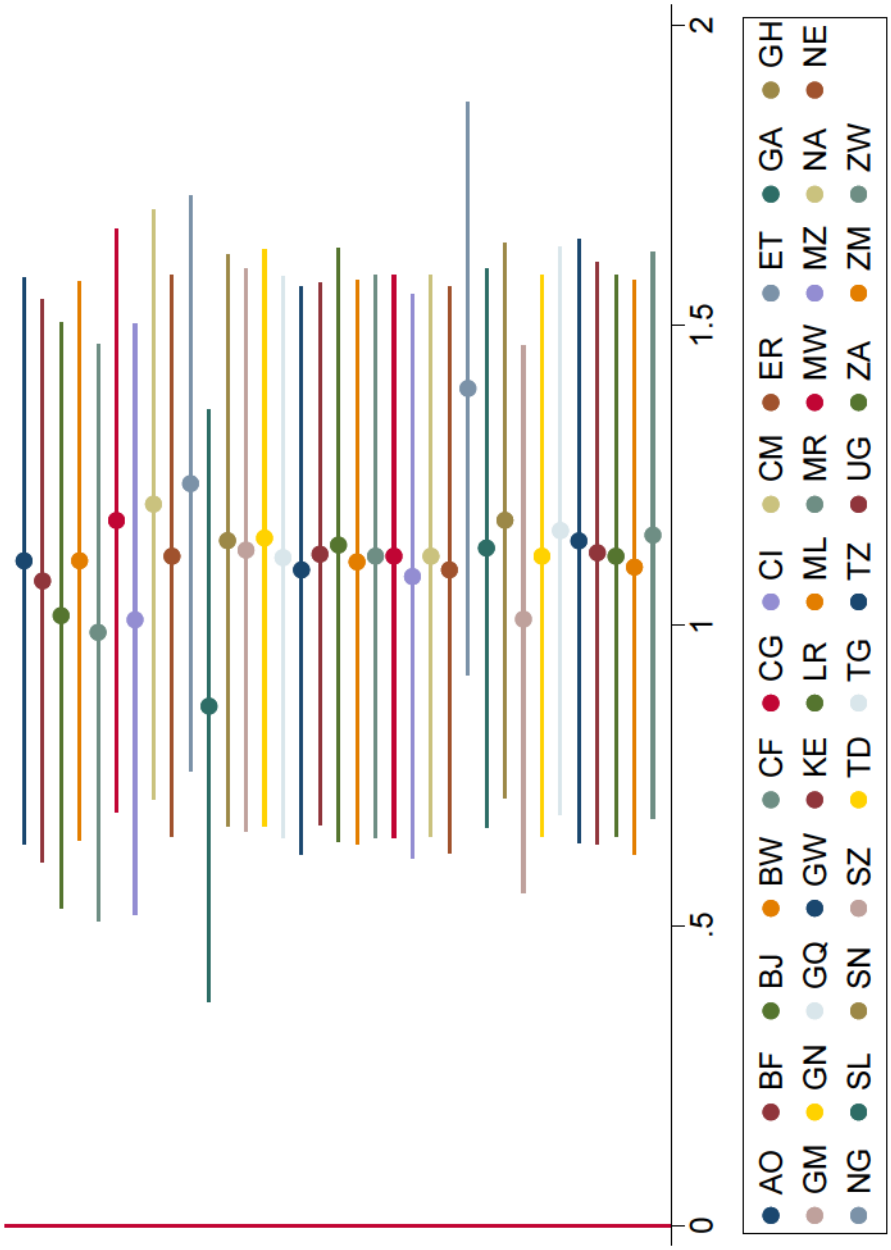


Figure A.2.8: This figure presents a leave-one-country-out robustness check for $ln(DFO_{50\%})$ on $ELF_{\gamma=6}$. The labels with the ISO2 codes of the 35 countries in the sample indicate which country is left out of the regression. All models include the full set of controls and coloniser fixed effects. See section "Methods" for the rationale and data sources of the variables. It can be noted from the graph, that the plotted 90% confidence intervals do not include 0. This means that the results remain statistically significant.

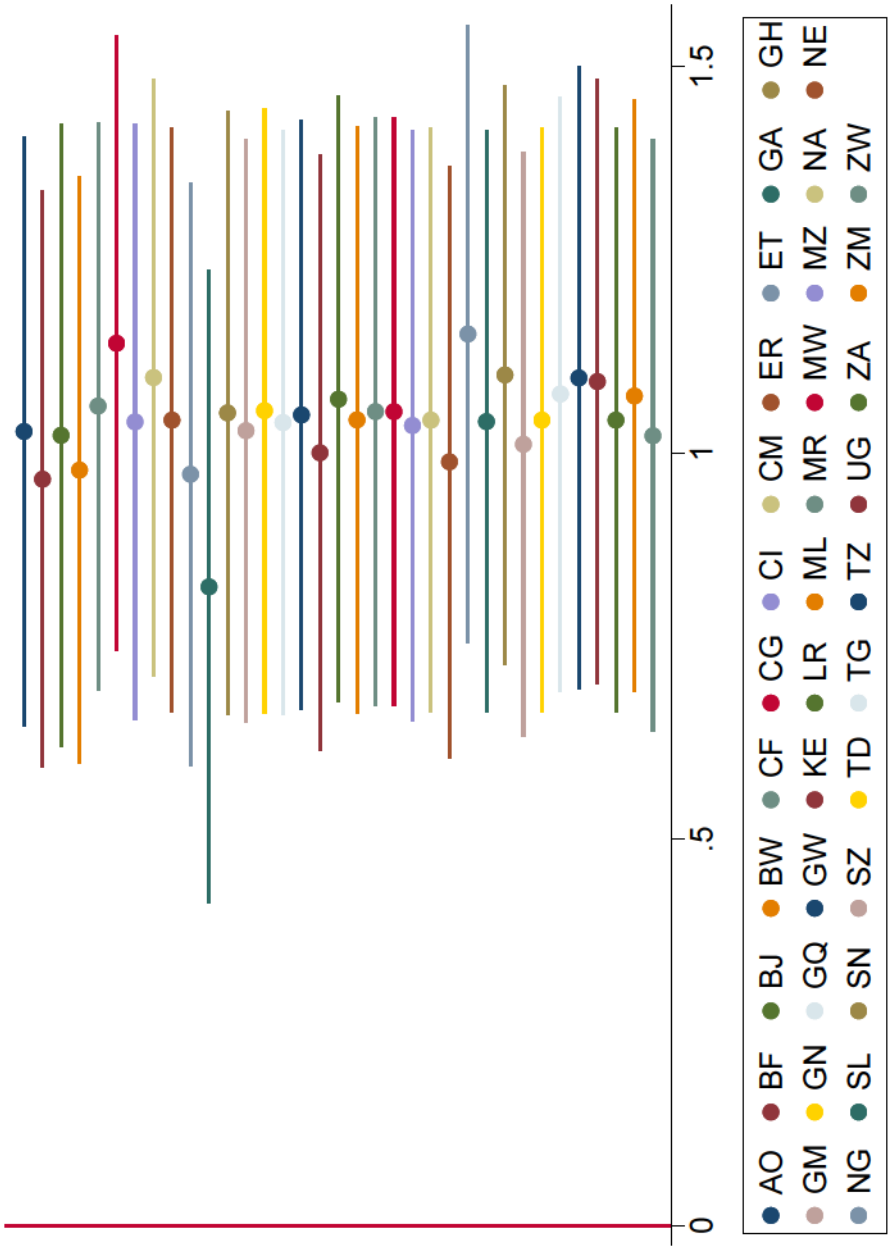


Figure A.2.9: This figure presents a leave-one-country-out robustness check for $ln(DFO_{25\%})$ on $ELP_{\gamma=6}$. The labels with the ISO2 codes of the 35 countries in the sample indicate which country is left out of the regression. All models include the full set of controls and coloniser fixed effects. See section "Methods" for the rationale and data sources of the variables. It can be noted from the graph, that the plotted 90% confidence intervals do not include 0. This means that the results remain statistically significant.

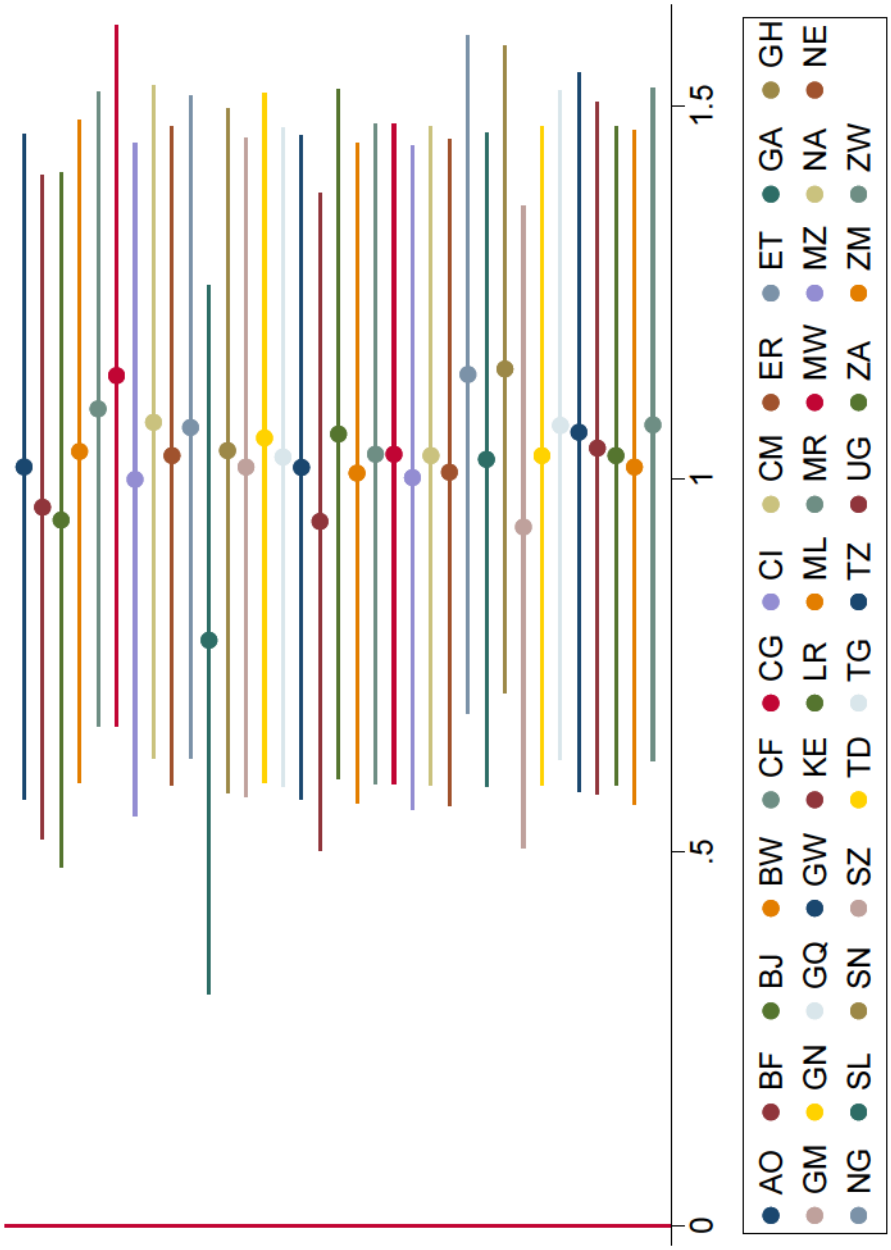


Figure A.2.10: This figure presents a leave-one-country-out robustness check for $ln(DFO_{50\%})$ on $ELP_{\gamma=6}$. The labels with the ISO2 codes of the 35 countries in the sample indicate which country is left out of the regression. All models include the full set of controls and coloniser fixed effects. See section "Data and methods" for the rationale and data sources of the variables. It can be noted from the graph, that the plotted 90% confidence intervals do not include 0. This means that the results remain statistically significant.

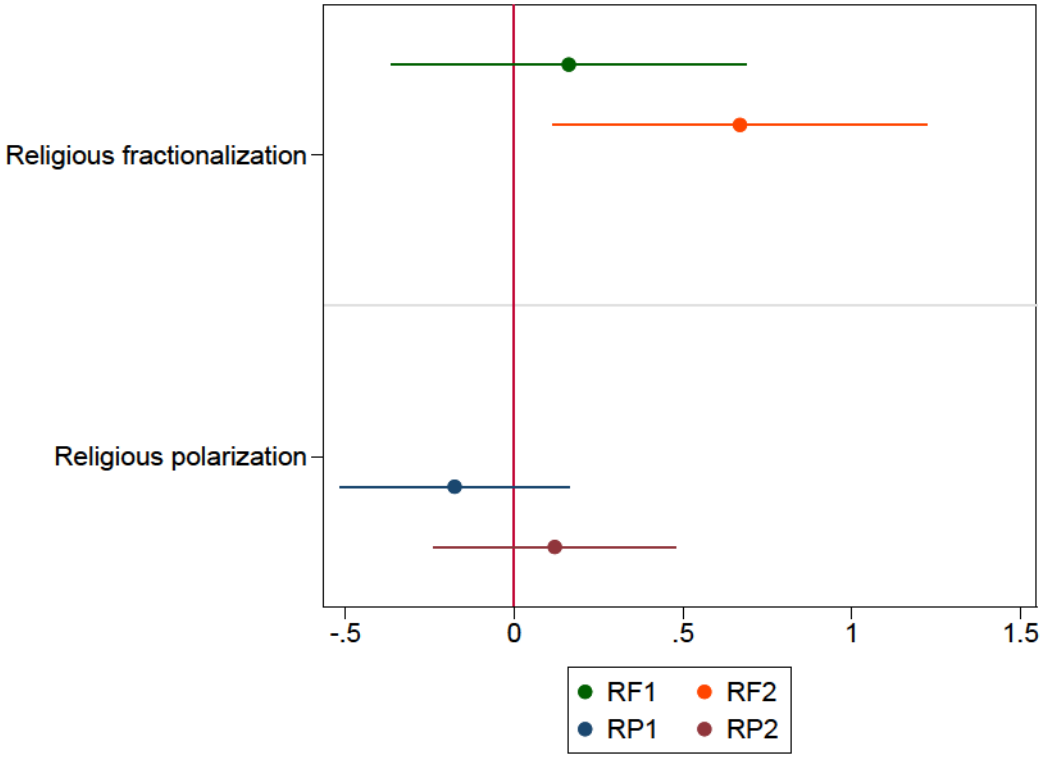


Figure A.2.11: The figure represents estimates from four regressions: (RF1) of $ln(DFO_{25\%})$ on religious fractionalisation (RF) without controls and without European coloniser fixed effects; (RF2) of $ln(DFO_{25\%})$ on religious fractionalisation with controls and European coloniser fixed effects; (RP1) of $ln(DFO_{25\%})$ on religious polarisation (RP) without controls and without European coloniser fixed effects; (RP2) of $ln(DFO_{25\%})$ on religious polarisation with controls and European coloniser fixed effects. It can be noted from the graph that RF becomes statistically significant, respectively its confidence interval excludes 0, only in model RF2. All point estimates are represented with their 90% confidence intervals, based on robust standard errors.

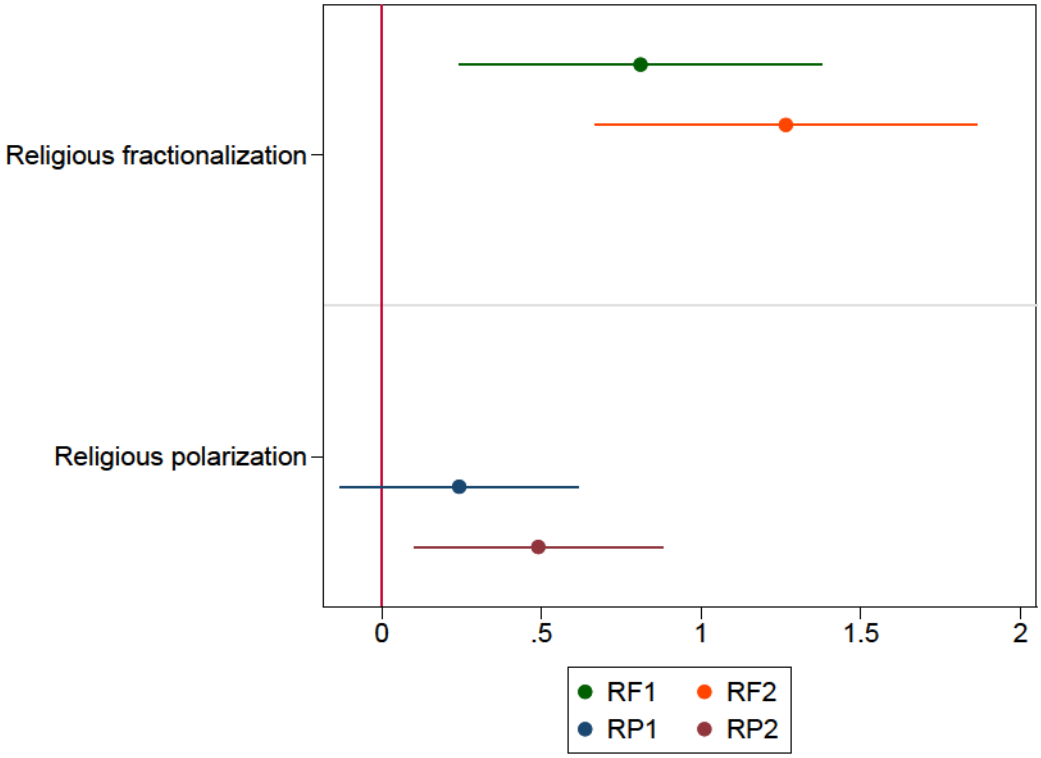
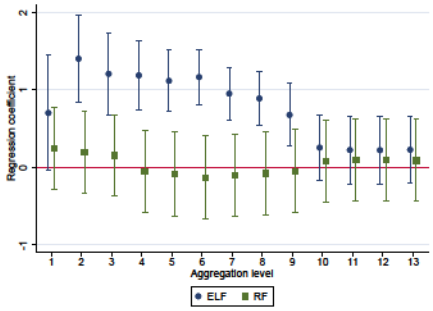
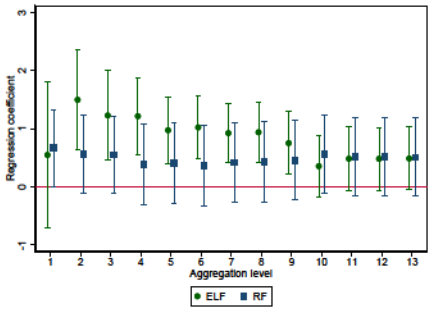


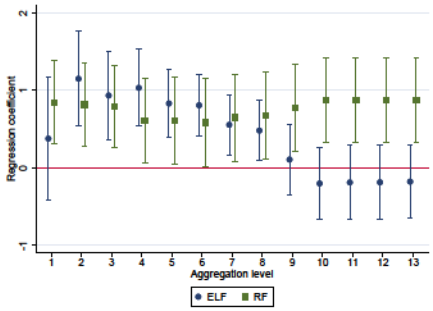
Figure A.2.12: The figure represents estimates from four regressions: (RF1) of $ln(DFO_{50\%})$ on religious fractionalisation (RF) without controls and without European coloniser fixed effects; (RF2) of $ln(DFO_{50\%})$ on religious fractionalisation with controls and European coloniser fixed effects; (RP1) of $ln(DFO_{50\%})$ on religious polarisation (RP) without controls and without European coloniser fixed effects; (RP2) of $ln(DFO_{50\%})$ on religious polarisation with controls and European coloniser fixed effects. It can be noted from the graph that RP becomes statistically significant, respectively its confidence interval excludes 0, only with model RP2. In contrast, RF is statistically significant with both models. All point estimates are represented with their 90% confidence intervals, based on robust standard errors.



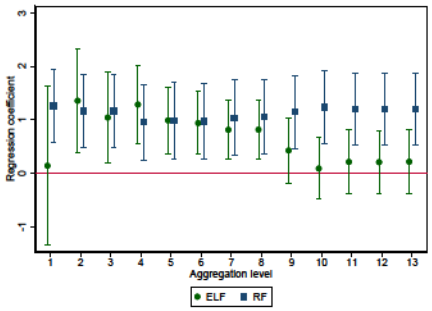
(a) $ln(DFO_{25\%})$ on ELF_γ and RF without controls and fixed effects



(b) $ln(DFO_{25\%})$ on ELF_γ and RF with controls and fixed effects

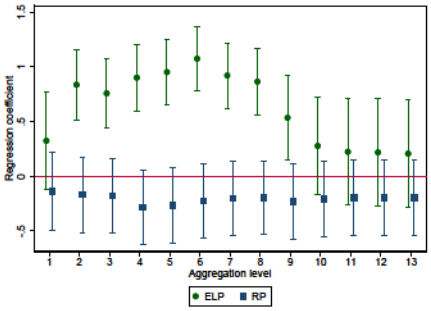


(c) $ln(DFO_{50\%})$ on ELF_γ and RF without controls and fixed effects

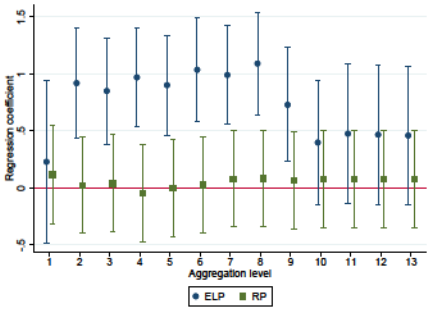


(d) $ln(DFO_{50\%})$ on ELF_γ and RF with controls and fixed effects

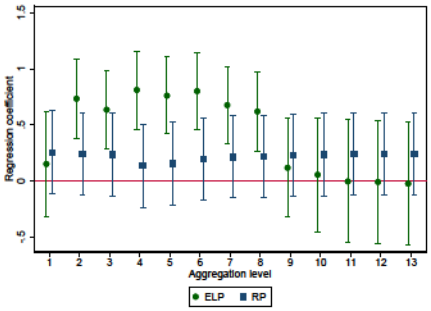
Figure A.2.13: The figure represents estimates from four regressions: (a) of $ln(DFO_{25\%})$ on ethno-linguistic fractionalisation ELF_γ and religious fractionalisation (RF) without controls and without European coloniser fixed effects; (b) of $ln(DFO_{25\%})$ on ethno-linguistic fractionalisation ELF_γ and religious fractionalisation (RF) with controls and European coloniser fixed effects; (c) of $ln(DFO_{50\%})$ on ethno-linguistic fractionalisation ELF_γ and religious fractionalisation (RF) without controls and without European coloniser fixed effects; (d) of $ln(DFO_{50\%})$ on ethno-linguistic fractionalisation ELF_γ and religious fractionalisation (RF) with controls and European coloniser fixed effects. All point estimates are represented with their 90% confidence intervals, based on robust standard errors.



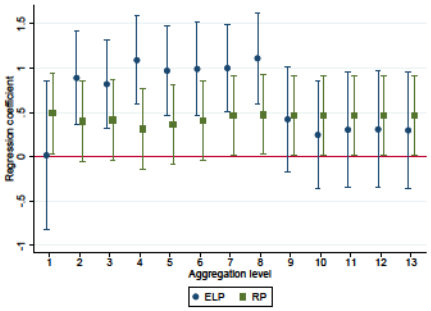
(a) $ln(DFO_{25\%})$ on ELP_γ and RP without controls and fixed effects



(b) $ln(DFO_{25\%})$ on ELP_γ and RP with controls and fixed effects



(c) $ln(DFO_{50\%})$ on ELP_γ and RP without controls and fixed effects



(d) $ln(DFO_{50\%})$ on ELP_γ and RP with controls and fixed effects

Figure A.2.14: The figure represents estimates from four regressions: (a) of $ln(DFO_{25\%})$ on ethno-linguistic polarisation ELP_γ and religious polarisation (RP) without controls and without European coloniser fixed effects; (b) of $ln(DFO_{25\%})$ on ethno-linguistic polarisation ELP_γ and religious polarisation (RP) with controls and European coloniser fixed effects; (c) of $ln(DFO_{50\%})$ on ethno-linguistic polarisation ELP_γ and religious polarisation (RP) without controls and without European coloniser fixed effects; (d) of $ln(DFO_{50\%})$ on ethno-linguistic polarisation ELP_γ and religious polarisation (RP) with controls and European coloniser fixed effects. All point estimates are represented with their 90% confidence intervals, based on robust standard errors.

B. Aggregate deforestation (2001-2019) by threshold

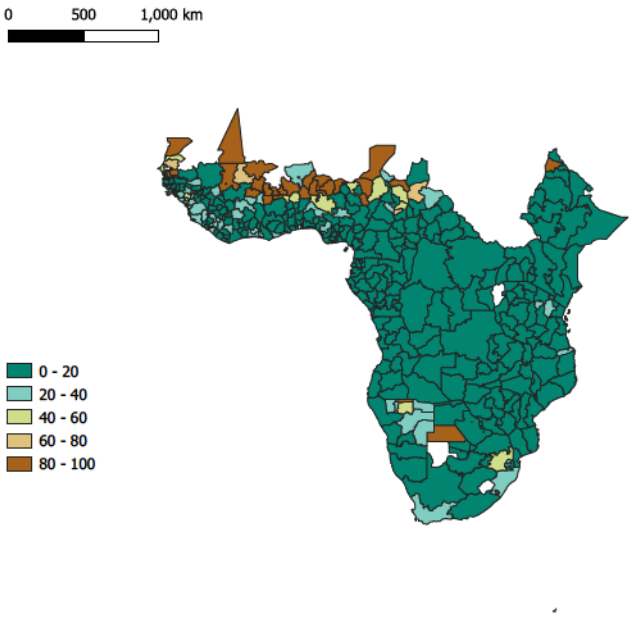


Figure B.2.1: Map of aggregate deforestation (2001-2019) for the 25% deforestation threshold in the sampled Sub-Saharan Africa countries

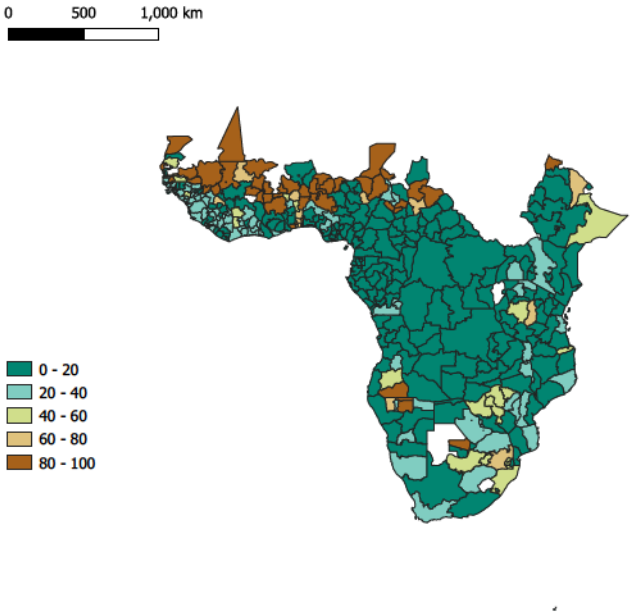


Figure B.2.2: Map of aggregate deforestation (2001-2019) for the 50% deforestation threshold in the sampled Sub-Saharan Africa countries

C. Oster's test for coefficient stability

The focus of this article is on the ecological legacies of the past, so reverse causality can be ruled out by design; however, endogeneity concerns cannot be dismissed. A possible approach to address them is to apply a coefficient stability test. The purpose of this test is to assess the bias from unobservable confounders using the selection on observables in the regressions' specifications. I implement Oster's test (Oster, 2019) that has been used in other political economy contributions (Ricart-Huguet, 2021) and aims to build consistent bounds around the true value of the key independent variables. If the bounds exclude 0, this means that unobservables are less important than observables and that the treatment effect on the outcome excludes 0. In order to calculate Oster's bounds, a value of R^2_{max}, which is the R^2 in hypothetical regressions of deforestation on ethno-linguistic diversity and all observable and unobservable (i.e., unknown) controls. Relying on Ricart-Huguet (2021), I calculate Oster's bounds with $R^2_{max} = 1.1\hat{R}^2$, $R^2_{max} = 1.2\hat{R}^2$, $R^2_{max} = 1.3\hat{R}^2$ which means to increase the observed $\hat{R}^2$ with 10%, 20%, and 30%, respectively. Furthermore, I implement $R^2_{max} = 1.8\hat{R}^2$, Oster's suggestion to use $R^2_{max} = \min[2.2\hat{R}^2, 1]$ and the most conservative approach to set $R^2_{max} = 1$ (González and Miguel, 2015). A key component in Oster's test, δ, is defined as the ratio of unobservables to observables and provides insight regarding the importance of unobservables to observables in order for the regression coefficients of ELF and ELP to become 0. Similarly to Ricart-Huguet (2021), I calculate Oster's bounds for $\delta = 1$ at which unobservables and observables have equal importance.

Table C.2.1: Results from Oster's test

R^2_{max}	$= 1.1\hat{R}^2$	$= 1.2\hat{R}^2$	$= 1.3\hat{R}^2$	$= 1.8\hat{R}^2$	$= \min[2.2\hat{R}^2, 1]$	$= 1$
	(1)	(2)	(3)	(4)	(5)	(6)
			$ln(DFO_{25\%})$			
$\delta_{ELF_{\gamma=2}}$	[1.56, 1.58]	[1.56, 1.60]	[1.56, 1.63]	[1.56, 1.81]	[1.56, 2.09]	[1.56, -1.84]
$\delta_{ELP_{\gamma=2}}$	[0.93, 0.94]	[0.93, 0.95]	[0.93, 0.96]	[0.93, 1.07]	[0.93, 1.23]	[0.93, -0.56]
$\delta_{ELF_{\gamma=4}}$	[1.29, 1.30]	[1.29, 1.32]	[1.29, 1.33]	[1.29, 1.44]	[1.29, 1.59]	[1.29, 5.11]
$\delta_{ELP_{\gamma=4}}$	[0.96, 0.97]	[0.96, 0.98]	[0.96, 0.99]	[0.96, 1.07]	[0.96, 1.19]	[0.96, -0.40]
$\delta_{ELF_{\gamma=6}}$	[1.09, 1.06]	[1.09, 1.03]	[1.09, 0.99]	[1.09, 0.64]	[1.09, -0.43]	[1.09, -20.05]
$\delta_{ELP_{\gamma=6}}$	[1.04, 1.01]	[1.04, 0.98]	[1.04, 0.94]	[1.04, 0.52]	[1.04, -1.02]	[1.04, -18.18]
$\delta_{ELF_{\gamma=8}}$	[1.00, 1.01]	[1.00, 1.03]	[1.00, 1.04]	[1.00, 1.21]	[1.00, 2.15]	[1.00, 0.71]
$\delta_{ELP_{\gamma=8}}$	[1.10, 1.13]	[1.10, 1.17]	[1.10, 1.23]	[1.10, 1.96]	[1.10, -0.69]	[1.10, 0.50]
			$ln(DFO_{50\%})$			
$\delta_{ELF_{\gamma=2}}$	[1.49, 1.53]	[1.49, 1.58]	[1.49, 1.63]	[1.49, 1.99]	[1.49, 2.51]	[1.49, -4.02]
$\delta_{ELP_{\gamma=2}}$	[0.94, 0.97]	[0.94, 1.00]	[0.94, 1.04]	[0.94, 1.29]	[0.94, 1.68]	[0.94, -2.12]

Continued on next page

Table C.2.1 – continued from previous page

R^2_{max}	$= 1.1\hat{R}^2$	$= 1.2\hat{R}^2$	$= 1.3\hat{R}^2$	$= 1.8\hat{R}^2$	$= \min[2.2\hat{R}^2, 1]$	$= 1$
$\delta_{ELF_{\gamma=4}}$	[1.47, 1.52]	[1.47, 1.56]	[1.47, 1.61]	[1.47, 1.93]	[1.47, 2.35]	[1.47, -6.30]
$\delta_{ELP_{\gamma=4}}$	[1.15, 1.19]	[1.15, 1.23]	[1.15, 1.29]	[1.15, 1.65]	[1.15, 2.18]	[1.15, -2.52]
$\delta_{ELF_{\gamma=6}}$	[1.12, 1.14]	[1.12, 1.16]	[1.12, 1.19]	[1.12, 1.44]	[1.12, 2.01]	[1.12, -0.08]
$\delta_{ELP_{\gamma=6}}$	[1.03, 1.06]	[1.03, 1.08]	[1.03, 1.11]	[1.03, 1.40]	[1.03, 2.15]	[1.03, 0.05]
$\delta_{ELF_{\gamma=8}}$	[0.97, 1.02]	[0.97, 1.08]	[0.97, 1.14]	[0.97, 1.69]	[0.97, 2.78]	[0.97, -0.72]
$\delta_{ELP_{\gamma=8}}$	[1.12, 1.20]	[1.12, 1.29]	[1.12, 1.41]	[1.12, 2.46]	[1.12, 4.06]	[1.12, -0.48]

Oster's bounds consist of estimates of regression coefficients of ethno-linguistic diversity from two regressions. The lower bound is from the main regression specifications in Figures 2.1– 2.2. The upper bound is for the specified in this table R^2_{max} and Oster's δ, defined as the ratio of unobservables to observables, equal to one. This value of δ means that unobservables and observables have equal relevance. The bounds only include 0, meaning that unobservables become more important than observables, only if R^2 increases in some of the cases by 220% or more, which is unlikely to happen.

List of countries in the full sample

Due to data quality and availability considerations, the analysis is restricted to the following 35 countries, for which high quality survey data on human diversity are available (Gershman and Rivera, 2018): Angola, Benin, Botswana, Burkina Faso, Cameroon, Central African Republic, Chad, Republic of the Congo, Côte d'Ivoire, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe. Although human diversity data is available for Djibouti, similarly to Bare et al. (2015), I exclude this country from the analysis because its values for the implemented deforestation thresholds are zero. In a similar vein, all administrative units in the sampled 35 countries that have zero values for the implemented deforestation thresholds are excluded from the analysis.

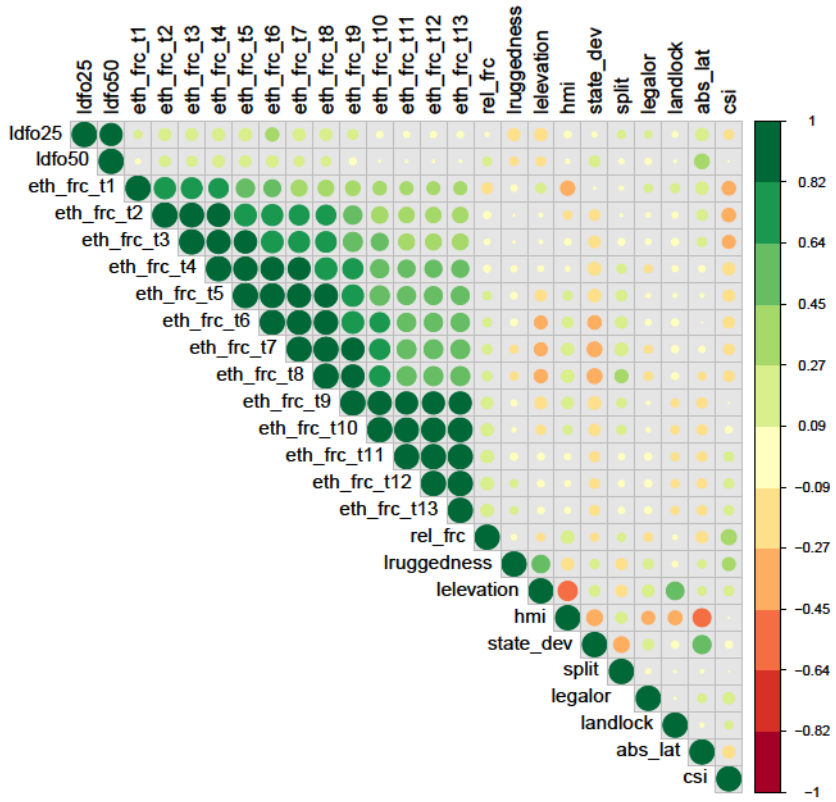


Figure C.2.1: Correlation plot of deforestation, fractionalisation and all controls

Note: ldfo25 and ldfo50 stand respectively for the 25% and 50% log-transformed deforestation aggregate thresholds for the period 2001-2019, eth_frc_1–eth_frc_13 – for tiers 1–13 of ethno-linguistic fractionalisation, rel_frc – for religious fractionalisation, lruggedness – for log-transformed ruggedness, lelevation – for log-transformed elevation, hmi – for the Human Mobility Index (Özak, 2010, 2018), state_dev – for the level of for precolonial state development (Gennaioli and Rainer, 2007; Nunn, 2008; Larcom et al., 2016), split – for ethnic groups that are divided by colonial borders (Ziltener and Künzler, 2013), legalor – for legal origin (Nunn, 2008), landlock – for landlocked status (Collier, 2008; Michalopoulos and Papaioannou, 2017), abs_lat – for absolute latitude, csi – for the Caloric Suitability Index (Galor and Özak, 2015, 2016).

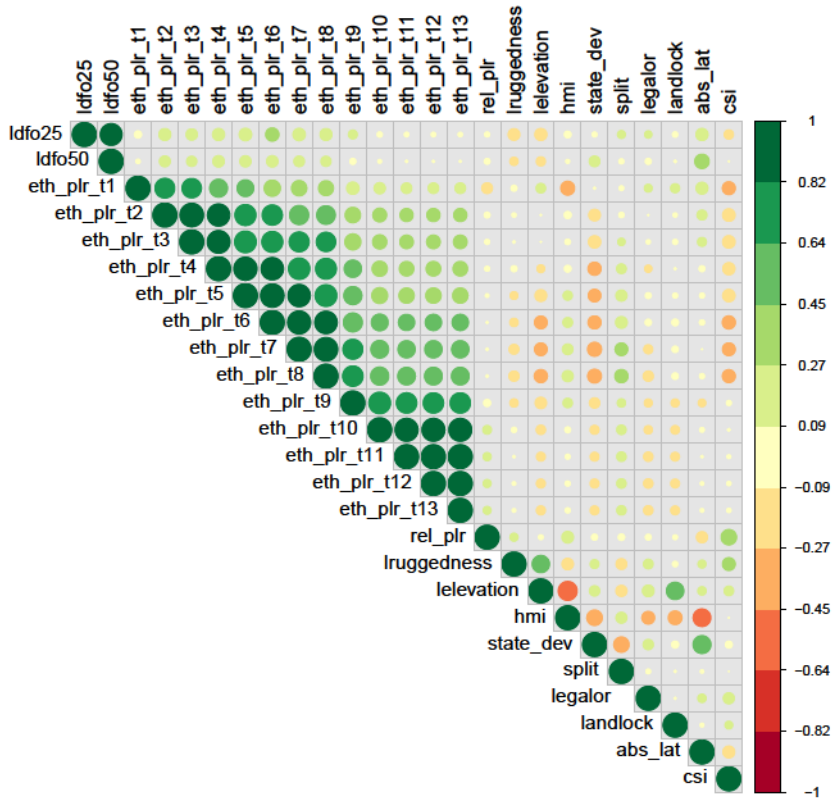


Figure C.2.2: Correlation plot of deforestation, polarisation and all controls

Note: ldfo25 and ldfo50 stand respectively for the 25% and 50% log-transformed deforestation aggregate thresholds for the period 2001-2019, eth_plr_1–eth_plr_13 – for tiers 1–13 of ethno-linguistic polarisation, rel_plr – for religious polarisation, lruggedness – for log-transformed ruggedness, lelevation – for log-transformed elevation, hmi – for the Human Mobility Index (Özak, 2010, 2018), state_dev – for the level of for precolonial state development (Gennaioli and Rainer, 2007; Nunn, 2008; Larcom et al., 2016), split – for ethnic groups that are divided by colonial borders (Ziltener and Künzler, 2013), legalor – for legal origin (Nunn, 2008), landlock – for landlocked status (Collier, 2008; Michalopoulos and Papaioannou, 2017), abs_lat – for absolute latitude, csi – for the Caloric Suitability Index (Galor and Özak, 2015, 2016).

Table C.2.2: Descriptive statistics of the full sample

Statistic	N	Mean	St. Dev.	Min	Max
$ln(DFO_{25\%})$	287	2.19	1.16	-1.06	4.61
$ln(DFO_{50\%})$	287	2.62	1.27	-0.74	4.61
$ELF_{\gamma=1}$	287	0.06	0.13	0.00	0.67
$ELF_{\gamma=2}$	287	0.13	0.18	0.00	0.78
$ELF_{\gamma=3}$	287	0.16	0.20	0.00	0.80
$ELF_{\gamma=4}$	287	0.20	0.23	0.00	0.81
$ELF_{\gamma=5}$	287	0.25	0.27	0.00	0.85
$ELF_{\gamma=6}$	287	0.29	0.29	0.00	0.89
$ELF_{\gamma=7}$	287	0.32	0.30	0.00	0.92
$ELF_{\gamma=8}$	287	0.34	0.30	0.00	0.92
$ELF_{\gamma=9}$	287	0.42	0.27	0.00	0.92
$ELF_{\gamma=10}$	287	0.49	0.26	0.00	0.92
$ELF_{\gamma=11}$	287	0.52	0.26	0.00	0.95
$ELF_{\gamma=12}$	287	0.53	0.26	0.00	0.95
$ELF_{\gamma=13}$	287	0.53	0.26	0.00	0.95
$ELP_{\gamma=1}$	287	0.11	0.24	0.00	1.00
$ELP_{\gamma=2}$	287	0.24	0.32	0.00	1.00
$ELP_{\gamma=3}$	287	0.27	0.32	0.00	1.00
$ELP_{\gamma=4}$	287	0.32	0.32	0.00	0.99
$ELP_{\gamma=5}$	287	0.35	0.33	0.00	0.98
$ELP_{\gamma=6}$	287	0.36	0.32	0.00	0.97
$ELP_{\gamma=7}$	287	0.39	0.33	0.00	0.97
$ELP_{\gamma=8}$	287	0.40	0.32	0.00	0.98
$ELP_{\gamma=9}$	287	0.52	0.28	0.00	1.00
$ELP_{\gamma=10}$	287	0.56	0.25	0.01	0.99
$ELP_{\gamma=11}$	287	0.57	0.23	0.01	0.99
$ELP_{\gamma=12}$	287	0.57	0.23	0.01	0.99
$ELP_{\gamma=13}$	287	0.57	0.23	0.01	0.99
State development	287	0.47	0.29	0.00	1.00
Split ethnic groups	287	1.81	0.39	1.00	2.00
Legal origin	287	0.44	0.50	0.00	1.00

Continued on next page

Table C.2.2 – continued from previous page

Statistic	N	Mean	St. Dev.	Min	Max
Human Mobility Index	287	0.30	0.03	0.21	0.39
Caloric Suitability Index	287	1488.50	392.39	4.46	2348.41
Landlocked status	287	0.72	0.45	0.00	1.00
ln(elevation)	287	-1.11	1.11	-5.18	0.85
ln(ruggedness)	287	-3.56	0.90	-7.50	-1.18
Absolute latitude	287	9.00	5.50	0.08	27.06

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Chapter 3

Deforestation, political elites and educational investments: Evidence from East and West Africa

Iva Mihaylova

Abstract

Deforestation is one of the most pressing challenges for humanity and in Africa—the focus of this article—its rates are particularly alarming. I build on the literature of the historical legacies and persistence of comparative development, focus on two factors—colonial education and political elites as its frequent consumers—and study their role for contemporary deforestation at the district level in sixteen former British and French colonies in eastern and western Africa. I find that districts in the former British colonies with higher investments in colonial education are less deforested today. Greater investments in colonial education are detrimental to contemporary forests in the French sample. In this article, political elites are proxied by cabinet ministers because they fundamentally influence the distribution of resources in settings where the official institutions are weak. I find that political elites have different forest "footprints" after independence and explain this finding with the dating back and persisting until today consequences of unequal colonial-era education. Overall, the results suggest that a better understanding of human capital and of African political elites at the subnational level could be key for the future of African sustainable development.

3.1. Introduction

Deforestation is one of the most pressing challenges for humanity and is directly linked to biodiversity loss, acceleration of climate change, heat-related health threats, disease outbreak, soil erosion, and diminished access to clean drinking water (Van der Werf et al., 2009; Hansen et al., 2013; Mapulanga and Naito, 2019; Masuda et al., 2019; Pennisi, 2020; Abman and Lundberg, 2020; Morand and Lajaunie, 2021). According to FAO & UNEP (2020), in Africa—the focus of this article—the rates of deforestation rank first in a global perspective and are accelerating: "*Africa had the highest net loss of forest area in 2010–2020. [...] Since 1990, Africa has reported an increase in the rate of net loss*" (11). At the same time, forests are a major, still available, natural solution to address the catastrophic consequences of climate change due to their ability to store carbon (Seymour and Busch, 2016). Furthermore, forests could reduce the total CO_2 emissions by 30 percent, which is required to keep warming below the 2 degree target though 2030 (Griscom et al., 2017; Popkin, 2019).

This article is motivated by a growing body of work that undertakes a historical approach and highlights that a substantial proportion of the variation in contemporary political, economic, and social outcomes has its roots in the past (Acemoglu et al., 2001; Huillery, 2009; Fenske, 2010, 2011; Hariri, 2012; Galor and Özak, 2015, 2016; Paine, 2019; Quoc-Anh et al., 2020; Nunn, 2020; Ricart-Huguet, 2021a,b). This literature on the historical legacies and persistence of comparative development frequently focuses on the impact of colonialism on development (Nunn, 2008; Galor and Özak, 2016; Galor et al., 2016), political regimes (Hariri, 2012), conflict (Arbatlı et al., 2020), and institutions (Acemoglu et al., 2001) but rarely on political elites or on investments, including in education (Ricart-Huguet, 2021a), that are shown to matter for contemporary outcomes (Woodberry, 2012; Cagé and Rueda, 2016, 2020). Furthermore, with the notable exception of Larcom et al. (2016), who focus on pre-colonial institutions, the legacies of the past for contemporary deforestation remain out of the scope of this literature. This article addresses these research gaps by undertaking a quantitative approach and by focusing on 311 districts within sixteen former British and French colonies in Africa. The analysis begins by highlighting why colonial-era educational investments[3] may play a persistent role in contemporary deforestation.

The motivation for this research focus is as follows. First, Cagé and Rueda (2016) demonstrate that early Protestant missionaries as principal providers of education in the British colonies of sub-Saharan Africa have had long-term effects on contemporary and regional civic and social capital, reflected by higher educational achievements, political participation, and newspa-

[3]The notions "education", "educational investments" and "investments in education" are used synonymously.

per readership. Second, Ricart-Huguet (2021a) shows that colonial education persists until the present day and is positively associated with current educational achievements for the same geographical region and units of analysis as the ones in this article. Third, a growing literature that has taken an ahistorical approach highlights the existence of a link between contemporary measures of education on the one hand and pro-environmental attitudes and the quality of the natural environment on the other hand (Beiser-McGrath and Bernauer, 2020; Ahmed and Wang, 2019; Iorember et al., 2021; Tang et al., 2021). The logical sequence of these contributions and their findings highlights the possibility that educational investments from the distant past—through their demonstrated persistence for the sample of countries in this article and the highlighted relationship between contemporary education versus quality of the natural environment—still shape contemporary deforestation.

In the second part of the analysis with the same geographical focus as the first one, I build on the established role of past education for a variety of contemporary outcomes (Ricart-Huguet, 2021a) and focus on political elites as common consumers of education before the easing of human capital constraints through the waves of democratisation in postcolonial Africa. Political elites are fundamental actors in political economy accounts of domestic distributive struggles for resources (Albertus and Menaldo, 2014; Albertus, 2015), democratisation (Collier, 1982; Albertus and Menaldo, 2014; Best et al., 2018), and political representation (Arriola, 2009; Kroeger, 2017). In addition, "*political elites in many developing countries continue to regard [...] forests as an endless source of potential wealth*" (McCarthy and Tacconi (2011), 119). However, little research systematically analyses the role of political elites for contemporary deforestation in Africa in a larger N comparative setting. This is surprising, given the number of micro-level studies that focus on diverse local contexts and confirm that postcolonial political elites accelerate deforestation in Africa (Bates, 1981; Ribot, 1993; Kanyinga, 2000; Rose, 2002; Larson and Ribot, 2007; Klopp, 2012; Morjaria, 2013; Ayana et al., 2013; Boone, 2014; Ongolo, 2015; Ongolo et al., 2018).

I build on Ricart-Huguet (2021a) in the second part of the analysis with a focus on political elites. He shows that the practice of the self-interested European colonisers to train Africans in colonial schools, including in those that have turned into elite cradles, with the goal to hire them afterwards in the colonial civil service for a fraction of the money they would pay to European administrators, still affects contemporary distributive politics, development, and regional political representation in these regions. As a pathway for the persistent role of colonial education, the author highlights the fact that *colonial education created a functioning till contemporary times for recruitment purposes limited pool of Africans* whose literacy and numeric skills are highly relevant and directly transferable to the *civil* service, including for potential cabinet minister positions. In contrast, *military* men did not enjoy the same access to high quality colonial education; some

of them were school dropouts or never attended school (Ricart-Huguet, 2021a). This colonial-era education rule with durable consequences until today has obviously influenced their career paths away from the important for political representation and distribution of (natural) resources civil service.

The fact that the colonial-era education of African political elites influences their career paths up to the present is relevant in the context of the findings of Dreher et al. (2009). The authors suggest that the educational background of political leaders matters for the policy choices that they make. The findings of Dreher et al. (2009) also speak to research on corporate governance that studies what types of managers, with what qualities and what characteristics, drive their companies forward when it comes to better environmental performance. In particular, Lewis et al. (2014) find that CEOs with an MBA degree are considerably more likely to voluntarily disclose environmental information.

Against the background of Dreher et al. (2009) and Lewis et al. (2014), there are good reasons to expect that political leaders' educational background also influences their choices concerning the natural environment. I contend that African postcolonial military versus civilian political elites systematically differ in their forest "footprints" and motivate my expectation with their divergent—dating back to the colonial era, and having persistent consequences until today—educational background.

Political elites tend to favour their birth regions when distributing resources (Hodler and Raschky, 2014). Favouritism is a well-known practice in this setting and ample evidence suggests that forest management in Africa is not an exception to this reality. Therefore, in part three of the analysis I study whether favouritism of civilian and military governments accelerates contemporary deforestation in the sampled African countries.

In the first part of the analysis, I show that investments in colonial education play a durable role for contemporary deforestation in the sixteen former British and French colonies in Africa: a beneficial one in the former and a detrimental one in the latter. In the second part of the analysis, I proxy postcolonial political elites with military and civilian cabinet ministers[4] because they fundamentally influence the distribution of resources (Ricart-Huguet, 2021a), to which category also belong forests. I find that post-colonial military cabinet ministers have consistently accelerated deforestation for lower, intermediate, and higher thresholds of deforestation. In contrast, post-colonial civilian cabinet ministers, although to a rather limited extent, seem to be beneficial to forests. In the final part of the analysis, I show that favouritism is a key mechanism to understand the detrimental role of post-colonial military political elites, but it has no explanatory

[4]The notions "military/civilian ministers", "born in the district cabinet ministers in military/civilian governments" and "military/civilian minister-share by district" are used interchangeably in this article.

power in the case of civilian political elites. Overall, the results suggest that a better understanding of human capital and of African political elites at the subnational level could be key for the future of African sustainable development.

While the central contribution of this article speaks to the body of work on the legacies of the past, it also complements prior research that assesses the relative performance of military versus civilian regimes with an exclusive focus until the moment on their political or economic (Collier, 1978; Omo-Bare, 1990; May et al., 2004) but not on their environmental performance. The study also contributes to the body of work on subnational development, prevalence of favouritism, public goods provision, natural resource management in low-income and developing countries, and on depletion of common resources (Ostrom, 1990; Hardin, 2009; Bernauer and Koubi, 2009; Hodler and Raschky, 2014; Alesina et al., 2019).

My empirical strategy includes regression models with country fixed effects and a rich set of geographic, pre-colonial, and colonial controls. I show that the main results do not change qualitatively when subsets of controls or no controls are used and when the capital cities are excluded. The results also remain stable if the highly skewed dependent variable, defined at various deforestation thresholds (Bare et al., 2015), is log-transformed, not transformed or transformed via the inverse hyperbolic sine (IHS) transformation. Still, it is possible that omitted variables bias the results. To address endogeneity concerns, I perform coefficient stability tests (Oster, 2019) in order to assess how likely it is that unobservables explain the results. I find that in order for this to happen, the importance of unobservables must become on average disproportionally larger than that of observables, which is unlikely to happen.

The rest of the article proceeds as follows. The next section develops the theoretical arguments and builds hypotheses about the links between the dependent variable (various deforestation thresholds) and the two sets of independent variables (colonial educational investments and political elites). Subsequently, I introduce the data, data processing considerations, and empirical model, and discuss the results and robustness checks. Finally, I explain the implications of the analysis and offer directions for future research.

3.2. Theoretical framework

The year 1960, the first year of observation of political elites in this article, is conventionally accepted as the year of Africa's independence from imperial rule *"for the good reason that it saw the end of colonial rule in most of the French colonies south of the Sahara as well as in the most populous British and Belgian ones (Nigeria and Congo respectively)"* (Austin (2010), 11). The multiparty systems

initially introduced after the formal political independence were swiftly banned (Collier, 1982) and the political regime became authoritarian. The subsequent waves of democratisation brought a beneficial transformation for the common people through the introduction of public policies and political practices. This process, however, was also marked by political instability (Bates, 2015). The turbulence of democratic transition has also proven to be detrimental to forests (Klopp, 2012; Morjaria, 2013; Sanford, 2020).

Figure 3.1 presents the dynamics of the post-colonial political regimes in the sampled countries in East and West Africa and illustrates their complex and uneven journey with periods of movements towards democratisation and backsliding towards autocracy. This figure also motivates the initial focus of the literature review on theories from the two extreme poles of the political system—autocracies and democracies—to answer the question of which of them performs better in addressing the human impact on the natural environment as well as how and why and to provide part of the background for the hypotheses subsequently formulated in this section.

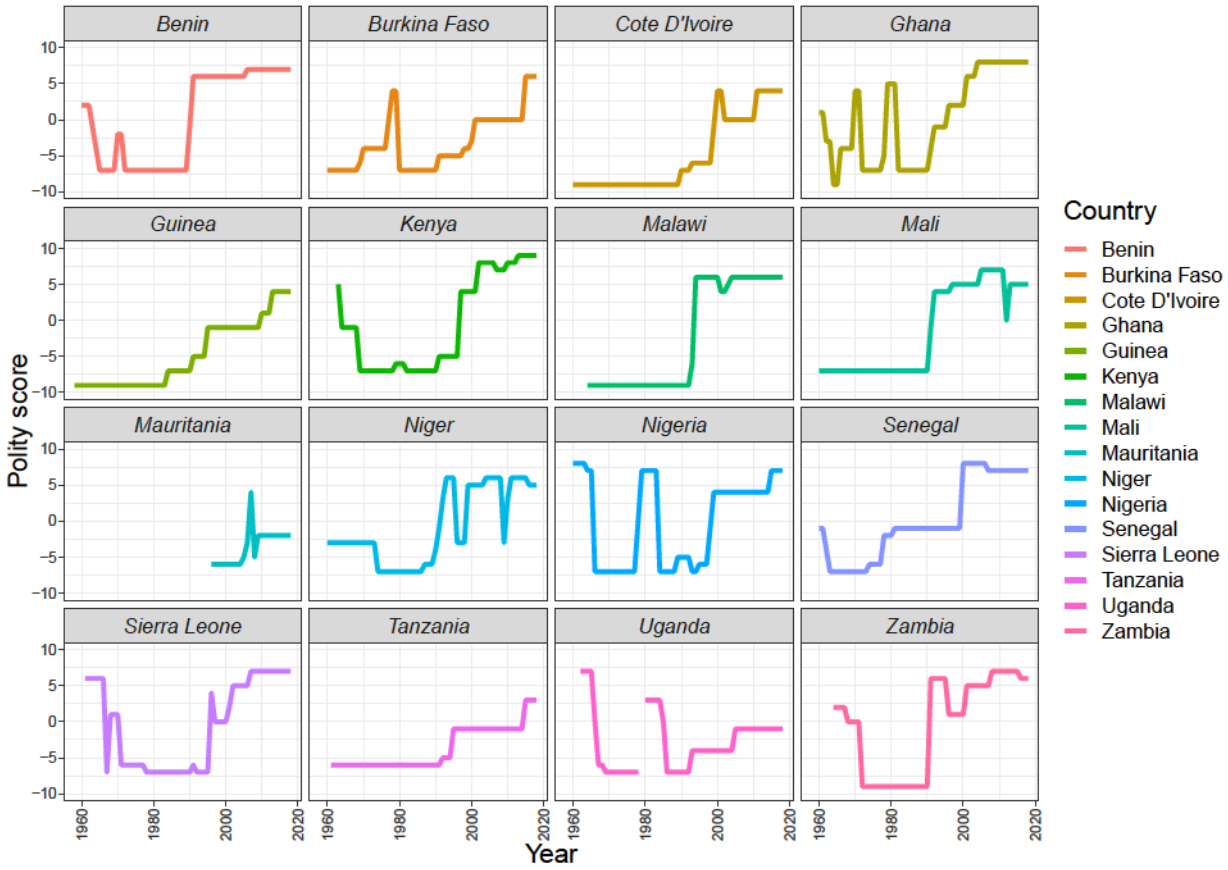


Figure 3.1: This figure represents the 1958-2018 dynamics of the variable Polity2 from the popular Polity5 database, which monitors political authority trends (Marshall and Gurr, 2020). For this variable, the authors coded the characteristics of political regimes on a 21-point scale in the interval [-10, 10] as follows: autocracies [-10, -6], undefined regimes [-5, 5], and democracies [6, 10].

The literature on the link between democracy and environmental quality is extensive. A

prominent theoretical argument on the role of democracy in the provision of essential public goods, including environmental quality and reducing human pressures on the terrestrial biosphere, concerns the median voter, who decides which public policies will be implemented (Bernauer and Koubi, 2009). In such a setting, with well-developed democratic institutions, political leaders have the incentive to consider the policy preferences of the broad electorate because they depend on it for their re-election (Spilker, 2008). The tendency to participate in international environmental agreements, freedom of expression for bringing new relevant environmental topics to the discussion, free media, which increases environmental awareness, democratic accountability, and freedom of association to mobilise and lobby are further mechanisms that promote environmental quality under democratic forms of government (Povitkina, 2018; Povitkina and Jagers, 2021).

Despite the existence of ample theoretical reasons to believe that an equal sign between democracy and environmental quality exists, a number of theoretical arguments suggest the opposite. Among the prominent ones is the short-term planning horizon of democratically elected governments that face electoral cycle constraints and apply re-election calculus (Congleton, 1992). As a result, such governments may be less willing to introduce stricter environmental policies and to consider policies' long-run horizon and future generations' interests, which are relevant for climate change (Bernauer and Koubi, 2009; Stadelmann-Steffen, 2011). The short-term focused interests of democratically elected governments may also motivate their opportunistic behaviour, generate corruption episodes, and cause them to cater to business interests (Povitkina, 2018). Similar to the competing theoretical arguments on whether democracy leads to better environmental quality, the existing empirical literature provides mixed evidence (Bernauer and Koubi, 2009; Povitkina, 2018; Povitkina and Jagers, 2021).

Although the literature explores the link between autocratic regimes and environmental quality to a much lesser extent, it has various different facets (Ward et al., 2014; Bruun, 2020; Carlitz and Povitkina, 2021). However, a central building block of the theoretical arguments is the various forms of elites. Since this article focuses on the role of political elites in deforestation, I review only the literature with an emphasis on political elites and, ideally, the quality of the natural environment. Departing from the binary definition of political systems as autocratic and democratic, De Mesquita et al. (2005) propose a theoretical model that aims to explain the factors that may shape the selection of autocratic political leaders and their resource allocation decisions. The authors argue that the size of the winning coalition determines the types of policies that the autocratic leader in power will enact. Concretely, when the winning coalition is big, political leaders have to provide more public goods to ensure their political survival. In contrast, when the winning coalition is small, leaders focus on providing the core supporters of their regime with a large amount of private benefits. In this setting, patronage politics and favouritism, which are com-

monly highlighted as a highly dominant feature of African politics, thrive (Arriola and Johnson, 2014; Hodler and Raschky, 2014; Kroeger, 2020).

Ward et al. (2014) extend De Mesquita et al.'s model to account for the impact on environmental quality of authoritarian rulers' T-period investment decisions. The logic of this model is as follows: autocratic rulers are much less politically accountable than those under democratic regimes and, therefore, enjoy much more freedom in their focused on rent extraction investment decisions. The increasing state capacity over time, reflected in Ward et al.'s model by a tax collection ratio, induces the leader to invest both in infrastructure and in environmental protection because they will generate more rents for the ruler. The model paints a grim picture of the link between autocratic regimes and environmental quality: "*environmental problems will get worse as a function of state capacity as long as infrastructural public goods investment is more productive of surplus than investment in environmental regulation*" (Ward et al. (2014), 331).

Ward et al. (2014) realistically model the dynamic investment decisions of political elites in authoritarian states as intertemporal choices between more infrastructure and better environmental quality. However, this model does not consider education as one of the possibilities to lead a country to a new, more sustainable, level of development. I focus on education and build expectations about the direction of its influence on the quality of the natural environment. The existing literature on the link between education and environmental quality is a useful starting point for building my expectations.

This literature primarily takes a ahistorical approach and provides competing theoretical explanations concerning the nexus between education and natural environment outcomes and attitudes. On the one hand, arguments for a negative relationship exist. The logic is as follows: better education is likely to increase personal income; consequently, richer people make a greater contribution to fossil fuels emissions because they consume more non-renewable goods and services (Beiser-McGrath and Bernauer, 2020; Tang et al., 2021). On the other hand, there are arguments for a positive link between education and environmental quality. Higher educational investments tend "*to direct individuals away from environmentally-damaging behaviour towards more efficient use of energy resources, increased awareness about the importance of environment protection and encourage participation in activities that promote and support a clean environment*" (Tang et al. (2021), 3). The empirical evidence concerning the link between education and environmental quality is mixed: null results in Busch and Ferretti-Gallon (2017) and Harring et al. (2020) and a positive association in Godoy et al. (1998), Ahmed and Wang (2019), Iorember et al. (2021), and Tang et al. (2021).

The literature that underscores the importance of history for explaining present-day outcomes

is closest and most relevant to the setting of this article. Such a contribution is the study by Cagé and Rueda (2016), who find that geographical proximity to printing press facilities introduced in the 19th century by protestant missionaries as principal providers of education in British colonial Africa is positively associated with contemporary education, political participation and higher newspaper readership. Furthermore, Ricart-Huguet (2021a) shows that colonial education persists until the present day and is positively associated with contemporary education for the same districts within the same former British and French colonies as the ones in this article. The findings of Ricart-Huguet (2021a) and Cagé and Rueda (2016) emphasise the possibility that educational investments from the distant past—through their demonstrated persistence for the sample of countries in this article and the highlighted relationship between contemporary education and contemporary quality of the natural environment (Beiser-McGrath and Bernauer, 2020; Ahmed and Wang, 2019; Iorember et al., 2021; Tang et al., 2021)—still shape contemporary deforestation.

I expect a negative association between colonial education and contemporary deforestation because education makes a life away from the traditional agriculture-based subsistence in many developing countries possible. Therefore, education should reduce the pressure of agriculture on forests (Dewees, 1995). Furthermore, Alemán and Kim (2015) show that increased levels of education have a democratising effect that is more pronounced in poor countries. In addition, the effect of colonial education, which persists to the present day, is shown to have a beneficial effect on contemporary socio-political outcomes Cagé and Rueda (2016). Linking the findings of Alemán and Kim (2015), Cagé and Rueda (2016) and Ricart-Huguet (2021a) to the waves of democratisation in Africa after independence (Ricart-Huguet, 2019a) and the literature on the relationship between democracy and the environment reinforces the expectation for an ongoing beneficial role of colonial education on the quality of the natural environment, including reflected by lower deforestation. Taken together, these arguments yield hypothesis 1:

> **HYPOTHESIS 1**: Higher investments in colonial education should **negatively** covary with contemporary deforestation.

Ricart-Huguet (2021a) provides evidence for the same sample of countries as used in this article that the total of the minister shares per district explains 42 percent of the association between colonial and contemporary education. The study shows that post-colonial ministers are a legacy by-product of a colonial-era education rule for recruitment into the civil service of the European colonial administration, which aimed to reduce its costs by selecting and training Africans for subsequent employment in its civil service. Military men were not members of the colonial civil service and did not enjoy such access to colonial high-quality education; some of them were even school drop-outs, or never attended school (Ricart-Huguet, 2021a). The author demonstrates that

this colonial period civil service recruitment rule established a durable and limited recruitment pool of highly qualified candidates for civilian service positions that continued to function and *favour* individuals on the basis of their education even after independence, when human capital constraints were reduced, for example as a result of the democratisation wave in the 1990s. Ricart-Huguet (2021a) finds that the effect of colonial education is more pronounced in post-colonial civilian that in military governments.

Hypothesis 1 is motivated by the highlighted link between colonial education and the quality of the contemporary natural environment. Hypothesis 2 builds on this theoretical foundation and complements it with the fact that the colonial educational background of military versus civilian elites differs and persists even in post-colonial Africa. To develop my expectations for hypothesis 2, I review the relevant literature that helps to answer the following questions: Is there scientific evidence that allows to assume that military and civilian elites differ in their ecological performance? Can the unequal access to colonial education explain these differences, and, if so, what is the direction of their expected association with deforestation?

The broader literature on the relative performance of military versus civilian regimes is a useful starting point for assessing their differences. It is suggested that they depend on the concrete context. A series of contributions reports evidence that a significant difference between civilian and military regimes consists of their political and rarely their economic performance (McKinlay and Cohan, 1975; Collier, 1982; Omo-Bare, 1990; May et al., 2004; Kasum, 2012). Compared with civilian regimes, military ones are found to score worse on measures like minimisation of violence, responsiveness to popular wishes, non-coercive rule, and legitimation (Nordlinger (1977), cited by May et al. (2004)). May et al. (2004) also draws the conclusion, based on the findings of Luckham (1991), that it is possible to make a safe generalisation that military regimes are usually—although to varying degrees—authoritarian.

The case study by Ayana et al. (2013) on Ethiopia reveals a key characteristic of military governments' leadership and how it affects forests. According to the authors, military governments did not allow environmental conservation demands and accountability to enter the political agenda and to challenge the dominant "*'capitalisation' policies or forestland use strategies*" (Ongolo et al. (2018), 1) in post-colonial Africa: "*the top-down command-and-control system of the [...] military government did not allow open competition between groups advocating strong production forestry and/or other land use options [...] due to the vanguard political nature of the then [...] military regime the underlying environmental conservation coalition had never posed visible challenge to the then dominant production forestry coalition*" (Ayana et al. (2013), 190–191).

The tenure of military regimes is usually short and prone to instability (Geddes, 2003; Kroeger,

2020). Such conditions are also conductive to deforestation (Burgess et al., 2015; Kikuta, 2020; Anders, 2020). Ongolo et al. (2018) observe this phenomenon in Côte d'Ivoire. The authors suggest the conversion of forests into agricultural land as a concrete mechanism that accelerates deforestation in this setting: *"According to a United Nations Environment Programme report [...], the 2002–2010 'political-military' crises had a strong impact on forest ecosystem sustainability. The number of classified forestlands ('forêts classées') that were transformed into agricultural lands doubled during the crisis period, according to the UNEP estimations from 575,300 ha in 2002 to close to 1,300,000 ha in 2012"* (13).

Up to this point, the arguments introduced suggest that military political elites may be detrimental to forests. However, a key difference between civilian and military governments in the post-colonial sample of East and West African countries is their educational background, dating back to colonial times. Civilians have had access to high-quality colonial education; in contrast, their military counterparts could be school drop-outs or could lack education entirely (Ricart-Huguet, 2021a). Besley et al. (2011) complement this line of research by suggesting that more highly educated individuals have a beneficial effect on economic growth. Dreher et al. (2009) report evidence that the educational and professional background of governors can successfully explain their policy choices. These findings of the political economy literature speak to research on corporate governance that studies what types of managers, with what qualities and what characteristics, drive their companies forward when it comes to better environmental performance. In particular, Lewis et al. (2014) find that CEOs with an MBA degree are considerably more likely to voluntary disclose environmental information. The combination of arguments so far implies that education in the past, due to its shown persistence till today, may affect indirectly deforestation through the profile of chosen (or not) to be trained political elites and their subsequent different policy choices.

What expectations can be built regarding the forest "footprints" of civilian political elites? The fact that civilian governments were formed by well-educated Africans could influence their decision making. Ricart-Huguet (2021a) suggests that a background in elite schools is likely to motivate civilian governors to allocate more revenues to education than their military counterparts. Omo-Bare (1990) provides evidence that civilian regimes have allocated a larger share of the gross domestic product to education and health expenditures than military regimes. The literature presented for hypothesis 1 demonstrates that a greater supply of education may lead to less deforestation. Against this background, my expectation is that civilian elites are less detrimental to Africa's forests due to their educational background, which can motivate them to invest more in education, subsequently leading to more sustainable development (Tang et al., 2021). This argument does not deny but softens the detrimental effect of favouritism and political patronage (Ricart-Huguet, 2021a) on deforestation because higher investments in education will increase the

number of educated voters and their interest in holding politicians accountable for their decisions (Hodler and Raschky, 2014) including concerning forest management.

In the same pro-environmental direction work the waves of democratisation in Africa, which facilitated increasingly democratic, participatory, and competitive elections and enabled the reinforcement of democratic values (Ricart-Huguet, 2019a). The latter should work pro-environmentally, as the literature on the link between democracy and environmental quality has revealed. Against the background of this literature and the fact that leaders' educational background influences their (pro-environmental) strategic decisions, civilian elites could be expected to have a lower forest "footprint" in comparison to their military counterparts.

These arguments lead to hypothesis 2 regarding political elites, using the shares of military and civilian ministers by district for each decade in the period 1960–2010 as proxies. Cabinet ministers are chosen because they play an influential role in the distribution of resources (Ricart-Huguet, 2021a), including forests. The key independent variables defined in this way are denoted in the subsequent empirical analysis by ln(*Civilians*) and ln(*Military*), respectively. Hypothesis 2 reads as follows:

> **HYPOTHESIS 2**: Military minister-shares by district should **positively** covary more strongly with contemporary deforestation than civilian minister-shares by district.

Political elites tend to favour their birth regions when distributing resources (Hodler and Raschky, 2014). Favouritism is defined as the systematic preference of individuals in the provision of resources on the basis of criteria other than need or marginal value (Dickens, 2018). Favouritism could operate through political patronage networks (Jiang and Zhang, 2020; Ricart-Huguet, 2021a). The forest sector of Africa is not immune to this common practice. For example, Kanyinga (2000) provides evidence about abusive land allocation in Kenya that benefits both military and civilian political elites: *"mass allocations of prime lands or plots—hereafter referred to as 'grants from above'—are made to politicians, influential senior civil servants, military officers, aides to senior leaders, and other influential people or those who have the necessary connections to get presidential consent for such allocations. [...] The occupants are always evicted to give way to 'development'. They are not compensated for their tree crops or any development undertaken on the land"* (16).

The detailed case study by Klopp (2012) complements this evidence by showing that patrons in central state positions favour their clients in land allocation and destroy forests: *"With the Minister of the Environment a political appointee of the President, what this meant in practice was that the President and his associates could alter legal boundaries of forests. [...] they often did this without informing the relevant forestry officials [...] this made decisions over forest excisions susceptible to the politics of*

patronage" (356). Ribot (1993) provides similar evidence for favouritism operating via patronage politics in Senegal, which accelerates deforestation. Charcoal commerce, with key relevance to the country's economy, is highly concentrated in the hands of 15–20 rural merchants, who not only control the market but also have unofficial relationships with ministries, the forestry department, and other relevant institutions, such as unions, that help them to extract benefits and shape policies to their own advantage, which may involve "*cutting green trees*" (Ribot (1993), 580). The findings presented, with a focus on restricted geographic locations, suggest that favouritism can accelerate deforestation. They motivate hypothesis 3:

> **HYPOTHESIS 3**: The practised favouritism by post-colonial African governments should **positively** co-vary with contemporary deforestation.

3.3. Data and methods

To estimate the hypotheses, I combine high-resolution geospatial data on deforestation with historical data on post-colonial political elites and colonial educational investments in East and West Africa. I also include a variety of controls to address the potential omitted variable bias. The purpose of this section is to present the data and econometric approach used.

3.3.1. Dependent variable: Deforestation thresholds

The dependent variable are various deforestation rates. I calculate them on the basis of Version 1.7 of the geospatial dataset of Hansen et al. (2013). I choose these data due to their high resolution, frequent application it the related literature (Larcom et al. (2016); Bare et al. (2015); Leblois et al. (2017); Abman (2018); Abman and Carney (2020a,c); Abman and Lundberg (2020)), and the fact that "*the coverage is global, the method is accurate, and the data are not susceptible to interference from parties that seek to conceal or misrepresent information*" (Sanford (2020), 14).

Although highly popular before the emergence of the recent trend of combining geospatial methods and social science questions, I do not use the deforestation data of the UN Food and Agriculture Organization (FAO) due to the critique of Zabala (2018). In her study on Africa, she explains that the FAO uses a combination of different sources to compile its dataset, which "*may raise incomparability concerns due to differences in the acquisition of remote sensing data, on the algorithms and definitions of forest cover applied, and on the validation and calibration processes*" (Zabala (2018), 4).

A specific feature of Hansen et al.'s dataset is that it contains annual deforestation data and aggregate reforestation data, measured for different periods. This means that no netting between deforestation and reforestation data should be carried out because the different methodologies and time periods used will bias the results. Although not without caveats, Hansen et al.'s data are the best currently available data source. Therefore, following the related literature (Burgess et al., 2012; Bare et al., 2015; Leblois et al., 2017; Zabala, 2018; Alesina et al., 2019; Abman and Lundberg, 2020; Sanford, 2020), I use Hansen et al.'s deforestation data in the subsequent analysis.

These data allow for the calculation of the so-called deforestation thresholds or bounds (Hansen et al. 2013; Bare et al. 2015; Leblois 2017). If we take Version 1.7 of Hansen et al.'s data as an example, the thresholds indicate in which year between 2001 and 2019 the forest cover measured in the baseline year of 2000 dropped to zero. By adhering to this definition and by applying the computational algorithm of Leblois et al., the 25 percent threshold is calculated by considering as forest only grid cells with more than 25 percent forest cover in 2000 that contain trees with a height of more than 5 meters. If none of the grid cells with more than 25 percent of forest cover are deforested in a certain year, that is, they do not reach 0, 0 percent deforestation occurs for this particular threshold, and, if all the grid cells for the same threshold are deforested, a 100 percent deforestation rate is recorded. This means that, for each administrative unit in the sample, the deforestation measures vary between 0 percent and 100 percent for each threshold (Figures B.3.1–B.3.2 and Tables D.3.1–D.3.2).

Since these data are highly skewed, I log-transform them as a standard practice. As a robustness check, I apply the inverse hyperbolic transformation (IHS), defined as $\ln(x + \sqrt{(x)^2 + 1})$. The advantage of using IHS consists of the possibility of retaining zero deforestation rates, while its performance is similar to the log-transformed deforestation rates for the higher values (Bruederle and Hodler, 2018). Figures D.3.1–D.3.2 in the Appendix illustrate that the non-transformed, log-transformed, and IHS-transformed deforestation thresholds are highly correlated but the statistical distribution of the latter two is much closer to the normal one. A further robustness check that I implement involves re-estimating the econometric analysis for the non-transformed and highly skewed deforestation rates.[5]

Although Hansen et al.'s data allow me to calculate the gross deforestation rates and although computing the deforestation thresholds is optional, their implementation is particularly relevant because it allows me *"to examine varying forms of land use change and forest ecosystems in tropical regions"* (Bare et al. (2015), 4). Relying on Bare et al., who study the association of foreign aid and the 20 percent and, respectively, 50 percent deforestation threshold in Sub-Saharan Africa,

[5]Similarly to Bare et al. (2015), I exclude all administrative units with zero deforestation in this robustness check.

I calculate and log-transform all the deforestation thresholds with an incremental step of 5 percent between the lower and the upper bound implemented by them. The construction of the dependent variable with such refined granularity from high-resolution geospatial data allows me to increase the precision of the analysis of whether post-colonial political elites and colonial education are associated with lower, intermediate, or higher levels of deforestation.

3.3.2. Independent variables: Colonial education and political elites

The data sources of the two independent variables, colonial educational investments and post-colonial elites, are Huillery (2009) and Ricart-Huguet (2021a). These data were collected and aggregated by using digitalised maps from Gallica, which is the digital repository of the French National Library. Figure E.3.1 presents an example of one of the maps used (Quoc-Anh et al., 2020). Due to data quality and availability considerations, I use the following proxies for education in the subsequent regression analysis: protestant missionaries (variable *Missions*) in the sample of former British colonies and public teachers (variable *Teachers*) in the sample of former French colonies. In the full sample, colonial educational investments (variable *Education*) are obtained by aggregating *Missions* and *Education*.

The political elites are represented by two sets of proxies, compiled over the period 1960–2010. The first one is the share of the cabinet ministers in military (variable *Military*) or civilian (variable *Civilians*) governments who were born in the respective district. The second one consists of two separate indicator functions that equal one if a head of the military government (variable $Heads_M$) or, respectively, a head of the civilian government (variable $Heads_C$) was born in one of the 311 districts in the sample. While the first proxy is broader and captures political representation, the second one specifically captures regional favouritism (Ricart-Huguet, 2021a; Hodler and Raschky, 2014). Due to their high degree of skewness, all the independent variables that are not defined as indicator functions are log-transformed for the regression analysis.

3.3.3 Control variables

The study builds on standard regression techniques. Four sets of controls that may influence political elites, colonial education, and deforestation are used in the regression specifications. First, pre-colonial institutions are demonstrated to matter for contemporary deforestation and development (Larcom et al., 2016; Nunn, 2020). As part of this group, I include variables that reflect the jurisdictional hierarchy beyond the local community, the type of slavery, settlement patterns, the intensity of agriculture, an ethnic fractionalisation index, an indicator of a kingdom

at the end of the 19th century, and an indicator of a trading post before the colonial conquest (Ricart-Huguet, 2021a).

I consider the following standard geographical controls that capture climatic conditions and the opportunity cost of keeping or cutting down trees (Abman, 2018): terrain elevation, ruggedness, an indicator variable showing whether the district contains navigable rivers, and the log-transformed area of the district (Ricart-Huguet, 2021a). The European colonisers had a profound environmental effect on the natural environment of Africa. Their detrimental impact partially stemmed from their agricultural practices to cultivate cash crops and to eradicate the rotation-based crops that were traditionally grown before their arrival (Crosby, 2004). To account for this change in the natural environment, I also incorporate into the analysis the post-1500 CE variant of the Caloric Suitability Index (CSI) by Galor and Özak (2015, 2016); Galor et al. (2016). It is a high-resolution spatial dataset with global coverage that reflects the potential agricultural yield of crops available for cultivation after the arrival of the European colonisers. Compared with the alternative approach of using indexes of land for agriculture as controls, the CSI is preferable because it captures more fully the large variation in the potential caloric yield for land that is equally suitable for agriculture (Galor and Özak, 2015). Therefore, the CSI is better suited to environmental quality and development studies because—in addition to mitigating endogeneity concerns by using potential crop yields—it captures better the opportunity cost of the alternative uses of land.

I consider colonial infrastructure, railroads and health expenditures in the analysis because they are alternatives in which the colonial empires have invested and because they may confound the role of colonial educational investments (Ricart-Huguet, 2021a). The regression analysis also includes variables that help to explain economic development: indicators of noble metals (gold, silver, and diamonds) and base metals as well as the mean of the 1960–2010 district population (Ricart-Huguet, 2021a). The source of the list of capital cities that I implement in the robustness checks is Ricart-Huguet (2021b).

3.3.4. Empirical Strategy

I focus on colonial districts within the sampled countries rather than on ethnic groups. The motivation for this choice is the argument for selecting as the level of analysis the one at which the data are collected and the fact that 80 percent of the colonial borders in the sample still exist while ethnic homelands have disappeared; hence, choosing them would force homogeneity where it frequently does not exist (Ricart-Huguet, 2021a). Although the dependent variable is longitudinal, the data on colonial education are cross-sectional and those on political elites are aggregated

for each decade in the period 1960–2010 (Ricart-Huguet, 2021a). Therefore, similarly to other contributions (Huillery, 2009; Woodberry, 2012; Galor and Özak, 2016; Galor et al., 2016; Larcom et al., 2016; Cagé and Rueda, 2016; Ricart-Huguet, 2021a,b; Quoc-Anh et al., 2020), I implement a cross-sectional setting with variants of the following regression specifications:

$$ldfo_{h\%\,i,c} = \alpha_1 + \alpha_2 Education_{i,c} + X'_{i,c}\alpha_3 + Country_c + \epsilon_{i,c} \quad (1)$$

$$ldfo_{h\%\,i,c} = \beta_1 + \beta_2 Military_{i,c} + \beta_3 Education_{i,c} + X'_{i,c}\beta_4 + Country_c + \zeta_{i,c} \quad (2)$$

$$ldfo_{h\%\,i,c} = \gamma_1 + \gamma_2 Civilians_{i,c} + \gamma_3 Education_{i,c} + X'_{i,c}\gamma_4 + Country_c + \xi_{i,c} \quad (3)$$

$$ldfo_{h\%\,i,c} = \delta_1 + \delta_2 Heads_{Mi,c} + \delta_3 Education_{i,c} + X'_{i,c}\delta_4 + Country_c + \phi_{i,c} \quad (4)$$

$$ldfo_{h\%\,i,c} = \kappa_1 + \kappa_2 Heads_{Ci,c} + \kappa_3 Education_{i,c} + X'_{i,c}\kappa_4 + Country_c + \psi_{i,c} \quad (5)$$

Log-transformed deforestation ($ldfo_{h\%}$), defined at thresholds of $h = [20\%, \cdots, 50\%]$ with an incremental step $\Delta = 5\%$ is the dependent variable in the main regression specifications. The coefficients of interest are: α_2 – for hypothesis 1 (with *Education* in the full sample, *Missions* in the British colonies sample and *Teachers* in the French colonies sample), β_2 and γ_2 – for hypothesis 2 as well as δ_2 and κ_2 – for hypothesis 3. I implement country fixed effects $Country_c$ in all regression models in order to restrict the variation of the main variables to their within-country values. Similarly to the study of Müller-Crepon (2020) on British and French colonial Africa, I cluster the standard errors at the province level to account for dependencies among districts within the same province. To increase the precision of the estimation, I stepwise add several sets of the introduced geographic, pre-colonial, and colonial variables and the district population (1960–2010) to the vector of controls X.

3.4. Results

For the purpose of clarity, the results are organised as follows. The estimates of the 35 percent deforestation threshold ($ldfo_{35\%}$) are representative of the results of the testing of hypotheses 1 and 2 and are presented in Tables 3.1–3.2, respectively. Complementary results for the rest of the deforestation thresholds are presented in Tables A.3.1–A.3.3 for the same hypotheses and models. Tables A.3.4–A.3.22 contain their robustness checks, Tables 3.3 and A.3.28 report the results of the testing of hypothesis 3, and Tables A.3.23–A.3.27—its robustness checks. All results are analysed in this section.

Table 3.1 reports the results for the 35 percent deforestation threshold for hypothesis 1. Col-

umn 1 contains the estimates for colonial education for the full sample, column 2 those for the former British colonies, and column 3 those for the former French colonies. As expected, the coefficient of education in the full and British samples is negative. Surprisingly, education has a positive association with deforestation in the French former colonies, which may be a result of their unsustainable growth. These estimates are obtained from regression models with a full set of geographical, pre-colonial, colonial controls, log-transformed population for the period 1960-2010 and country fixed effects.

Table 3.1: Log-transformed deforestation threshold 35% and colonial educational investments

Hypothesis 1	(1) Full sample	(2) British sample	(3) French sample
ln(Education)	-0.108*		
	(0.059)		
ln(Missions)		-0.266***	
		(0.079)	
ln(Teachers)			0.487*
			(0.230)
N	274	198	76
adj. R^2	0.439	0.306	0.281
Common additional terms:			
Geographical controls	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes
Country FE	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the 35% deforestation threshold ($ldfo_{35\%}$). The key independent variable is all regression specifications is a proxy of education. The regression models contain country fixed effects and a full set of controls, which consists of geographic (terrain elevation, ruggedness, an indicator variable whether the district contains navigable rivers, log-transformed area of the district, post 1500 version of the Caloric Suitability Index, noble and base metals indicators), pre-colonial (ethno-linguistic fractionalisation, intensity of agriculture, jurisdictional hierarchy beyond local community, type of slavery, indicator of a kingdom at the end of the nineteenth century, indicator of a trading post before the colonial conquest), colonial controls (infrastructure, health expenditures, railroad indicator) and log-transformed population (1960–2010).

Additional Table A.3.1 compares the 35 percent deforestation threshold and all the other deforestation thresholds in the range 20–50 percent. It shows that, for the whole sample, the results are statistically significant for all the deforestation thresholds that are equal to or higher than 30 percent. These results seem to be driven by the British sample, in which the results for all the deforestation thresholds in the range 20-–50 percent are statistically significant at the 1 percent significance level. In contrast, the French former colonies are statistically significant only for the intermediate deforestation thresholds of 30 and 35 percent. The results for the full and British samples remain robust to the exclusion of the colonial controls, the log-transformed population (Table A.3.4) and of all the controls (Table A.3.5). In these cases, the 30 and 35 percent deforestation thresholds in the French former colonies lose their statistical significance. However, this

may be due to the limited number of observations in this sample and the lower precision of the estimation when key controls are excluded.

Table 3.2: Log-transformed deforestation threshold 35% and minister-shares by district

Hypothesis 2	(1) 1960-69	(2) 1970-79	(3) 1980-89	(4) 1990-99	(5) 2000-10
Panel A: Military minister-shares by district (1960-2010) ln(*Military*)					
Full sample	0.101*	0.255***	0.093	0.187**	0.179*
	(0.052)	(0.078)	(0.064)	(0.084)	(0.100)
N	274	274	274	274	274
adj. R^2	0.440	0.455	0.440	0.449	0.449
British sample	0.066	0.268*	0.136**	0.095*	0.226
	(0.055)	(0.149)	(0.057)	(0.052)	(0.175)
N	198	198	198	198	198
adj. R^2	0.304	0.320	0.308	0.306	0.319
French sample	0.150	0.239**	0.070	0.349***	0.164
	(0.102)	(0.089)	(0.115)	(0.100)	(0.104)
N	76	76	76	76	76
adj. R^2	0.280	0.303	0.270	0.332	0.290
Panel B: Civilian minister-shares by district (1960-2010) ln(*Civilians*)					
Full sample	-0.019	-0.135*	-0.110*	0.008	0.039
	(0.040)	(0.071)	(0.059)	(0.073)	(0.052)
N	274	274	274	274	274
adj. R^2	0.437	0.446	0.443	0.436	0.437
British sample	-0.003	-0.083	-0.108*	0.003	0.056
	(0.053)	(0.074)	(0.053)	(0.075)	(0.040)
N	198	198	198	198	198
adj. R^2	0.302	0.307	0.312	0.302	0.304
French sample	0.005	-0.207	-0.094	0.063	-0.005
	(0.063)	(0.147)	(0.234)	(0.089)	(0.117)
N	76	76	76	76	76
adj. R^2	0.266	0.300	0.271	0.268	0.266
Common additional terms:					
Geographical controls	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the 35% deforestation threshold ($ldfo_{35\%}$). The key independent variables in the regression specifications are the military minister-shares by district ln(*Military*) in the upper panel and civilian minister-shares by district ln(*Civilians*) in the lower panel for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects.

Columns 1–5 in the upper panel of Table 3.2 contain the results for hypothesis 2 concerning the 35 percent deforestation threshold and military cabinet ministers for each decade in the period 1960–2010 with a full set of controls and country fixed effects. As expected, the coefficient of the military minister shares by district, ln(*Military*), is positive and statistically significant at the 10, 5, or 1 percent level for all the decades except 1980–1989. Additional Table A.3.2 shows that the results for the rest of the deforestation thresholds remain qualitatively unchanged.

Overall, the results for military cabinet ministers systematically confirm that they have contributed to deforestation in post-colonial Africa. It can be noted from Table A.3.2 that the results are consistently highly statistically significant at the 1 percent level for all the deforestation thresholds in the decade 1970–1979, when payment deficits deteriorated African countries' economic stability as a result of the first oil crisis (Van de Walle, 2001). In this regard, Omo-Bare (1990) suggests that military governments may be more successful in applying austerity measures through coercion and in reducing the budget spending requested by the IMF and the World Bank as external creditors, including cutting subsidies on important items such as food, housing, and transportation. This situation may have encouraged a turn to uncontrolled cutting down of trees for the land to be used for other activities, including agriculture. Studies that cover this period (Brink and Eva, 2009; Gibbs et al., 2010) confirm this trend. The results in Table A.3.2 are also highly statistically significant for the 1990s, when *"the trend [...] has been for African states to withdraw from basic developmental activities and focus the expenditures entirely on government consumption"* (Van de Walle (2001), 16). Additional Tables A.3.9 and A.3.10 for the military cabinet ministers reveal that they have played a detrimental role for forests in both the French and the British former colonies. However, they have made a stronger contribution to the overall results in the latter case than in the former one.

Columns 1–5 in the lower panel of Table 3.2 contain the regression results for hypothesis 2 concerning the 35 percent deforestation threshold and the civilian minister shares by district, ln(*Civilians*), for each decade in the period 1960–2010, with a full set of controls and country fixed effects. In contrast to their military counterparts and contrary to the expectation for hypothesis 2, civilian cabinet ministers seem to play a beneficial role for forests, reflected by a negative coefficient for ln(*Civilians*). However, the ecological efficiency or disciplining role of civilian cabinet ministers is of a modest extent as it can be observed for the full sample only for the 1970s and 1980s and seems to be driven by the British former colonies. Additional Tables A.3.3, A.3.16, and A.3.17 complement these results with estimates for all the other deforestation thresholds by splitting them into the full, British, and French samples, respectively. These additional results reveal that the negative association between civilian cabinet ministers and deforestation for the full sample is entirely driven by the former British colonies. As a robustness check, I re-estimate the regression models from Tables 3.2 and A.3.3 with country fixed effects but exclude colonial controls and post-colonial population (Table A.3.18) as well as without controls (Table A.3.19). The results remain stable in both cases.

The results for hypothesis 3 concerning favouritism of born in the district one or more military heads of government $Heads_M$ are reported in Table 3.3, and those for civilian heads of government $Heads_C$ in Table A.3.28. The regression models contain a full set of controls and country fixed

effects. These results suggest that only the military heads of government were detrimental to forests and are consistent with the prediction of hypothesis 3. The estimates in the full sample are statistically significant for lower to intermediate deforestation thresholds up to the 35 percent bound, and seem to be led by the French former colonies. In contrast, the coefficients of $Heads_C$ remain statistically insignificant for all deforestation thresholds in Table A.3.28.

Table 3.3: Log-transformed deforestation thresholds 20%–50% and heads of military governments

Hypothesis 3	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_M$	0.397**	0.403**	0.225*	0.215*	0.102	0.114	0.075
	(0.159)	(0.147)	(0.127)	(0.124)	(0.110)	(0.101)	(0.080)
N	281	278	275	274	270	269	266
adj. R^2	0.385	0.391	0.437	0.439	0.447	0.441	0.375
British sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_M$	0.159	0.223	0.117	0.120	0.023	-0.044	-0.073
	(0.204)	(0.190)	(0.179)	(0.172)	(0.146)	(0.140)	(0.113)
N	198	198	198	198	198	198	196
adj. R^2	0.297	0.308	0.306	0.303	0.300	0.303	0.244
French sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_M$	0.622**	0.574**	0.280	0.235	0.057	0.049	0.090
	(0.237)	(0.249)	(0.229)	(0.215)	(0.150)	(0.162)	(0.161)
N	83	80	77	76	72	71	70
adj. R^2	0.284	0.274	0.254	0.272	0.349	0.321	0.317
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable in all regression specifications are born in the district heads of military governments ($Heads_M$). The regression models contain a full set of controls and country fixed effects.

In addition to re-estimating the main regression models for the 35 percent deforestation threshold in Tables 3.1–3.3 and for all the other deforestation thresholds in Tables A.3.1–A.3.3 with subsets including controls and excluding controls, I transform the highly skewed deforestation measures with the inverse hyperbolic sine (IHS) transformation. These results are presented in Table A.3.6 for colonial education, Table A.3.13 for military cabinet ministers, Table A.3.20 for civilian cabinet ministers, and Table A.3.25 for measuring favouritism only among heads of military governments who were born in the district as their civilian counterparts are not statistically significant and do not participate in the robustness checks. Compared with the main regression estimates, the additional results do not change qualitatively except that public teachers, as a proxy

for colonial education in the French former colonies, become statistically insignificant, which may be due to the limited sample size.

As a further robustness check, I re-estimate the main regression specifications in Tables 3.1–3.3 and A.3.1–A.3.3 without transforming the deforestation measures. Tables A.3.7, A.3.14, A.3.21, and A.3.26 contain these additional results. They do not differ qualitatively from the IHS case. The results remain robust when I exclude the capital cities from the main regression models in Tables 3.1–3.3 and A.3.1–A.3.3. This robustness check is presented in Tables A.3.8, A.3.15, A.3.22 and A.3.27. The results remain stable.

To address endogeneity concerns, I conduct Oster's coefficient stability test (Oster, 2019) with regard to the main results in Tables 3.1–3.3 and Tables A.3.1–A.3.3. Part C of the Appendix contains the rationale for this test. Its results are presented in Table C.3.1. They exclude 0 and, hence, remain robust except for ln(*Civilians*) for the most conservative $R^2_{max} = 1$. The latter result is not a reason for concern as such a high value of R^2 is unlikely to be reached in a real world application.

3.5. Conclusion

A wide range of literature points out that contemporary development cannot be fully understood without taking into consideration its historical roots. This article breaks new ground by undertaking a historical approach and by showing in a comprehensive quantitative manner that colonial-era educational investments in sixteen former British and French colonies in sub-Saharan Africa play a durable role for their contemporary deforestation. In the second part of the analysis, I show that military versus civilian political elites, proxied by cabinet ministers, differ in their forest management performance. Higher district shares of cabinet ministers in postcolonial military cabinets consistently accelerate contemporary deforestation. In contrast, higher district shares of cabinet ministers in post-colonial civilian cabinets work moderately in the opposite direction. I argue that a key mechanism to understand this result is military versus civilian cabinets ministers' unequal colonial-era education, which is shown to have long-term persistent effects until today, and the fact that decision makers' educational background influences their policy decisions. In the third part of the analysis, I find that although regional favouritism may have positive effects on local development (Hodler and Raschky, 2014; De Luca et al., 2018), it is detrimental to forests in the sample of countries if one or more heads of military governments are born in the respective district. Civilian heads of government are not immune to favouritism, but it seems not to contribute meaningfully to unsustainable forest use in the sampled African countries.

The results of this article can inform policy decisions. Concretely, it demonstrates that a natural starting point to address Africa's deforestation problem at its roots is to provide more equal access to education that could reduce the pressure on forests of agriculture as a traditional way of subsistence in many low-income and developing countries (Dewees, 1995). Is the argument of this article generalisable to other geographical areas beyond East and West Africa? As this study has demonstrated, democratisation in favouritism-based settings can be detrimental to forests. However, democratisation also provides new opportunities to design policies and institutions that can help reverse this adverse ecological trend. This argument should be relevant for other developing cou ntries in which education could play a crucial role due to its constraining effect on regional favouritism (Hodler and Raschky, 2014) and the possibility of positively influencing forest management.

This article has also highlighted the importance of political elites for forest management in Africa. However, economic elites can also be highly relevant in forest management settings. The third important actor is the general population, with whom both the political and the economic elites are willing to build coalitions in order to achieve their goals (Albertus and Menaldo, 2014). Paniagua (2018) suggests that it is not realistic to always assume that economic elites are active within a single economic sector; they should rather be regarded as investors who diversify their asset portfolios among various economic sectors. The author reports evidence that the interests of economic elites differ depending on their types of investments. Economic elites with broadly diversified portfolios of assets among sectors would tend to favour policies that comprise multiple sectors; in contrast, investments in specific sectors would motivate only prioritisation of measures that exclusively benefit them (Paniagua, 2018). Against this background, further research is needed in order to understand the consequences of the interaction of interests of political and economic elites on forests, based on the level of diversification of asset portfolios and their coalitions with the general public in the process of democratisation in Africa (Cheeseman, 2008; Murray, 2020; Hinfelaar and Wahman, 2021) and in other developing countries.

This article joins the recent trend in the social sciences literature to use high resolution remotely-sensed data with extensive coverage that enables better identification and to study research questions that not long ago were impossible to be addressed due to data availability challenges (Klopp, 2012; Donaldson and Storeygard, 2016; Zabala, 2018). The approach of this study to combine geospatial deforestation data with historical records in a cross-sectional setting opens a promising avenue for future research on elites' forest "footprints." Specifically, it can be extended to a panel-data setting when high-quality geospatial forest data becomes available for a longer period of time. Future studies may also consider undertaking a mixed methods approach by combining high-resolution quantitative data with detailed qualitative evidence in a larger *N* setting.

Appendix to Chapter 3

A. Additional results

Table A.3.1: Log-transformed deforestation thresholds 20%–50% and colonial educational investments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Education*)	-0.080	-0.101	-0.102*	-0.108*	-0.102*	-0.097*	-0.120*
	(0.059)	(0.064)	(0.059)	(0.059)	(0.056)	(0.053)	(0.068)
N	281	278	275	274	270	269	266
adj. R^2	0.378	0.383	0.436	0.439	0.449	0.443	0.377
British sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Missions*)	-0.225***	-0.257***	-0.260***	-0.266***	-0.251***	-0.236***	-0.250**
	(0.064)	(0.080)	(0.079)	(0.079)	(0.073)	(0.071)	(0.093)
N	198	198	198	198	198	198	196
adj. R^2	0.299	0.308	0.309	0.306	0.304	0.306	0.248
French sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Teachers*)	0.364	0.543	0.546**	0.487*	0.220	0.250	0.518
	(0.456)	(0.462)	(0.194)	(0.230)	(0.175)	(0.240)	(0.329)
N	83	80	77	76	72	71	70
adj. R^2	0.272	0.262	0.260	0.281	0.363	0.336	0.331
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable in all regression models is a proxy of education. The regression models contain a full set of controls and country fixed effects.

Table A.3.2: Log-transformed deforestation thresholds 20%–50% and military minister-shares by district

Full sample	(1) $ldfo_{20\%}$	(2) $ldfo_{25\%}$	(3) $ldfo_{30\%}$	(4) $ldfo_{35\%}$	(5) $ldfo_{40\%}$	(6) $ldfo_{45\%}$	(7) $ldfo_{50\%}$
ln(*Military*), 1960-69	0.100	0.092*	0.093*	0.101*	0.072	0.084*	0.094*
	(0.071)	(0.054)	(0.052)	(0.052)	(0.043)	(0.046)	(0.053)
N	281	278	275	274	270	269	266
adj. R^2	0.379	0.384	0.437	0.440	0.449	0.443	0.378
ln(*Military*), 1970-79	0.161**	0.188***	0.245***	0.255***	0.204***	0.192**	0.189**
	(0.064)	(0.066)	(0.075)	(0.078)	(0.074)	(0.076)	(0.076)
N	281	278	275	274	270	269	266
adj. R^2	0.383	0.390	0.451	0.455	0.458	0.450	0.384
ln(*Military*), 1980-89	0.106*	0.113*	0.090	0.093	0.094	0.116*	0.156**
	(0.055)	(0.060)	(0.064)	(0.064)	(0.073)	(0.065)	(0.058)
N	281	278	275	274	270	269	266
adj. R^2	0.380	0.385	0.437	0.440	0.450	0.445	0.384
ln(*Military*), 1990-99	0.216***	0.238***	0.188**	0.187**	0.130**	0.142**	0.180**
	(0.058)	(0.078)	(0.081)	(0.084)	(0.061)	(0.065)	(0.071)
N	281	278	275	274	270	269	266
adj. R^2	0.392	0.400	0.447	0.449	0.453	0.447	0.385
ln(*Military*), 2000-10	0.172**	0.178**	0.179*	0.179*	0.159	0.124	0.113
	(0.075)	(0.079)	(0.097)	(0.100)	(0.099)	(0.092)	(0.100)
N	281	278	275	274	270	269	266
adj. R^2	0.386	0.392	0.447	0.449	0.457	0.446	0.380
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the military minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects.

Table A.3.3: Log-transformed deforestation thresholds 20%–50% and civilian minister-shares by district

Full sample	(1) $ldfo_{20\%}$	(2) $ldfo_{25\%}$	(3) $ldfo_{30\%}$	(4) $ldfo_{35\%}$	(5) $ldfo_{40\%}$	(6) $ldfo_{45\%}$	(7) $ldfo_{50\%}$
ln(*Civilians*), 1960-1969	-0.050	-0.035	-0.020	-0.019	-0.013	-0.006	-0.000
	(0.058)	(0.054)	(0.040)	(0.040)	(0.041)	(0.042)	(0.049)
N	281	278	275	274	270	269	266
adj. R^2	0.377	0.381	0.434	0.437	0.447	0.440	0.375
ln(*Civilians*), 1970-1979	-0.118	-0.128	-0.126*	-0.135*	-0.120*	-0.118*	-0.138*
	(0.091)	(0.086)	(0.068)	(0.071)	(0.060)	(0.060)	(0.073)
N	281	278	275	274	270	269	266
adj. R^2	0.382	0.389	0.443	0.446	0.455	0.448	0.385
ln(*Civilians*), 1980-1989	-0.135**	-0.127*	-0.105*	-0.110*	-0.087	-0.083	-0.089
	(0.066)	(0.065)	(0.060)	(0.059)	(0.052)	(0.054)	(0.071)
N	281	278	275	274	270	269	266
adj. R^2	0.385	0.389	0.440	0.443	0.451	0.444	0.379
ln(*Civilians*), 1990-1999	-0.004	-0.002	0.012	0.008	-0.009	-0.002	-0.032
	(0.074)	(0.073)	(0.069)	(0.073)	(0.078)	(0.084)	(0.097)
N	281	278	275	274	270	269	266
adj. R^2	0.376	0.380	0.434	0.436	0.447	0.440	0.375
ln(*Civilians*), 2000-2010	-0.005	0.005	0.035	0.039	0.049	0.063	0.053
	(0.057)	(0.054)	(0.053)	(0.052)	(0.045)	(0.048)	(0.060)
N	281	278	275	274	270	269	266
adj. R^2	0.376	0.380	0.435	0.437	0.448	0.443	0.376
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Population, logged (1960–2010)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the civilian minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects.

Table A.3.4: Log-transformed deforestation thresholds 20%–50% and colonial educational investments: Excluded additional colonial investments and post-colonial population

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Education*)	-0.080	-0.101	-0.102*	-0.108*	-0.102*	-0.097*	-0.120*
	(0.059)	(0.064)	(0.059)	(0.059)	(0.056)	(0.053)	(0.068)
N	281	278	275	274	270	269	266
adj. R^2	0.378	0.383	0.436	0.439	0.449	0.443	0.377
UK sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Missions*)	-0.196**	-0.219**	-0.222**	-0.227**	-0.218***	-0.209***	-0.222***
	(0.075)	(0.085)	(0.082)	(0.082)	(0.071)	(0.064)	(0.070)
N	198	198	198	198	198	198	196
adj. R^2	0.310	0.317	0.318	0.314	0.314	0.319	0.263
French sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Teachers*)	-0.277	-0.191	-0.017	-0.040	-0.144	-0.153	-0.119
	(0.188)	(0.143)	(0.071)	(0.066)	(0.086)	(0.121)	(0.157)
N	83	80	77	76	72	71	70
adj. R^2	0.300	0.280	0.283	0.306	0.398	0.365	0.317
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	No	No	No	No	No	No	No
ln(population), 1960–2010	No	No	No	No	No	No	No
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable in all regression models is a proxy of education. This table is identical to table A.3.1 but the regression specifications do not include colonial controls and the logged population (1960-2010).

Table A.3.5: Log-transformed deforestation thresholds 20%–50% and colonial educational investments: Excluded controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Education*)	-0.076	-0.082	-0.067	-0.070	-0.074	-0.070	-0.092
	(0.057)	(0.063)	(0.066)	(0.066)	(0.060)	(0.055)	(0.061)
N	281	278	275	274	270	269	266
adj. R^2	0.381	0.380	0.416	0.416	0.419	0.398	0.323
UK sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Missions*)	-0.189*	-0.215**	-0.228**	-0.232**	-0.229**	-0.222**	-0.251***
	(0.090)	(0.101)	(0.099)	(0.098)	(0.089)	(0.080)	(0.084)
N	198	198	198	198	198	198	196
adj. R^2	0.257	0.256	0.235	0.231	0.204	0.188	0.132
French sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Teachers*)	-0.089	-0.039	0.083	0.075	-0.029	-0.025	-0.039
	(0.228)	(0.208)	(0.094)	(0.105)	(0.062)	(0.059)	(0.084)
N	83	80	77	76	72	71	70
adj. R^2	0.265	0.265	0.335	0.344	0.450	0.415	0.365
Common additional terms:							
Geographical controls	No	No	No	No	No	No	No
Pre-colonial controls	No	No	No	No	No	No	No
Colonial controls	No	No	No	No	No	No	No
ln(population), 1960–2010	No	No	No	No	No	No	No
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable in all regression models is a proxy of education. This table is identical to table A.3.1 but the regression specifications do not include any controls.

Table A.3.6: IHS-transformed deforestation thresholds 20%–50% and colonial educational investments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample	$ihs_dfo_{20\%}$	$ihs_dfo_{25\%}$	$ihs_dfo_{30\%}$	$ihs_dfo_{35\%}$	$ihs_dfo_{40\%}$	$ihs_dfo_{45\%}$	$ihs_dfo_{50\%}$
ln(*Education*)	-0.066	-0.081	-0.088*	-0.103*	-0.093*	-0.077	-0.053
	(0.048)	(0.054)	(0.051)	(0.051)	(0.047)	(0.054)	(0.076)
N	283	279	277	277	274	274	272
adj. R^2	0.344	0.383	0.407	0.407	0.365	0.353	0.282
British sample	$ihs_dfo_{20\%}$	$ihs_dfo_{25\%}$	$ihs_dfo_{30\%}$	$ihs_dfo_{35\%}$	$ihs_dfo_{40\%}$	$ihs_dfo_{45\%}$	$ihs_dfo_{50\%}$
ln(*Missions*)	-0.226***	-0.259***	-0.263***	-0.269***	-0.255***	-0.238***	-0.188**
	(0.061)	(0.076)	(0.076)	(0.077)	(0.071)	(0.069)	(0.079)
N	199	199	199	199	199	199	198
adj. R^2	0.297	0.305	0.309	0.307	0.296	0.286	0.193
French sample	$ihs_dfo_{20\%}$	$ihs_dfo_{25\%}$	$ihs_dfo_{30\%}$	$ihs_dfo_{35\%}$	$ihs_dfo_{40\%}$	$ihs_dfo_{45\%}$	$ihs_dfo_{50\%}$
ln(*Teachers*)	-0.136	0.512	0.263	-0.039	-0.193	-0.287	-0.028
	(0.264)	(0.445)	(0.416)	(0.700)	(0.646)	(0.592)	(0.602)
N	84	80	78	78	75	75	74
adj. R^2	0.201	0.269	0.270	0.319	0.389	0.444	0.448
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable in all regression models is a proxy of education. The regression models contain a full set of controls and country fixed effects. The difference between this table and table A.3.1 consists in the dependent variable: here it is transformed via the inverse hyperbolic transformation (IHS) and there it is log-transformed.

Table A.3.7: Non-transformed deforestation thresholds 20%–50% and colonial educational investments

Full sample	(1) $dfo_{20\%}$	(2) $dfo_{25\%}$	(3) $dfo_{30\%}$	(4) $dfo_{35\%}$	(5) $dfo_{40\%}$	(6) $dfo_{45\%}$	(7) $dfo_{50\%}$
ln(*Education*)	-2.541*	-2.670*	-3.003*	-3.097*	-2.996*	-3.135*	-3.201
	(1.250)	(1.566)	(1.707)	(1.719)	(1.663)	(1.769)	(1.963)
N	276	273	271	271	268	268	266
adj. R^2	0.545	0.529	0.571	0.577	0.589	0.588	0.528
UK sample	$dfo_{20\%}$	$dfo_{25\%}$	$dfo_{30\%}$	$dfo_{35\%}$	$dfo_{40\%}$	$dfo_{45\%}$	$dfo_{50\%}$
ln(*Missions*)	-5.527**	-6.102**	-6.658**	-6.801**	-6.692**	-6.890**	-6.924**
	(2.067)	(2.459)	(2.746)	(2.824)	(2.795)	(3.105)	(3.090)
N	197	197	197	197	197	197	196
adj. R^2	0.276	0.282	0.301	0.302	0.313	0.322	0.239
French sample	$dfo_{20\%}$	$dfo_{25\%}$	$dfo_{30\%}$	$dfo_{35\%}$	$dfo_{40\%}$	$dfo_{45\%}$	$dfo_{50\%}$
ln(*Teachers*)	0.201	6.529	11.891	12.375	7.942	4.512	13.266
	(4.873)	(7.933)	(7.231)	(7.349)	(8.034)	(8.835)	(11.961)
N	79	76	74	74	71	71	70
adj. R^2	0.555	0.529	0.484	0.503	0.530	0.547	0.545
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable in all regression models is a proxy of education. The regression models contain a full set of controls and country fixed effects. The difference between this table and table A.3.1 consists in the dependent variable: here it is not transformed and there it is log-transformed.

Table A.3.8: Log-transformed deforestation thresholds 20%–50% and colonial educational investments: Excluded capital cities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Education*)	-0.089	-0.107	-0.105*	-0.112*	-0.102*	-0.093*	-0.120*
	(0.061)	(0.067)	(0.062)	(0.062)	(0.058)	(0.054)	(0.065)
N	266	264	261	260	256	255	252
adj. R^2	0.341	0.352	0.406	0.408	0.419	0.416	0.356
British sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Missions*)	-0.237***	-0.272***	-0.270***	-0.275***	-0.256***	-0.239***	-0.249**
	(0.066)	(0.083)	(0.083)	(0.083)	(0.078)	(0.075)	(0.092)
N	190	190	190	190	190	190	188
adj. R^2	0.298	0.307	0.306	0.302	0.301	0.307	0.251
French sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Teachers*)	0.596	0.751	0.712	0.638	0.295	0.262	0.534
	(0.715)	(0.713)	(0.475)	(0.515)	(0.336)	(0.369)	(0.408)
N	76	74	71	70	66	65	64
adj. R^2	0.256	0.253	0.227	0.247	0.317	0.283	0.276
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable in all regression models is a proxy of education. The regression models contain a full set of controls and country fixed effects. In contrast to table A.3.1, this table excludes capital cities.

Table A.3.9: Log-transformed deforestation thresholds 20%–50% and military minister-shares by district: Former British colonies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
British colonies	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Military*), 1960-69	0.041	0.052	0.059	0.066	0.064	0.071	0.090
	(0.047)	(0.049)	(0.053)	(0.055)	(0.055)	(0.056)	(0.054)
N	198	198	198	198	198	198	196
adj. R^2	0.295	0.305	0.307	0.304	0.302	0.305	0.247
ln(*Military*), 1970-79	0.212**	0.238**	0.255*	0.268*	0.257	0.245	0.243
	(0.097)	(0.107)	(0.139)	(0.149)	(0.166)	(0.166)	(0.158)
N	198	198	198	198	198	198	196
adj. R^2	0.306	0.319	0.322	0.320	0.317	0.317	0.256
ln(*Military*), 1980-89	0.137*	0.141*	0.131**	0.136**	0.134**	0.117**	0.151**
	(0.076)	(0.069)	(0.057)	(0.057)	(0.052)	(0.050)	(0.055)
N	198	198	198	198	198	198	196
adj. R^2	0.301	0.311	0.311	0.308	0.306	0.307	0.250
ln(*Military*), 1990-99	0.112**	0.117**	0.095*	0.095*	0.079	0.066	0.104
	(0.048)	(0.055)	(0.050)	(0.052)	(0.052)	(0.060)	(0.067)
N	198	198	198	198	198	198	196
adj. R^2	0.300	0.310	0.309	0.306	0.303	0.304	0.247
ln(*Military*), 2000-10	0.215	0.213	0.223	0.226	0.183	0.139	0.145
	(0.131)	(0.138)	(0.168)	(0.175)	(0.171)	(0.162)	(0.168)
N	198	198	198	198	198	198	196
adj. R^2	0.310	0.320	0.322	0.319	0.311	0.308	0.249
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the military minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects. This table differs from table A.3.2 in that it contains only the former British colonies sample.

Table A.3.10: Log-transformed deforestation thresholds 20%–50% and military minister-shares by district: Former French colonies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
French sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Military*), 1960-69	0.156	0.083	0.140	0.150	0.092	0.101	0.115**
	(0.109)	(0.092)	(0.106)	(0.102)	(0.066)	(0.071)	(0.045)
N	83	80	77	76	72	71	70
adj. R^2	0.269	0.251	0.257	0.280	0.355	0.329	0.326
ln(*Military*), 1970-79	0.116**	0.122*	0.226**	0.239**	0.202***	0.188**	0.132
	(0.052)	(0.063)	(0.082)	(0.089)	(0.064)	(0.072)	(0.101)
N	83	80	77	76	72	71	70
adj. R^2	0.266	0.256	0.279	0.303	0.379	0.349	0.331
ln(*Military*), 1980-89	0.147	0.153	0.065	0.070	0.057	0.071	0.080
	(0.162)	(0.146)	(0.123)	(0.115)	(0.120)	(0.085)	(0.070)
N	83	80	77	76	72	71	70
adj. R^2	0.272	0.263	0.249	0.270	0.352	0.326	0.323
ln(*Military*), 1990-99	0.397*	0.449**	0.357***	0.349***	0.245**	0.205*	0.194*
	(0.184)	(0.159)	(0.101)	(0.100)	(0.097)	(0.098)	(0.106)
N	83	80	77	76	72	71	70
adj. R^2	0.319	0.337	0.314	0.332	0.384	0.346	0.340
ln(*Military*), 2000-10	0.249*	0.212*	0.168	0.164	0.172	0.147	0.128
	(0.123)	(0.104)	(0.107)	(0.104)	(0.102)	(0.102)	(0.101)
N	83	80	77	76	72	71	70
adj. R^2	0.293	0.277	0.270	0.290	0.382	0.347	0.337
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the military minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects. This table differs from table A.3.2 in that it contains only the former French colonies sample.

Table A.3.11: Log-transformed deforestation thresholds 20%–50% and military minister-shares by district: Excluded colonial investments and post-colonial population

Full sample	(1) $ldfo_{20\%}$	(2) $ldfo_{25\%}$	(3) $ldfo_{30\%}$	(4) $ldfo_{35\%}$	(5) $ldfo_{40\%}$	(6) $ldfo_{45\%}$	(7) $ldfo_{50\%}$
ln(*Military*), 1960-69	0.076	0.069	0.074	0.081	0.048	0.059	0.069
	(0.073)	(0.055)	(0.051)	(0.050)	(0.033)	(0.035)	(0.041)
N	281	278	275	274	270	269	266
adj. R^2	0.384	0.386	0.439	0.441	0.449	0.445	0.379
ln(*Military*), 1970-79	0.133**	0.167**	0.226***	0.234***	0.174**	0.162**	0.156**
	(0.063)	(0.065)	(0.068)	(0.072)	(0.068)	(0.070)	(0.075)
N	281	278	275	274	270	269	266
adj. R^2	0.388	0.393	0.452	0.455	0.457	0.451	0.384
ln(*Military*), 1980-89	0.069	0.081	0.065	0.067	0.060	0.078	0.108*
	(0.045)	(0.051)	(0.058)	(0.058)	(0.065)	(0.058)	(0.054)
N	281	278	275	274	270	269	266
adj. R^2	0.384	0.387	0.438	0.440	0.450	0.446	0.382
ln(*Military*), 1990-99	0.172***	0.200***	0.162**	0.160*	0.100*	0.108*	0.138*
	(0.050)	(0.071)	(0.076)	(0.079)	(0.056)	(0.062)	(0.074)
N	281	278	275	274	270	269	266
adj. R^2	0.393	0.400	0.447	0.448	0.452	0.448	0.384
ln(*Military*), 2000-10	0.149**	0.161**	0.168*	0.167*	0.144	0.108	0.097
	(0.070)	(0.077)	(0.092)	(0.095)	(0.093)	(0.087)	(0.098)
N	281	278	275	274	270	269	266
adj. R^2	0.391	0.395	0.448	0.450	0.457	0.448	0.381
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	No	No	No	No	No	No	No
ln(population), 1960–2010	No	No	No	No	No	No	No
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the military minister-shares by district for each decade in the period 1960-2010. In contrast to table A.3.2, the regression specifications in this table do not contain colonial investments and log-transformed post-colonial population (1960-2010).

Table A.3.12: Log-transformed deforestation thresholds 20%–50% and military minister-shares by district: Full sample, excluded controls

Full sample	(1) $ldfo_{20\%}$	(2) $ldfo_{25\%}$	(3) $ldfo_{30\%}$	(4) $ldfo_{35\%}$	(5) $ldfo_{40\%}$	(6) $ldfo_{45\%}$	(7) $ldfo_{50\%}$
ln(*Military*), 1960-69	0.095	0.090	0.097	0.103	0.063	0.073	0.075
	(0.087)	(0.072)	(0.063)	(0.063)	(0.043)	(0.046)	(0.052)
N	281	278	275	274	270	269	266
adj. R^2	0.380	0.377	0.415	0.415	0.415	0.396	0.316
ln(*Military*), 1970-79	0.138**	0.176***	0.222***	0.227***	0.171***	0.155***	0.136**
	(0.058)	(0.053)	(0.061)	(0.064)	(0.047)	(0.046)	(0.053)
N	281	278	275	274	270	269	266
adj. R^2	0.382	0.383	0.426	0.426	0.422	0.400	0.319
ln(*Military*), 1980-89	0.034	0.049	0.048	0.051	0.057	0.068	0.089*
	(0.051)	(0.054)	(0.057)	(0.056)	(0.057)	(0.052)	(0.043)
N	281	278	275	274	270	269	266
adj. R^2	0.376	0.375	0.412	0.412	0.415	0.396	0.318
ln(*Military*), 1990-99	0.144***	0.174***	0.155***	0.157**	0.114***	0.114**	0.136***
	(0.033)	(0.049)	(0.055)	(0.057)	(0.037)	(0.041)	(0.042)
N	281	278	275	274	270	269	266
adj. R^2	0.384	0.386	0.421	0.421	0.418	0.399	0.321
ln(*Military*), 2000-10	0.129**	0.144**	0.150*	0.150*	0.126	0.094	0.067
	(0.061)	(0.067)	(0.079)	(0.082)	(0.079)	(0.074)	(0.078)
N	281	278	275	274	270	269	266
adj. R^2	0.382	0.382	0.420	0.420	0.420	0.397	0.316
Common additional terms:							
Geographical controls	No	No	No	No	No	No	No
Pre-colonial controls	No	No	No	No	No	No	No
Colonial controls	No	No	No	No	No	No	No
ln(population), 1960–2010	No	No	No	No	No	No	No
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the military minister-shares by district for each decade in the period 1960-2010. In contrast to table A.3.2, the regression specifications in this table do not contain any controls.

Table A.3.13: IHS-transformed deforestation thresholds 20%–50% and military minister-shares by district: Full sample estimates

Full sample	(1) $ihs_dfo_{20\%}$	(2) $ihs_dfo_{25\%}$	(3) $ihs_dfo_{30\%}$	(4) $ihs_dfo_{35\%}$	(5) $ihs_dfo_{40\%}$	(6) $ihs_dfo_{45\%}$	(7) $ihs_dfo_{50\%}$
ln(*Military*), 1960-69	0.138	0.078	0.089*	0.104**	0.084	0.101*	0.125*
	(0.106)	(0.048)	(0.046)	(0.050)	(0.050)	(0.058)	(0.062)
N	283	279	277	277	274	274	272
adj. R^2	0.348	0.382	0.408	0.409	0.365	0.354	0.283
ln(*Military*), 1970-79	0.117*	0.180**	0.240***	0.262***	0.318***	0.243**	0.228**
	(0.065)	(0.066)	(0.073)	(0.078)	(0.103)	(0.096)	(0.103)
N	283	279	277	277	274	274	272
adj. R^2	0.345	0.389	0.420	0.422	0.387	0.364	0.290
ln(*Military*), 1980-89	0.046	0.091	0.073	0.073	0.133*	0.046	0.065
	(0.062)	(0.058)	(0.064)	(0.062)	(0.073)	(0.077)	(0.074)
N	283	279	277	277	274	274	272
adj. R^2	0.342	0.383	0.407	0.407	0.368	0.351	0.280
ln(*Military*), 1990-99	0.209**	0.211***	0.174**	0.170**	0.162**	0.064	0.070
	(0.079)	(0.074)	(0.076)	(0.080)	(0.065)	(0.076)	(0.086)
N	283	279	277	277	274	274	272
adj. R^2	0.357	0.396	0.415	0.414	0.370	0.352	0.280
ln(*Military*), 2000-2010	0.144**	0.165**	0.176**	0.172**	0.208**	0.162*	0.152
	(0.061)	(0.067)	(0.079)	(0.080)	(0.096)	(0.091)	(0.098)
N	283	279	277	277	274	274	272
adj. R^2	0.349	0.390	0.416	0.415	0.378	0.359	0.286
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the military minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects. The difference between this table and table A.3.2 consists in the dependent variable: here it is transformed via the inverse hyperbolic transformation (IHS) and there it is log-transformed.

Table A.3.14: Non-transformed deforestation thresholds 20%–50% and military minister-shares by district: Full sample estimates

Full sample	(1) $dfo_{20\%}$	(2) $dfo_{25\%}$	(3) $dfo_{30\%}$	(4) $dfo_{35\%}$	(5) $dfo_{40\%}$	(6) $dfo_{45\%}$	(7) $dfo_{50\%}$
ln(*Military*), 1960-69	1.849	1.133	2.727	2.916*	1.890*	2.197*	2.914*
	(2.762)	(1.577)	(1.734)	(1.691)	(1.049)	(1.162)	(1.454)
N	283	279	277	277	274	274	272
adj. R^2	0.524	0.528	0.566	0.573	0.557	0.533	0.466
ln(*Military*), 1970-79	3.367	4.604*	6.592**	6.696**	7.196***	6.384**	6.456**
	(2.481)	(2.631)	(2.960)	(3.007)	(2.357)	(2.498)	(3.079)
N	283	279	277	277	274	274	272
adj. R^2	0.527	0.536	0.578	0.585	0.573	0.544	0.475
ln(*Military*), 1980-89	1.646**	2.529	1.602	1.727	1.759	0.561	1.630
	(0.721)	(1.537)	(1.540)	(1.591)	(2.077)	(2.303)	(2.152)
N	283	279	277	277	274	274	272
adj. R^2	0.523	0.530	0.564	0.571	0.557	0.531	0.463
ln(*Military*), 1990-99	5.665***	6.541**	5.450**	5.537**	4.422**	2.799	3.979
	(1.871)	(2.615)	(2.364)	(2.527)	(1.761)	(2.065)	(2.478)
N	283	279	277	277	274	274	272
adj. R^2	0.539	0.549	0.576	0.583	0.564	0.534	0.468
ln(*Military*), 2000-10	2.883	3.526	4.480*	4.434*	5.332**	4.716*	4.888
	(2.009)	(2.136)	(2.391)	(2.420)	(2.536)	(2.525)	(2.946)
N	283	279	277	277	274	274	272
adj. R^2	0.526	0.534	0.573	0.579	0.570	0.541	0.473
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the military minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects. The difference between this table and table A.3.2 consists in the dependent variable: here it is not transformed and there it is log-transformed.

Table A.3.15: Log-transformed deforestation thresholds 20%–50% and military minister-shares by district: Excluded capital cities

Full sample	(1) $ldfo_{20\%}$	(2) $ldfo_{25\%}$	(3) $ldfo_{30\%}$	(4) $ldfo_{35\%}$	(5) $ldfo_{40\%}$	(6) $ldfo_{45\%}$	(7) $ldfo_{50\%}$
ln(*Military*), 1960-69	0.089	0.080*	0.089*	0.099**	0.070	0.087*	0.084
	(0.062)	(0.047)	(0.046)	(0.047)	(0.047)	(0.051)	(0.050)
N	266	264	261	260	256	255	252
adj. R^2	0.340	0.352	0.406	0.409	0.418	0.416	0.355
ln(*Military*), 1970-79	0.126*	0.159**	0.234***	0.246***	0.200**	0.188**	0.177**
	(0.072)	(0.071)	(0.075)	(0.079)	(0.082)	(0.084)	(0.084)
N	266	264	261	260	256	255	252
adj. R^2	0.342	0.356	0.417	0.421	0.427	0.422	0.360
ln(*Military*), 1980-89	0.074	0.089	0.073	0.078	0.087	0.114*	0.152***
	(0.070)	(0.066)	(0.070)	(0.070)	(0.077)	(0.064)	(0.055)
N	266	264	261	260	256	255	252
adj. R^2	0.340	0.352	0.405	0.408	0.420	0.418	0.361
ln(*Military*), 1990-99	0.194***	0.222***	0.178**	0.178**	0.122*	0.142**	0.178**
	(0.059)	(0.076)	(0.081)	(0.084)	(0.062)	(0.066)	(0.073)
N	266	264	261	260	256	255	252
adj. R^2	0.350	0.367	0.414	0.417	0.422	0.420	0.362
ln(*Military*), 2000-10	0.164*	0.177*	0.185	0.184	0.160	0.125	0.106
	(0.092)	(0.096)	(0.117)	(0.121)	(0.122)	(0.115)	(0.121)
N	266	264	261	260	256	255	252
adj. R^2	0.347	0.360	0.416	0.418	0.426	0.420	0.357
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the military minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects. In contrast to table A.3.2, this table excludes capital cities.

Table A.3.16: Log-transformed deforestation thresholds 20%–50% and civilian minister-shares by district: Former British colonies

British colonies	(1) $ldfo_{20\%}$	(2) $ldfo_{25\%}$	(3) $ldfo_{30\%}$	(4) $ldfo_{35\%}$	(5) $ldfo_{40\%}$	(6) $ldfo_{45\%}$	(7) $ldfo_{50\%}$
ln(*Civilians*), 1960-69	0.002	0.007	-0.001	-0.003	-0.013	-0.023	-0.007
	(0.053)	(0.054)	(0.053)	(0.053)	(0.053)	(0.058)	(0.067)
N	198	198	198	198	198	198	196
adj. R^2	0.295	0.304	0.305	0.302	0.301	0.303	0.244
ln(*Civilians*), 1970-79	-0.062	-0.066	-0.081	-0.083	-0.096	-0.114	-0.137
	(0.076)	(0.075)	(0.074)	(0.074)	(0.073)	(0.076)	(0.085)
N	198	198	198	198	198	198	196
adj. R^2	0.297	0.307	0.309	0.307	0.306	0.310	0.254
ln(*Civilians*), 1980-89	-0.117**	-0.108**	-0.107*	-0.108*	-0.111*	-0.118*	-0.130
	(0.051)	(0.049)	(0.052)	(0.053)	(0.059)	(0.066)	(0.092)
N	198	198	198	198	198	198	196
adj. R^2	0.306	0.314	0.315	0.312	0.311	0.313	0.256
ln(*Civilians*), 1990-99	0.014	0.010	0.004	0.003	-0.009	-0.014	-0.040
	(0.075)	(0.074)	(0.075)	(0.075)	(0.078)	(0.083)	(0.097)
N	198	198	198	198	198	198	196
adj. R^2	0.295	0.304	0.305	0.302	0.300	0.303	0.245
ln(*Civilians*), 2000-10	0.035	0.037	0.054	0.056	0.062	0.084*	0.057
	(0.041)	(0.040)	(0.039)	(0.040)	(0.044)	(0.048)	(0.069)
N	198	198	198	198	198	198	196
adj. R^2	0.296	0.305	0.307	0.304	0.303	0.308	0.246
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the military minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects. While table A.3.3 reports results for the full sample, this table reports results only for the former British colonies sample, based on the same regression specifications.

Table A.3.17: Log-transformed deforestation thresholds 20%–50% and civilian minister-shares by district: Former French colonies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
French sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
ln(*Civilians*), 1960-69	-0.138	-0.093	-0.007	0.005	0.076	0.106	0.054
	(0.154)	(0.130)	(0.065)	(0.063)	(0.068)	(0.080)	(0.090)
N	83	80	77	76	72	71	70
adj. R^2	0.271	0.255	0.246	0.266	0.355	0.333	0.319
ln(*Civilians*), 1970-79	-0.176	-0.218	-0.210	-0.207	-0.095	-0.060	-0.073
	(0.179)	(0.180)	(0.150)	(0.147)	(0.085)	(0.105)	(0.137)
N	83	80	77	76	72	71	70
adj. R^2	0.274	0.276	0.281	0.300	0.358	0.325	0.322
ln(*Civilians*), 1980-89	-0.169	-0.168	-0.099	-0.094	0.029	0.084	0.107
	(0.303)	(0.288)	(0.253)	(0.234)	(0.121)	(0.095)	(0.099)
N	83	80	77	76	72	71	70
adj. R^2	0.270	0.260	0.251	0.271	0.349	0.326	0.325
ln(*Civilians*), 1990-99	0.004	0.022	0.070	0.063	0.106	0.129	0.071
	(0.089)	(0.083)	(0.091)	(0.089)	(0.148)	(0.154)	(0.159)
N	83	80	77	76	72	71	70
adj. R^2	0.259	0.249	0.248	0.268	0.354	0.330	0.319
ln(*Civilians*), 2000-10	-0.034	-0.021	-0.017	-0.005	0.032	0.017	-0.005
	(0.108)	(0.104)	(0.121)	(0.117)	(0.081)	(0.066)	(0.073)
N	83	80	77	76	72	71	70
adj. R^2	0.260	0.249	0.246	0.266	0.349	0.321	0.316
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the military minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects. While table A.3.3 reports results for the full sample, this table reports results only for the former French colonies sample, based on the same regression specifications.

Table A.3.18: Log-transformed deforestation thresholds 20%–50% and civilian minister-shares by district: Excluded colonial investments and post-colonial population

Full sample	(1) $ldfo_{20\%}$	(2) $ldfo_{25\%}$	(3) $ldfo_{30\%}$	(4) $ldfo_{35\%}$	(5) $ldfo_{40\%}$	(6) $ldfo_{45\%}$	(7) $ldfo_{50\%}$
ln(*Civilians*), 1960-69	-0.064	-0.051	-0.033	-0.034	-0.038	-0.034	-0.031
	(0.055)	(0.052)	(0.038)	(0.040)	(0.038)	(0.038)	(0.049)
N	281	278	275	274	270	269	266
adj. R^2	0.386	0.387	0.438	0.440	0.450	0.445	0.378
ln(*Civilians*), 1970-79	-0.118	-0.127	-0.118*	-0.127*	-0.126*	-0.127*	-0.143*
	(0.086)	(0.079)	(0.062)	(0.066)	(0.062)	(0.063)	(0.076)
N	281	278	275	274	270	269	266
adj. R^2	0.392	0.396	0.447	0.449	0.459	0.455	0.391
ln(*Civilians*), 1980-89	-0.137**	-0.131**	-0.108*	-0.114*	-0.102*	-0.101	-0.110
	(0.064)	(0.061)	(0.057)	(0.058)	(0.057)	(0.060)	(0.077)
N	281	278	275	274	270	269	266
adj. R^2	0.394	0.396	0.445	0.447	0.455	0.451	0.385
ln(*Civilians*), 1990-99	-0.036	-0.033	-0.014	-0.019	-0.038	-0.036	-0.062
	(0.076)	(0.072)	(0.063)	(0.067)	(0.067)	(0.068)	(0.080)
N	281	278	275	274	270	269	266
adj. R^2	0.383	0.385	0.437	0.439	0.449	0.444	0.379
ln(*Civilians*), 2000-10	-0.026	-0.015	0.016	0.018	0.019	0.026	0.016
	(0.065)	(0.060)	(0.052)	(0.052)	(0.048)	(0.049)	(0.054)
N	281	278	275	274	270	269	266
adj. R^2	0.383	0.385	0.437	0.439	0.448	0.444	0.377
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	No	No	No	No	No	No	No
ln(population), 1960–2010	No	No	No	No	No	No	No
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the civilian minister-shares by district for each decade in the period 1960-2010. In contrast to table A.3.3, the regression specifications in this table do not contain colonial investments and log-transformed post-colonial population (1960–2010).

Table A.3.19: Log-transformed deforestation thresholds 20%–50% and civilian minister-shares by district: Full sample and excluded controls

Full sample	(1) $ldfo_{20\%}$	(2) $ldfo_{25\%}$	(3) $ldfo_{30\%}$	(4) $ldfo_{35\%}$	(5) $ldfo_{40\%}$	(6) $ldfo_{45\%}$	(7) $ldfo_{50\%}$
ln(*Civilians*), 1960-69	-0.038	-0.022	-0.002	-0.001	-0.009	-0.008	-0.010
	(0.050)	(0.048)	(0.039)	(0.041)	(0.038)	(0.039)	(0.042)
N	281	278	275	274	270	269	266
adj. R^2	0.377	0.374	0.411	0.411	0.413	0.394	0.314
ln(*Civilians*), 1970-79	-0.124	-0.128*	-0.112*	-0.119*	-0.111*	-0.117*	-0.130*
	(0.078)	(0.070)	(0.058)	(0.061)	(0.060)	(0.061)	(0.072)
N	281	278	275	274	270	269	266
adj. R^2	0.386	0.385	0.420	0.421	0.422	0.403	0.326
ln(*Civilians*), 1980-89	-0.148**	-0.139**	-0.111*	-0.114*	-0.095*	-0.089	-0.097
	(0.066)	(0.063)	(0.057)	(0.057)	(0.056)	(0.058)	(0.073)
N	281	278	275	274	270	269	266
adj. R^2	0.390	0.387	0.420	0.420	0.420	0.399	0.321
ln(*Civilians*), 1990-99	-0.027	-0.023	-0.008	-0.011	-0.025	-0.024	-0.053
	(0.078)	(0.076)	(0.071)	(0.073)	(0.072)	(0.073)	(0.081)
N	281	278	275	274	270	269	266
adj. R^2	0.376	0.374	0.411	0.411	0.413	0.394	0.316
ln(*Civilians*), 2000-10	-0.021	-0.012	0.013	0.015	0.014	0.018	-0.004
	(0.066)	(0.061)	(0.055)	(0.054)	(0.048)	(0.050)	(0.056)
N	281	278	275	274	270	269	266
adj. R^2	0.376	0.374	0.411	0.411	0.413	0.394	0.314
Common additional terms:							
Geographical controls	No	No	No	No	No	No	No
Pre-colonial controls	No	No	No	No	No	No	No
Colonial controls	No	No	No	No	No	No	No
ln(population), 1960–2010	No	No	No	No	No	No	No
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the civilian minister-shares by district for each decade in the period 1960-2010. In contrast to table A.3.3, the regression specifications in this table do not contain any controls.

Table A.3.20: IHS-transformed deforestation thresholds 20%–50% and civilian minister-shares by district: Full sample estimates

Full sample	(1) $ihs_dfo_{20\%}$	(2) $ihs_dfo_{25\%}$	(3) $ihs_dfo_{30\%}$	(4) $ihs_dfo_{35\%}$	(5) $ihs_dfo_{40\%}$	(6) $ihs_dfo_{45\%}$	(7) $ihs_dfo_{50\%}$
ln(*Civilians*), 1960-69	-0.045	-0.041	-0.044	-0.048	-0.066	-0.073	-0.081
	(0.050)	(0.053)	(0.050)	(0.054)	(0.062)	(0.063)	(0.069)
N	283	279	277	277	274	274	272
adj. R^2	0.343	0.381	0.406	0.407	0.365	0.354	0.283
ln(*Civilians*), 1970-79	-0.132	-0.126	-0.157*	-0.196*	-0.191*	-0.222**	-0.238**
	(0.092)	(0.089)	(0.088)	(0.108)	(0.102)	(0.101)	(0.116)
adj. R^2	0.350	0.388	0.418	0.424	0.380	0.373	0.303
ln(*Civilians*), 1980-89	-0.140**	-0.128*	-0.133**	-0.163**	-0.148**	-0.123*	-0.131
	(0.067)	(0.064)	(0.063)	(0.075)	(0.068)	(0.068)	(0.083)
N	283	279	277	277	274	274	272
adj. R^2	0.351	0.389	0.415	0.419	0.373	0.358	0.286
ln(*Civilians*), 1990-99	-0.006	-0.024	-0.028	-0.055	-0.035	-0.043	-0.065
	(0.079)	(0.077)	(0.079)	(0.095)	(0.109)	(0.112)	(0.123)
N	283	279	277	277	274	274	272
adj. R^2	0.342	0.380	0.405	0.406	0.363	0.351	0.280
ln(*Civilians*), 2000-10	-0.029	-0.017	-0.002	0.010	0.007	0.048	0.047
	(0.057)	(0.056)	(0.062)	(0.054)	(0.048)	(0.053)	(0.060)
N	283	279	277	277	274	274	272
adj. R^2	0.342	0.380	0.405	0.405	0.362	0.351	0.280
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the civilian minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects. The difference between this table and table A.3.3 consists in the dependent variable: here it is transformed via the inverse hyperbolic transformation (IHS) and there it is log-transformed.

Table A.3.21: Non-transformed deforestation thresholds 20%–50% and civilian minister-shares by district

Full sample	(1) $dfo_{20\%}$	(2) $dfo_{25\%}$	(3) $dfo_{30\%}$	(4) $dfo_{35\%}$	(5) $dfo_{40\%}$	(6) $dfo_{45\%}$	(7) $dfo_{50\%}$
ln(*Civilians*), 1960-69	-0.074	0.254	0.179	0.237	0.227	0.143	-0.118
	(1.128)	(1.111)	(1.020)	(1.052)	(1.259)	(1.243)	(1.398)
N	283	279	277	277	274	274	272
adj. R^2	0.522	0.527	0.563	0.569	0.555	0.531	0.462
ln(*Civilians*), 1970-79	-2.513	-2.942	-3.343	-3.573	-3.327*	-3.852**	-4.530**
	(1.873)	(2.074)	(2.068)	(2.204)	(1.890)	(1.805)	(2.126)
N	283	279	277	277	274	274	272
adj. R^2	0.526	0.534	0.571	0.578	0.563	0.540	0.475
ln(*Civilians*), 1980-89	-2.324*	-2.315	-2.613	-2.797*	-2.532*	-2.081	-2.130
	(1.297)	(1.402)	(1.538)	(1.573)	(1.273)	(1.269)	(1.480)
N	283	279	277	277	274	274	272
adj. R^2	0.526	0.531	0.568	0.575	0.560	0.534	0.465
ln(*Civilians*), 1990-99	2.167	1.949	1.910	1.649	1.947	1.986	1.587
	(1.678)	(1.582)	(1.381)	(1.482)	(1.690)	(1.784)	(2.128)
N	283	279	277	277	274	274	272
adj. R^2	0.525	0.530	0.565	0.571	0.557	0.533	0.464
ln(*Civilians*), 2000-10	-0.080	0.122	0.394	0.615	0.991	1.835**	1.450
	(1.265)	(1.161)	(1.557)	(1.455)	(1.060)	(0.885)	(1.135)
N	283	279	277	277	274	274	272
adj. R^2	0.522	0.527	0.563	0.570	0.556	0.533	0.464
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the civilian minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects. The difference between this table and table A.3.3 consists in the dependent variable: here it is not transformed and there it is log-transformed.

Table A.3.22: Log-transformed deforestation thresholds 20%–50% and civilian minister-shares by district: Excluded capital cities

Full sample	(1) $ldfo_{20\%}$	(2) $ldfo_{25\%}$	(3) $ldfo_{30\%}$	(4) $ldfo_{35\%}$	(5) $ldfo_{40\%}$	(6) $ldfo_{45\%}$	(7) $ldfo_{50\%}$
ln(*Civilians*), 1960-69	-0.059	-0.041	-0.026	-0.025	-0.017	-0.010	-0.009
	(0.064)	(0.058)	(0.042)	(0.041)	(0.041)	(0.041)	(0.050)
N	266	264	261	260	256	255	252
adj. R^2	0.340	0.351	0.403	0.406	0.417	0.414	0.353
ln(*Civilians*), 1970-79	-0.125	-0.129	-0.128*	-0.137*	-0.122*	-0.118*	-0.143*
	(0.095)	(0.088)	(0.071)	(0.075)	(0.063)	(0.063)	(0.075)
adj. R^2	0.345	0.358	0.412	0.416	0.425	0.422	0.364
ln(*Civilians*), 1980-89	-0.133**	-0.126*	-0.104*	-0.109*	-0.083	-0.079	-0.078
	(0.065)	(0.064)	(0.059)	(0.058)	(0.051)	(0.054)	(0.069)
N	266	264	261	260	256	255	252
adj. R^2	0.347	0.358	0.409	0.412	0.421	0.418	0.356
ln(*Civilians*), 1990-99	-0.027	-0.023	-0.011	-0.017	-0.035	-0.029	-0.062
	(0.080)	(0.075)	(0.069)	(0.073)	(0.077)	(0.083)	(0.096)
N	266	264	261	260	256	255	252
adj. R^2	0.338	0.350	0.403	0.406	0.417	0.414	0.355
ln(*Civilians*), 2000-10	-0.004	0.001	0.029	0.033	0.042	0.056	0.041
	(0.060)	(0.058)	(0.057)	(0.056)	(0.051)	(0.054)	(0.066)
N	266	264	261	260	256	255	252
adj. R^2	0.338	0.349	0.403	0.406	0.418	0.416	0.354
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variables in all regression models are the civilian minister-shares by district for each decade in the period 1960-2010. The regression models contain a full set of controls and country fixed effects. In contrast to table A.3.3, this table excludes capital cities.

Table A.3.23: Log-transformed deforestation thresholds 20%–50% and heads of military governments: Excluded colonial investments and post-colonial population

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_M$	0.378***	0.387***	0.225**	0.215**	0.103	0.107	0.050
	(0.134)	(0.119)	(0.104)	(0.103)	(0.092)	(0.084)	(0.071)
N	281	278	275	274	270	269	266
adj. R^2	0.391	0.394	0.440	0.441	0.449	0.444	0.377
British sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_M$	0.503*	0.436*	0.180	0.140	-0.062	-0.114	-0.132
	(0.234)	(0.202)	(0.132)	(0.117)	(0.080)	(0.130)	(0.105)
N	83	80	77	76	72	71	70
adj. R^2	0.299	0.285	0.287	0.308	0.390	0.357	0.313
French sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_M$	0.503*	0.436*	0.180	0.140	-0.062	-0.114	-0.132
	(0.234)	(0.202)	(0.132)	(0.117)	(0.080)	(0.130)	(0.105)
N	83	80	77	76	72	71	70
adj. R^2	0.299	0.285	0.287	0.308	0.390	0.357	0.313
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	No	No	No	No	No	No	No
ln(population), 1960–2010	No	No	No	No	No	No	No
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable is an indicator function that equals to one if a head of military government ($Heads_M$) was born in the district. The table differs from table 3.3 in that it does not contain colonial investments and log-transformed post-colonial population (1960-2010).

Table A.3.24: Log-transformed deforestation thresholds 20%–50% and heads of military governments: Full sample and excluded controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_M$	0.227**	0.245**	0.100	0.091	-0.005	-0.037	-0.141
	(0.111)	(0.095)	(0.089)	(0.085)	(0.081)	(0.097)	(0.115)
N	281	278	275	274	270	269	266
adj. R^2	0.379	0.378	0.412	0.411	0.413	0.394	0.315
UK sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_M$	0.212	0.280**	0.163	0.164	0.075	0.025	-0.102
	(0.165)	(0.129)	(0.138)	(0.126)	(0.118)	(0.145)	(0.183)
N	198	198	198	198	198	198	196
adj. R^2	0.233	0.227	0.197	0.193	0.165	0.153	0.092
French sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_M$	0.250*	0.192	0.005	-0.020	-0.132	-0.142	-0.200*
	(0.133)	(0.140)	(0.085)	(0.092)	(0.104)	(0.118)	(0.104)
N	83	80	77	76	72	71	70
adj. R^2	0.267	0.268	0.332	0.341	0.452	0.417	0.371
Common additional terms:							
Geographical controls	No	No	No	No	No	No	No
Pre-colonial controls	No	No	No	No	No	No	No
Colonial controls	No	No	No	No	No	No	No
ln(population), 1960–2010	No	No	No	No	No	No	No
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable is an indicator function that equals to one if a head of military government ($Heads_M$) was born in the district. The table differs from table 3.3 in that it does not contain any controls.

Table A.3.25: IHS-transformed deforestation thresholds 20%–50% and heads of military governments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample	$ihs_dfo_{20\%}$	$ihs_dfo_{25\%}$	$ihs_dfo_{30\%}$	$ihs_dfo_{35\%}$	$ihs_dfo_{40\%}$	$ihs_dfo_{45\%}$	$ihs_dfo_{50\%}$
$Heads_M$	0.373**	0.384**	0.226	0.204	0.170	-0.066	-0.262
	(0.156)	(0.150)	(0.137)	(0.131)	(0.114)	(0.148)	(0.225)
N	283	279	277	277	274	274	272
adj. R^2	0.350	0.389	0.408	0.407	0.364	0.351	0.282
UK sample	$ihs_dfo_{20\%}$	$ihs_dfo_{25\%}$	$ihs_dfo_{30\%}$	$ihs_dfo_{35\%}$	$ihs_dfo_{40\%}$	$ihs_dfo_{45\%}$	$ihs_dfo_{50\%}$
$Heads_M$	0.140	0.203	0.093	0.092	-0.005	-0.071	-0.397
	(0.211)	(0.197)	(0.187)	(0.181)	(0.157)	(0.152)	(0.333)
N	199	199	199	199	199	199	198
adj. R^2	0.294	0.304	0.305	0.304	0.292	0.282	0.197
French sample	$ihs_dfo_{20\%}$	$ihs_dfo_{25\%}$	$ihs_dfo_{30\%}$	$ihs_dfo_{35\%}$	$ihs_dfo_{40\%}$	$ihs_dfo_{45\%}$	$ihs_dfo_{50\%}$
$Heads_M$	0.538**	0.566**	0.383	0.269	0.310	-0.272	-0.189
	(0.223)	(0.246)	(0.260)	(0.191)	(0.244)	(0.305)	(0.296)
N	84	80	78	78	75	75	74
adj. R^2	0.205	0.280	0.269	0.310	0.382	0.436	0.438
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable is an indicator function that equals to one if a head of military government ($Heads_M$) was born in the district. The regression models contain a full set of controls and country fixed effects. The difference between this table and table 3.3 consists in the dependent variable: here it is transformed via the inverse hyperbolic transformation (IHS) and there it is log-transformed.

Table A.3.26: Non-transformed deforestation thresholds 20%–50% and heads of military governments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample	$dfo_{20\%}$	$dfo_{25\%}$	$dfo_{30\%}$	$dfo_{35\%}$	$dfo_{40\%}$	$dfo_{45\%}$	$dfo_{50\%}$
$Heads_M$	8.487*	7.496	5.062	4.677	2.595	1.365	-0.607
	(4.750)	(4.429)	(3.643)	(3.584)	(3.215)	(3.628)	(3.383)
N	276	273	271	271	268	268	266
adj. R^2	0.550	0.532	0.572	0.577	0.588	0.586	0.526
UK sample	$dfo_{20\%}$	$dfo_{25\%}$	$dfo_{30\%}$	$dfo_{35\%}$	$dfo_{40\%}$	$dfo_{45\%}$	$dfo_{50\%}$
$Heads_M$	1.976	1.348	0.837	0.623	-0.115	-0.269	-2.879
	(4.503)	(4.568)	(4.856)	(4.834)	(4.777)	(4.413)	(3.911)
N	197	197	197	197	197	197	196
adj. R^2	0.272	0.278	0.297	0.298	0.309	0.318	0.236
French sample	$dfo_{20\%}$	$dfo_{25\%}$	$dfo_{30\%}$	$dfo_{35\%}$	$dfo_{40\%}$	$dfo_{45\%}$	$dfo_{50\%}$
$Heads_M$	15.915	14.414	14.401	13.730	5.946	0.544	0.997
	(10.774)	(9.260)	(9.759)	(9.570)	(5.406)	(6.460)	(7.392)
N	79	76	74	74	71	71	70
adj. R^2	0.562	0.533	0.486	0.503	0.522	0.536	0.534
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable is an indicator function that equals to one if a head of military government ($Heads_M$) was born in the district. The regression models contain a full set of controls and country fixed effects. The difference between this table and table 3.3 consists in the dependent variable: here it is not transformed and there it is log-transformed.

Table A.3.27: Log-transformed deforestation thresholds 20%–50% and heads of military governments: Full sample and excluded capitals

Full sample	(1) $ldfo_{20\%}$	(2) $ldfo_{25\%}$	(3) $ldfo_{30\%}$	(4) $ldfo_{35\%}$	(5) $ldfo_{40\%}$	(6) $ldfo_{45\%}$	(7) $ldfo_{50\%}$
$Heads_M$	0.408**	0.415***	0.249*	0.240*	0.114	0.139	0.078
	(0.162)	(0.149)	(0.125)	(0.123)	(0.104)	(0.089)	(0.067)
N	266	264	261	260	256	255	252
adj. R^2	0.347	0.360	0.407	0.409	0.418	0.415	0.353
UK sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_M$	0.232	0.294	0.169	0.171	0.064	-0.007	-0.072
	(0.209)	(0.206)	(0.184)	(0.180)	(0.143)	(0.120)	(0.096)
N	190	190	190	190	190	190	188
adj. R^2	0.297	0.310	0.303	0.300	0.297	0.303	0.247
French sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_M$	0.578**	0.493**	0.258	0.217	0.046	0.044	0.084
	(0.253)	(0.201)	(0.196)	(0.190)	(0.166)	(0.151)	(0.164)
N	76	74	71	70	66	65	64
adj. R^2	0.259	0.255	0.216	0.234	0.300	0.264	0.258
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable is an indicator function that equals to one if a head of military government ($Heads_M$) was born in the district. The regression models contain a full set of controls and country fixed effects. In contrast to 3.3, this table excludes capital cities.

Table A.3.28: Log-transformed deforestation thresholds 20%–50% and heads of civilian governments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_C$	0.141	0.120	0.121	0.109	0.132	0.164	0.146
	(0.102)	(0.110)	(0.126)	(0.128)	(0.129)	(0.130)	(0.107)
N	281	278	275	274	270	269	266
adj. R^2	0.378	0.382	0.436	0.438	0.449	0.444	0.377
British sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_C$	0.089	0.056	0.040	0.028	0.048	0.079	0.045
	(0.147)	(0.165)	(0.183)	(0.192)	(0.180)	(0.161)	(0.134)
N	198	198	198	198	198	198	196
adj. R^2	0.296	0.305	0.305	0.302	0.301	0.303	0.244
French sample	$ldfo_{20\%}$	$ldfo_{25\%}$	$ldfo_{30\%}$	$ldfo_{35\%}$	$ldfo_{40\%}$	$ldfo_{45\%}$	$ldfo_{50\%}$
$Heads_C$	-0.001	0.008	0.076	0.086	0.204	0.215	0.147
	(0.186)	(0.218)	(0.305)	(0.298)	(0.405)	(0.399)	(0.362)
N	83	80	77	76	72	71	70
adj. R^2	0.259	0.248	0.246	0.267	0.355	0.329	0.319
Common additional terms:							
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln(population), 1960–2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the province level in parentheses. This table contains the results for the full set of deforestation thresholds between 20% ($ldfo_{20\%}$) and 50% ($ldfo_{50\%}$) in the analysis. The key independent variable is an indicator function that equals to one if a head of civilian government ($Heads_C$) was born in the district. The regression models contain a full set of controls and country fixed effects.

B. Aggregate deforestation (2001-2019) by threshold

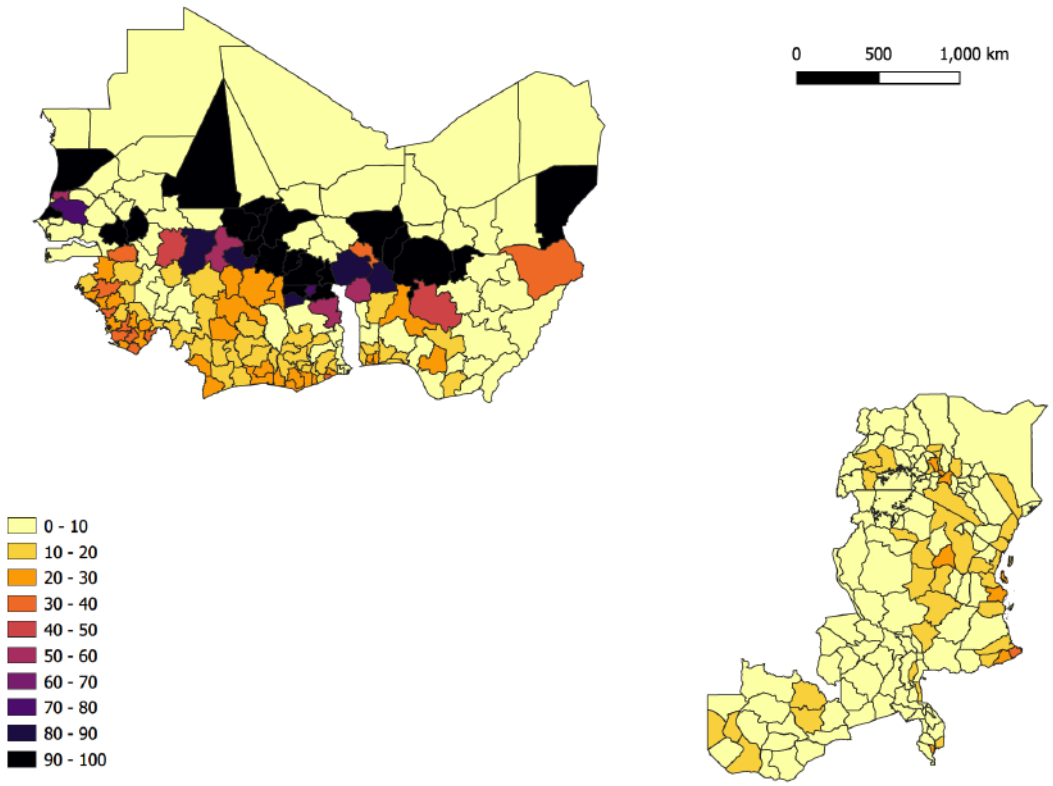


Figure B.3.1: Map of aggregate deforestation (2001-2019) for the 20% deforestation threshold in East and West Africa

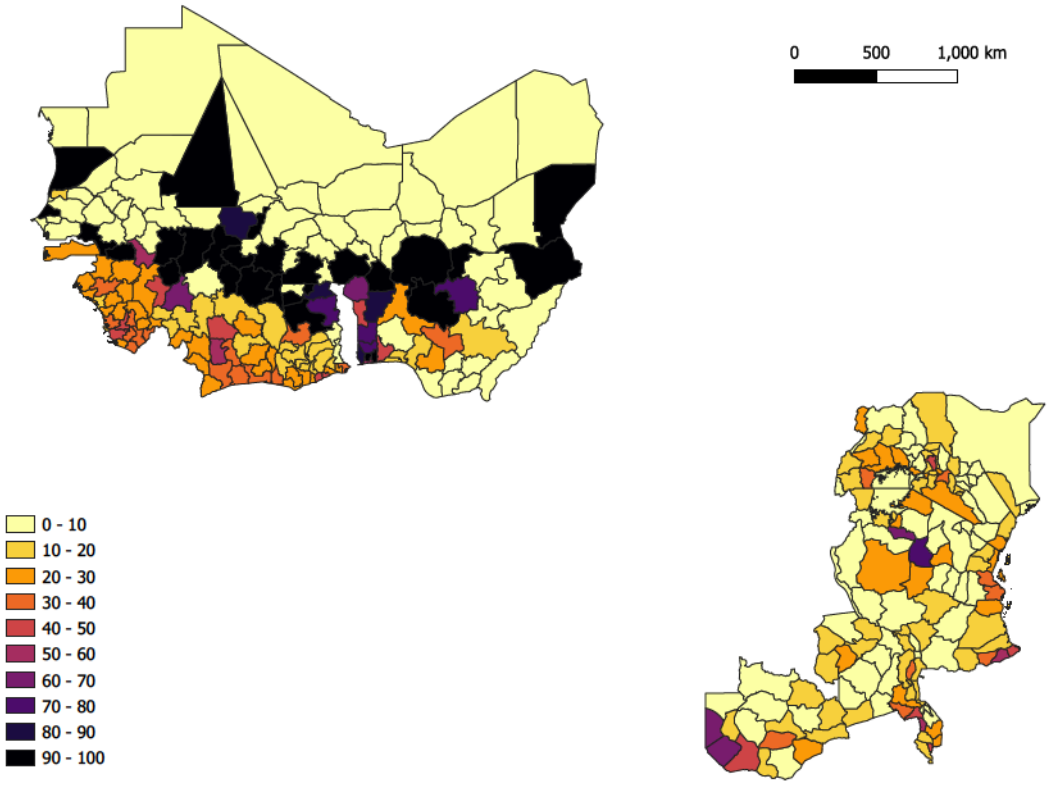


Figure B.3.2: Map of aggregate deforestation (2001-2019) for the 50% deforestation threshold in East and West Africa

C. Coefficient stability test

To address a possible endogeneity bias, I implement several variants of the proposed by Oster (2019) coefficient stability test. The test consists in calculating confidence intervals for the key independent variables. If these intervals exclude 0, this means that unobservables are less important than observables and that the reported results remain robust. In order to calculate the estimates of the test, a value of R^2_{max} must be chosen. It represents R^2_{max} in a regression that is assumed to contain all known and unknown controls in equations 1–5. Since the latter quantity is unknown, this regression should be understood as a hypothetical one. Relying on the existing literature, I choose several values of R^2_{max}: (1) $R^2_{max} = 0.6$, as a more stringent version of the recommended $R^2_{max} = 0.5$ by McKenzie (2012); (2) $R^2_{max} = 0.8$, proposed by Baird et al. (2008) and (3) $R^2_{max} = 1$, as per the maximally conservative but unlikely to be observed in practice value, proposed by González and Miguel (2015). The results of the coefficient stability tests for all statistically significant key independent variables in Tables A.3.1–A.3.3 are presented in Table C.3.1.

Table C.3.1: Results from Oster's coefficient stability test

Full sample	$R^2_{max} = 0.6$	$R^2_{max} = 0.8$	$R^2_{max} = 1$
ln(*Education*), $ldfo_{30}$	[-.102, -.163]	[-.102, -.290]	[-.102, -.418]
ln(*Education*), $ldfo_{35}$	[-.108, -.171]	[-.108, -.305]	[-.108, -.439]
ln(*Education*), $ldfo_{40}$	[-.102, -.137]	[-.102, -.224]	[-.102, -.311]
ln(*Education*), $ldfo_{45}$	[-.097, -.127]	[-.097, -.197]	[-.097, -.266]
ln(*Education*), $ldfo_{50}$	[-.120, -.164]	[-.120, -.226]	[-.120, -.287]
ln(*Military*), 1960-1969, $ldfo_{25}$	[.092, .098]	[.092, .107]	[.092, .116]
ln(*Military*), 1960-1969, $ldfo_{30}$	[.093, .086]	[.093, .073]	[.093, .060]
ln(*Military*), 1960-1969, $ldfo_{35}$	[.101, .099]	[.101, .094]	[.101, .090]
ln(*Military*), 1960-1969, $ldfo_{45}$	[.084, .095]	[.084, .123]	[.084, .150]
ln(*Military*), 1960-1969, $ldfo_{50}$	[.094, .120]	[.094, .157]	[.094, .194]
ln(*Military*), 1970-1979, $ldfo_{20}$	[.161, .239]	[.161, .349]	[.161, .460]
ln(*Military*), 1970-1979, $ldfo_{25}$	[.188, .222]	[.188, .273]	[.188, .325]
ln(*Military*), 1970-1979, $ldfo_{30}$	[.245, .277]	[.245, .356]	[.245, .435]
ln(*Military*), 1970-1979, $ldfo_{35}$	[.255, .290]	[.255, .382]	[.255, .473]
ln(*Military*), 1970-1979, $ldfo_{40}$	[.204, .237]	[.204, .330]	[.204, .422]
ln(*Military*), 1970-1979, $ldfo_{45}$	[.192, .228]	[.192, .317]	[.192, .407]

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Table C.3.1 – continued from previous page

	$R^2_{max} = 0.6$	$R^2_{max} = 0.8$	$R^2_{max} = 1$
ln(*Military*), 1970-1979, $ldfo_{50}$	[.189, .259]	[.189, .363]	[.189, .467]
ln(*Military*), 1980-1989, $ldfo_{20}$	[.106, .349]	[.106, .685]	[.106, 1.021]
ln(*Military*), 1980-1989, $ldfo_{25}$	[.113, .294]	[.113, .554]	[.113, .813]
ln(*Military*), 1980-1989, $ldfo_{40}$	[.106, .136]	[.106, .241]	[.106, .347]
ln(*Military*), 1980-1989, $ldfo_{45}$	[.113, .163]	[.113, .276]	[.113, .390]
ln(*Military*), 1990-1999, $ldfo_{20}$	[.216, .426]	[.216, .740]	[.216, 1.054]
ln(*Military*), 1990-1999, $ldfo_{25}$	[.238, .390]	[.238, .633]	[.238, .876]
ln(*Military*), 1990-1999, $ldfo_{30}$	[.188, .234]	[.188, .343]	[.188, .452]
ln(*Military*), 1990-1999, $ldfo_{35}$	[.187, .228]	[.187, .326]	[.187, .425]
ln(*Military*), 1990-1999, $ldfo_{40}$	[.130, .147]	[.130, .193]	[.130, .238]
ln(*Military*), 1990-1999, $ldfo_{45}$	[.142, .170]	[.142, .239]	[.142, .307]
ln(*Military*), 1990-1999, $ldfo_{50}$	[.180, .237]	[.180, .323]	[.180, .408]
ln(*Military*), 2000-2010, $ldfo_{20}$	[.172, .309]	[.172, .507]	[.172, .705]
ln(*Military*), 2000-2010, $ldfo_{25}$	[.178, .268]	[.178, .406]	[.178, .543]
ln(*Military*), 2000-2010, $ldfo_{30}$	[.179, .220]	[.179, .316]	[.179, .413]
ln(*Military*), 2000-2010, $ldfo_{35}$	[.179, .216]	[.179, .307]	[.179, .399]
$Heads_M$, $ldfo_{20}$	[.397, .924]	[.397, 1.678]	[.397, 2.428]
$Heads_M$, $ldfo_{25}$	[.403, .814]	[.403, 1.427]	[.403, 2.039]
$Heads_M$, $ldfo_{30}$	[.225, .415]	[.225, .826]	[.225, 1.237]
$Heads_M$, $ldfo_{35}$	[.215, .393]	[.215, .787]	[.215, 1.180]
ln(*Civilians*), 1970-1979, $ldfo_{30}$	[-.126, -.147]	[-.126, -.196]	[-.126, -.244]
ln(*Civilians*), 1970-1979, $ldfo_{35}$	[-.135, -.158]	[-.135, -.213]	[-.135, -.268]
ln(*Civilians*), 1970-1979, $ldfo_{40}$	[-.120, –.131]	[-.120, -.159]	[-.120, -.188]
ln(*Civilians*), 1970-1979, $ldfo_{45}$	[-.118, -.119]	[-.118, -.123]	[-.118, -.126]
ln(*Civilians*), 1970-1979, $ldfo_{50}$	[-.138, -.149]	[-.138 -.165]	[-.138, -.182]
ln(*Civilians*), 1980-1989, $ldfo_{20}$	[-.135, -.083]	[-.135, -.009]	[-.135, .063]
ln(*Civilians*), 1980-1989, $ldfo_{25}$	[-.127, -.084]	[-.127, -.022]	[-.127, .038]
ln(*Civilians*), 1980-1989, $ldfo_{30}$	[-.105, -.095]	[-.105, -.075]	[-.105, -.054]
ln(*Civilians*), 1980-1989, $ldfo_{35}$	[-.110, -.104]	[-.110, -.091]	[-.110, -.078]

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Table C.3.1 – continued from previous page

	$R^2_{max} = 0.6$	$R^2_{max} = 0.8$	$R^2_{max} = 1$

This table contains lower and upper bounds of the estimates of the coefficient stability tests. The lower bounds correspond to the statistically significant estimates of the independent variables in Tables A.3.1–A.3.3. The upper bounds are calculated by using the indicated R^2_{max} in the columns of this table. The notations in the first column indicate estimates from separate coefficient stability tests with regard to the full sample. For example, the notation ln(*Civilians*), 1980-1989, $ldfo_{35}$ refers to estimates from a coefficient stability test with key independent variable ln(*Civilians*) for the decade 1980-1989 and dependent variable the log-transformed 35% deforestation threshold $ldfo_{35}$. The estimates of the coefficient stability tests exclude 0 and, hence, remain robust except for *Civilians* for the most conservative $R^2_{max} = 1$. This, however, is not a reason for concern as such a high value of R^2 is unlikely to be reached in a real world application.

D. Descriptive statistics

Table D.3.1: District summary statistics for the former British colonies

	Observations	Mean	SD	Min	Max
$ldfo_{20\%}$	198	2.26	0.82	-0.52	4.61
$ldfo_{25\%}$	198	2.31	0.83	-0.52	4.61
$ldfo_{30\%}$	198	2.40	0.83	-0.56	4.61
$ldfo_{35\%}$	198	2.41	0.84	-0.57	4.61
$ldfo_{40\%}$	198	2.51	0.84	-0.59	4.61
$ldfo_{45\%}$	198	2.58	0.86	-0.46	4.61
$ldfo_{50\%}$	196	2.73	0.91	-0.54	4.61
$ihs_dfo_{20\%}$	199	2.95	0.83	0.00	5.30
$ihs_dfo_{25\%}$	199	3.00	0.84	0.00	5.30
$ihs_dfo_{30\%}$	199	3.09	0.84	0.00	5.30
$ihs_dfo_{35\%}$	199	3.10	0.85	0.00	5.30
$ihs_dfo_{40\%}$	199	3.20	0.85	0.00	5.30
$ihs_dfo_{45\%}$	199	3.27	0.88	0.00	5.30
$ihs_dfo_{50\%}$	198	3.40	0.95	0.00	5.30
$dfo_{20\%}$	199	13.87	16.25	0.00	100.00
$dfo_{25\%}$	199	14.61	16.85	0.00	100.00
$dfo_{30\%}$	199	15.81	17.25	0.00	100.00
$dfo_{35\%}$	199	16.02	17.44	0.00	100.00
$dfo_{40\%}$	199	17.56	18.04	0.00	100.00
$dfo_{45\%}$	199	19.13	19.42	0.00	100.00
$dfo_{50\%}$	198	22.18	21.07	0.00	100.00
ln(*Civilians*), 1960-69	199	1.07	1.03	0.00	3.22
ln(*Civilians*), 1970-79	199	0.87	0.96	0.00	3.29
ln(*Civilians*), 1980-89	199	1.01	0.98	0.00	3.33
ln(*Civilians*), 1990-99	199	0.91	0.95	0.00	3.21
ln(*Civilians*), 2000-10	199	1.25	0.85	0.00	3.15
ln(*Military*), 1960-69	199	0.41	0.83	0.00	3.26
ln(*Military*), 1970-79	199	0.48	0.82	0.00	2.97
ln(*Military*), 1980-89	199	0.59	0.89	0.00	3.34
ln(*Military*), 1990-99	199	0.56	0.91	0.00	3.52
ln(*Military*), 2000-10	199	0.45	0.82	0.00	3.33
$Heads_M$	199	0.07	0.25	0.00	1.00
$Heads_C$	199	0.13	0.34	0.00	1.00
ln(*Missions*)	199	1.00	0.78	0.00	3.30
ln(Infrastructure expenditures)	199	7.16	3.90	0.00	14.25
ln(Public health staff)	199	1.40	1.47	0.00	5.45
Railroads	199	0.50	0.50	0.00	1.00
Rivers	199	0.16	0.36	0.00	1.00
ln(Population), 1960-2010	199	13.11	1.09	9.84	16.03
Base metals	199	0.16	0.36	0.00	1.00
Noble metals	199	0.12	0.32	0.00	1.00
Caloric Suitability Index	199	3722.78	566.69	2218.04	4641.88
Ruggedness	199	0.53	0.43	0.02	2.61
ln(Area)	199	9.30	1.11	4.93	12.42
Intensity of agriculture	199	103.78	59.51	1.00	166.00
Settlement patterns	199	136.90	70.06	1.00	229.00
Jurisdictional hierarchy	199	138.90	85.67	1.00	260.00
Type of slavery	199	124.79	78.30	1.00	240.00
Kingdom at the end of 19 century	199	0.19	0.39	0.00	1.00
Pre-colonial trading post	199	0.08	0.26	0.00	1.00
Pre-colonial ethno-linguistic fractionalisation	199	0.42	0.24	0.00	0.94

Table D.3.2: District summary statistics for the former French colonies

	Observations	Mean	SD	Min	Max
$ldfo_{20\%}$	83	3.18	1.17	-0.81	4.61
$ldfo_{25\%}$	80	3.22	1.07	-0.10	4.61
$ldfo_{30\%}$	77	3.43	0.93	0.65	4.61
$ldfo_{35\%}$	76	3.46	0.94	0.63	4.61
$ldfo_{40\%}$	72	3.56	0.85	0.65	4.61
$ldfo_{45\%}$	71	3.64	0.83	0.87	4.61
$ldfo_{50\%}$	70	3.72	0.80	0.75	4.61
$ihs_dfo_{20\%}$	84	3.84	1.20	0.00	5.30
$ihs_dfo_{25\%}$	80	3.92	1.06	0.81	5.30
$ihs_dfo_{30\%}$	78	4.08	1.04	0.00	5.30
$ihs_dfo_{35\%}$	78	4.05	1.13	0.00	5.30
$ihs_dfo_{40\%}$	75	4.08	1.18	0.00	5.30
$ihs_dfo_{45\%}$	75	4.10	1.27	0.00	5.30
$ihs_dfo_{50\%}$	74	4.18	1.27	0.00	5.30
$dfo_{20\%}$	84	39.23	35.58	0.00	100.00
$dfo_{25\%}$	80	39.80	35.10	0.91	100.00
$dfo_{30\%}$	78	44.64	36.51	0.00	100.00
$dfo_{35\%}$	78	44.92	36.85	0.00	100.00
$dfo_{40\%}$	75	45.84	35.67	0.00	100.00
$dfo_{45\%}$	75	48.17	36.08	0.00	100.00
$dfo_{50\%}$	74	50.82	35.79	0.00	100.00
ln(*Civilians*), 1960-69	112	1.50	1.16	0.00	3.94
ln(*Civilians*), 1970-79	112	1.12	1.19	0.00	3.87
ln(*Civilians*), 1980-89	112	0.69	1.01	0.00	3.44
ln(*Civilians*), 1990-99	112	0.85	1.07	0.00	3.60
ln(*Civilians*), 2000-10	112	1.05	1.13	0.00	3.47
ln(*Military*), 1960-69	112	0.52	1.04	0.00	3.54
ln(*Military*), 1970-79	112	0.90	1.20	0.00	3.87
ln(*Military*), 1980-89	112	1.13	1.20	0.00	3.90
ln(*Military*), 1990-99	112	1.19	1.20	0.00	3.53
ln(*Military*), 2000-10	112	1.17	1.20	0.00	3.50
$Heads_M$	112	0.13	0.33	0.00	1.00
$Heads_C$	112	0.19	0.39	0.00	1.00
ln(*Teachers*)	112	1.65	0.72	0.36	4.28
ln(Infrastructure expenditures)	112	8.96	3.01	0.00	13.96
ln(Public health staff)	112	2.00	0.82	0.00	4.27
Railroads	112	0.30	0.46	0.00	1.00
Rivers	112	0.33	0.47	0.00	1.00
ln(Population), 1960-2010	112	12.80	0.86	9.16	14.60
Base metals	112	0.29	0.45	0.00	1.00
Noble metals	112	0.16	0.37	0.00	1.00
Caloric Suitability Index	112	2728.03	1282.46	0.00	4389.78
Ruggedness	112	0.23	0.22	0.02	1.08
ln(Area)	112	9.80	1.40	3.72	13.17
Intensity of agriculture	112	125.86	50.95	16.00	167.00
Settlement patterns	112	150.68	77.36	5.00	228.00
Jurisdictional hierarchy	112	165.89	75.73	7.00	260.00
Type of slavery	112	186.64	61.93	21.00	240.00
Kingdom at the end of 19 century	112	0.48	0.50	0.00	1.00
Pre-colonial trading post	112	0.08	0.27	0.00	1.00
Pre-colonial ethno-linguistic fractionalisation	112	0.46	0.21	0.00	0.87

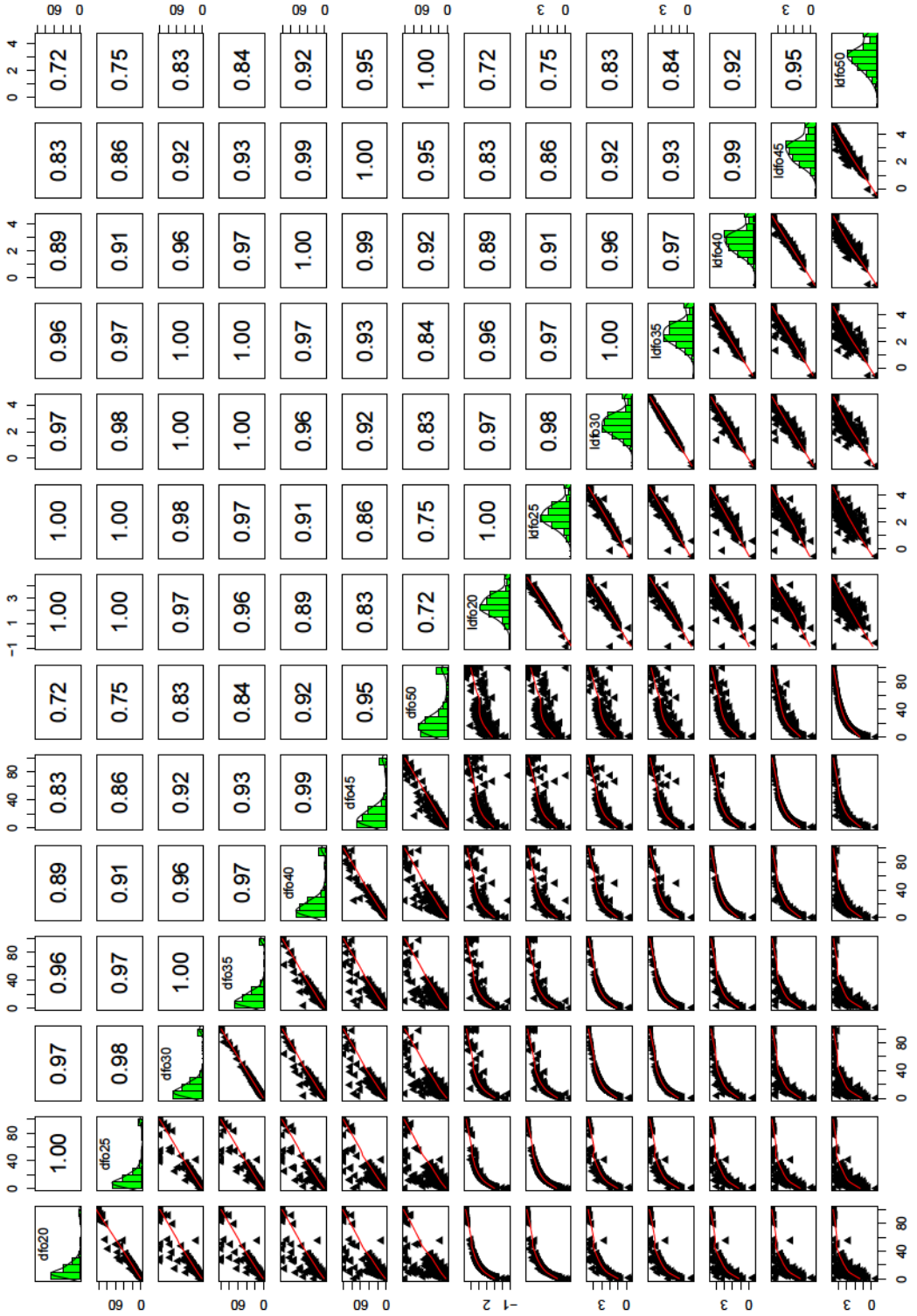


Figure D.3.1: Non-transformed versus log-transformed deforestation thresholds

Abbreviations: dfo20-dfo50 stands for the 20%-50% non-transformed deforestation thresholds; ldfo20-ldfo50 stands for the log-transformed 20%-50% deforestation thresholds.



Figure D.3.2: Non-transformed versus IHS-transformed deforestation thresholds

Abbreviations: dfo20-dfo50 stands for the 20%-50% non-transformed deforestation thresholds; ihs_dfo20-ihs_dfo50 stands for the IHS-transformed 20%-50% deforestation thresholds.

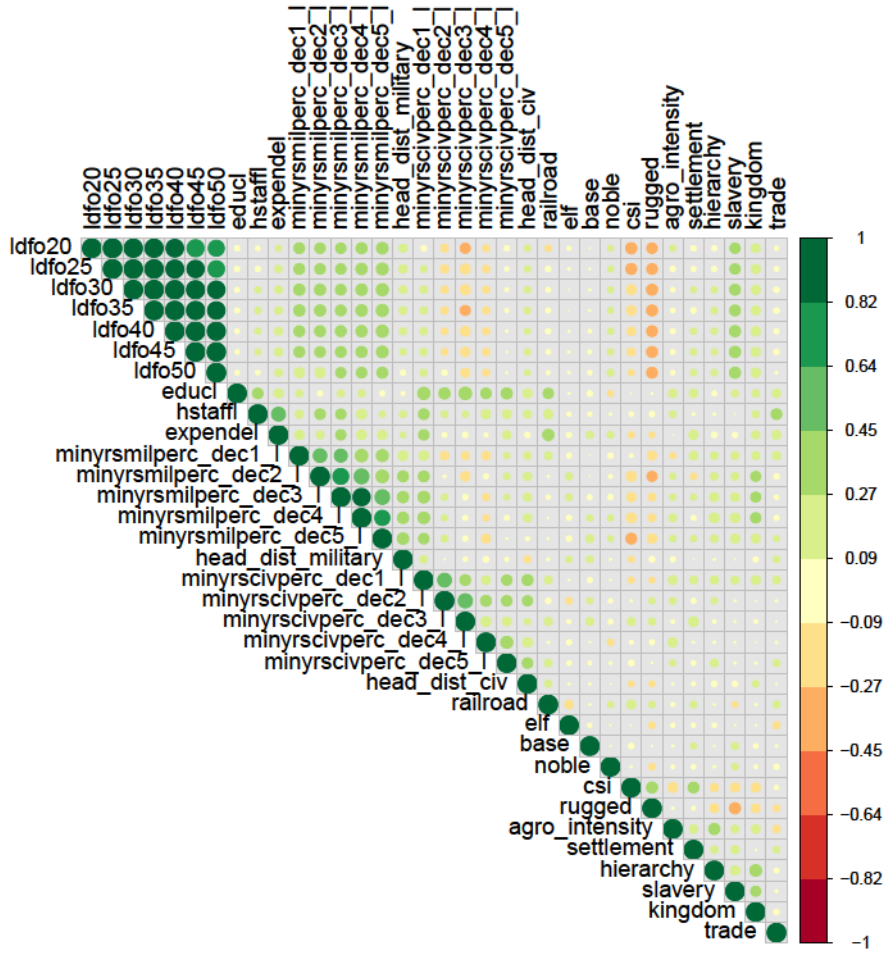
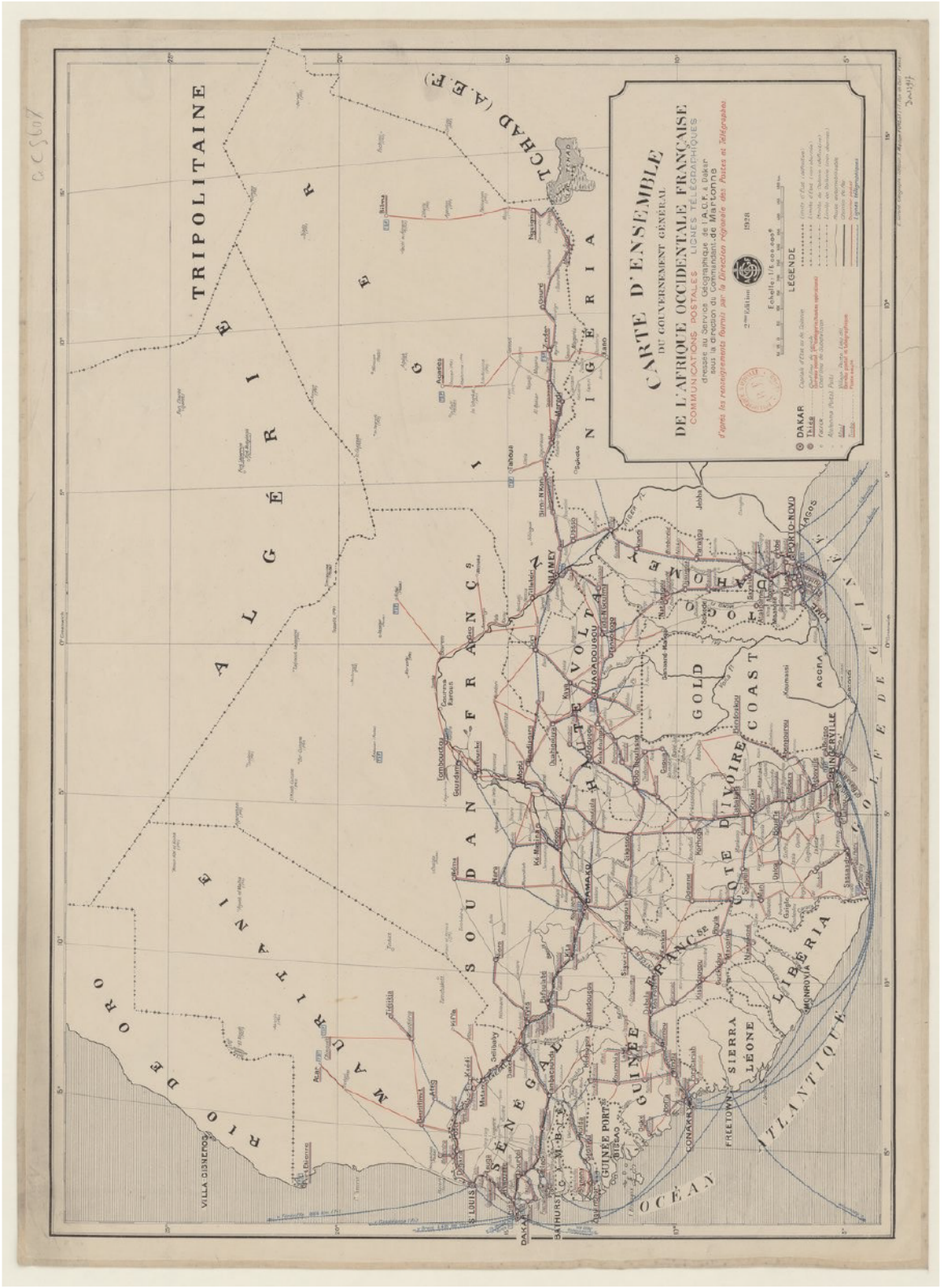


Figure D.3.3: Correlation plot of all variables

Abbreviations: ldfo20-ldfo50 stands for the 20%-50% log-transformed deforestation thresholds, educl – for log-transformed education in the full sample, hstaffl – for log-transformed public health staff, expendel – for log-transformed infrastructure expenditure, minyrsmilperc_dec1_l – minyrsmilperc_dec5_l – for log-transformed military minister shares by district for each of the five decades in the period 1960–2010, head_dist_mil – for heads of military governments, minyrscivperc_dec1_l – minyrscivperc_dec5_l – for log-transformed civilian minister shares by district for each decade in the period 1960–2010, head_dist_civ – for heads of civilian governments, railroad – for railroad infrastructure, elf – for pre-colonial ethnic fractionalization index, base – for base metals, noble – for gold, silver or diamonds, csi – for Caloric Suitability Index, rugged – for terrain ruggedness, agro_intensity – for intensity of agriculture, settlement – for settlement patterns, hierarchy – for jurisdictional hierarchy beyond the local community, slavery – for type of slavery, kingdom – indicator of a kingdom at the end of the 19 century, trade – indicator of a trading post before the colonial conquest.

E. Map of colonial West Africa in 1928



Source gallica.bnf.fr / Bibliothèque nationale de France

Figure E.3.1: Map of colonial West Africa in 1928 (Huillery, 2009; Quoc-Anh et al., 2020; Ricart-Huguet, 2021a)

Source: French National library, Gallica, `https://gallica.bnf.fr/ark:/12148/btv1b53066560h`. This historic map has been used to construct part of the geographic area that is illustrated in Figures B.3.1–B.3.2.

F. List of countries in the sample

Benin	Burkina Faso	Côte d'Ivoire	Ghana
Guinea	Kenya	Mali	Mauritania
Malawi	Niger	Nigeria	Senegal
Sierra Leone	Tanzania	Uganda	Zambia

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Chapter 4

Deforestation in Sierra Leone: Unpacking the role of traditional chiefs' power and social values

Iva Mihaylova

Abstract

Sierra Leone is affected by considerable deforestation that has multiple cascading effects, including diminishing water reserves, biosphere loss, and soil erosion. Traditional chiefs are a primary institution shaping multiple facets of socioeconomic development at the local level of many low-income and developing countries. Although the central role of traditional leaders for contemporary development outcomes is increasingly recognised in academic research, little is known about their impact on the natural environment. I fill this research gap by studying the link between deforestation and chiefs' power, along with the trust placed in them by their communities. I find that locations with weaker chiefs experience higher deforestation. Locations with higher trust in chiefs are associated with less deforestation. Chiefs' power only weakly mediates the relationship between trust and deforestation. These results imply that chiefs, due to the consistent trust of their communities, are important partners to win for the introduction of policies that aim at improving local forest management, including through the increasingly popular forestry decentralisation strategies.

4.1. Introduction

Deforestation is a pressing and multi-faceted environmental challenge in Sierra Leone. Expert estimates suggest that the country's original forest cover amounted to 60 percent, but in the course of the last 200 years, more than 97 percent of primary forests and more than 70 percent of total forest cover have been destroyed (IUCN, 1993; Blinker, 2006). Just between 2013 and 2019, Sierra Leone lost one million hectares of forests, which corresponding to 5 percent of Africa's total tropical forest loss (Forest Trends, 2021). Among the main sources of Sierra Leone's uncontrolled deforestation are mining, agricultural expansion, land appropriation for urbanisation use, and intensified firewood and charcoal demand as a primary energy source for 95 percent of the population (Blinker, 2006; UNEP, 2010). The massive deforestation leads to multiple cascading effects, including soil erosion, loss of soil fertility, biosphere loss, and diminishing water reserves (IUCN, 1993; Jackson, 2015; Thomson Reuters, 2019).

Given the well-known and enduring weakness of the state's bureaucratic apparatus to implement policies, including those pertaining to environmentally sustainable development and delivering public goods and services to rural constituencies, African politicians rely on executive cooperation with local-level traditional leaders, or chiefs (Baldwin, 2016). Typically hereditary, the status of traditional chiefs originates from their connection to the customs of their local community (Baldwin, 2014). Chiefs have the power to shape multiple facets of socioeconomic development in their communities. They allocate and manage land, act as a gatekeeper between the formal state and the local population, provide public goods, influence voting outcomes and the judicial system, collect taxes, organise health prevention, and may be partners of NGOs, donors, and development practitioners (Açemoğlu et al., 2014; Baldwin, 2014; Boamah, 2014; Boone, 2014; De Kadt and Larreguy, 2018; Baldwin and Raffler, 2019; Tieleman and Uitermark, 2019; Van der Windt and Voors, 2020; Kirst, 2020). Although the central role of traditional leaders in contemporary socioeconomic development is increasingly recognised in academic research, little is known about their impact on the natural environment.

How does chiefs' power relate to deforestation in Sierra Leone? I rely on Açemoğlu et al. (2014) and Van der Windt and Voors (2020) who proxy chiefs' power with the log-transformed number of ruling families per chiefdom. A higher number of ruling families per chiefdom in Sierra Leone weakens chiefs' power because it intensifies their conflict and political competition, including during election periods (Burrows, 1976; Açemoğlu et al., 2014). Conflict can accelerate deforestation (González and Miguel, 2015; Kikuta, 2020). In the same direction points the evidence by Klopp (2012) and Sanford (2020) that more contested competitive elections in weakly

institutionalised democracies exacerbate deforestation because timber can be used to finance electoral campaigns and forest resources—to win electoral support. Therefore, I hypothesise that weaker traditional chiefs, due to the intensification of political competition among them, could be motivated to use forests for political purposes that accelerate deforestation. The evidence that I find in a regression setting is in line with this expectation for low to intermediate and high deforestation thresholds and remains robust to the inclusion of district fixed effects, controls that influence development and also potentially the natural environment through the well-known Kuznets curve and Oster's coefficient stability test.

Trust, defined as trusters' subjective belief based on probabilistic reasoning that a trustee will behave trustworthily in the future across a variety of repeated situations (Bauer, 2019), is a multifaceted concept that plays a crucial role in social exchange (Schilke et al., 2015) and influences the quality of the natural environment (Carattini et al., 2015) and deforestation (Murtazashvili et al., 2019). Is communities' trust in chiefs beneficial to forests? While generalised (Sønderskov, 2008; Carattini et al., 2015; Murtazashvili et al., 2019; Jo, 2021) and political trust (Fairbrother, 2017) are among the dimensions of trust that have attracted increasing academic attention, the relevance of trust in chiefs in low-income and developing countries that face frequent environmental challenges has never been studied. I address this research gap and report consistent evidence that higher trust in chiefs is associated with less deforestation at low, intermediate, and higher deforestation thresholds.

Rather than based on democratic principles, the relationship between communities in Sierra Leone and their chiefs is based on asymmetric power dependence (Açemoğlu et al., 2014). The more powerful the chiefs are, the less powerful is the population in their chiefdom. Variation in power is shown to influence variation in trust (Schilke et al., 2015). Does chiefs' power partially mediate the relationship between trust in chiefs and deforestation? I find that chiefs' power only weakly mediates this relationship. This can be interpreted as beneficial to forests, because it means that all chiefs in Sierra Leone, if they are willing to address deforestation, have the potential to succeed because of the trust that their communities consistently place in them. The results of the analysis focusing on trust remain robust to the inclusion of district fixed effects with and without controls and Oster's coefficient stability test.

The article proceeds as follows. The next section provides background information concerning the evolution and authority of traditional chiefs in Sierra Leone and the implications for deforestation. This section also surveys the relevant literature on trust and the quality of the natural environment, environmental policies, and attitudes. Based on the discussed literature, I derive three hypotheses. Following this, geo-spatial data on deforestation are discussed, along with the

survey data on Sierra Leone, data sources of the covariates, and the empirical strategy. The results are subsequently presented before the article concludes.

4.2. Theoretical framework

Chiefs' power and its implications for deforestation

Traditional leaders are local authorities who derive their legitimacy from their association with the customs of their communities from pre-colonial times, but their contemporary power is frequently explained in the literature as a result of colonial powers' decisions of where to implement indirect rule (Baldwin, 2014; Baldwin and Ricart-Huguet, 2021). The development of traditional authorities in Sierra Leone is captured well by this common approach of conceptualising them.

In 1896, the British colonial administration adopted a new policy according to which the pre-colonial kingdoms that had existed until then were divided into chiefdoms and the principal traditional leaders, referred to as 'kings' and 'queens', were recognised as their governors under the title 'paramount chiefs' who usually rule for life (Conteh, 2013; Açemoğlu et al., 2014; Van der Windt and Voors, 2020). In Sierra Leone, only members of families recognised by the British colonial authorities in 1896 are allowed to become chiefs, and this colonial tradition is maintained after independence (Açemoğlu et al., 2014; Van der Windt and Voors, 2020). Disputes over family membership are usually resolved if the interested party can prove his or her lineage to a ruling family, which was recognised by the British colonial authorities (Açemoğlu et al., 2014). Similarly to other African countries (Boone, 2015; Majambu et al., 2019; Kirst, 2020; Baldwin and Ricart-Huguet, 2021), chiefs in Sierra Leone have considerable power to influence the socioeconomic life in their chiefdoms (Baldwin, 2016). They allocate land, manage natural resources, impose taxes, decide on juridical matters, organise health prevention, and provide local public goods (Ribot et al., 2010; Glennerster et al., 2013; Açemoğlu et al., 2014; Boamah, 2014; Baldwin, 2014, 2016; Kirst, 2020; Van der Windt and Voors, 2020).

How does chiefs' power relate to deforestation? On analogy to Açemoğlu et al. (2014) and Van der Windt and Voors (2020), the key independent variable that proxies chiefs' power in this analysis is the log-transformed number of ruling families per chiefdom (fam_num_ln). Van der Windt and Voors (2020) suggest that traditional leaders in Sierra Leone can be described well by Mancur Olson's stationary bandit model (Olson, 2000). A key assumption of this view is the local embeddedness of traditional leaders that gives them a permanent status in their communities and is reinforced by their usual ruling for life (Baldwin, 2016). Traditional chiefs depend on lo-

cal income-earning opportunities, which incentivise them to provide public goods (Olson, 2000), for example, basic local infrastructure. Casey et al. (2012) show that traditional chiefs in Sierra Leone are major facilitators of rural development, including the collective provision of local public goods such as wells, latrines, and schools. Consistent with Olson's stationary bandit model, Van der Windt and Voors (2020) argue that more powerful chiefs, reflected by a lower number of ruling families per chiefdom, were more efficient in controlling the spread of the Ebola disease because, due to their local embeddedness, they directly benefited from the outcomes of better disease prevention. Some of the traditional leaders even implemented active measures such as dissemination of health information and building of task forces in order to prevent a shut-down of the local economy that would imply a suspension of their income earning opportunities (Van der Windt and Voors, 2020).

There are good reasons to believe that chiefs also influence deforestation in Sierra Leone due to their substantial authority to provide public goods and to allocate land in their role *"as the 'custodians' of chiefdom lands"* (Ochiai (2017), 5). Both activities involve chiefs' assessment of the opportunity cost in relation to whether to keep forests or cut down trees. The study by Gibbs et al. (2010) reports evidence that transforming forests into agricultural land is a common practice in Africa. I assume that Olson's stationary bandit model holds when chiefs are *powerful*. I define this situation as the case in which the number of ruling families per chiefdom converges to one. I expect that more powerful chiefs will have a greater capacity and will be more efficient in preventing situations of uncontrollable cutting down of trees. In building my expectation, I rely on Açemoğlu et al. (2014) who find that more powerful chiefs, or, equivalently, chiefdoms with fewer ruling families, have more authority to influence whether people can sell land or use it for agriculture. Since traditional chiefs are embedded and depend on their local communities, I expect that they will be interested the natural environment to be available, in a good state, and usable not only in the present moment but also in the future. This behaviour of powerful chiefs aligns with Olson's description of a stationary bandit: *"he is not like the wolf that preys on the elk, but more like the rancher who makes sure that his cattle are protected and given water"* (Olson (2000), 11).

However, as suggested by Açemoğlu et al. (2014), the behaviour of the ruling families changes, when their number per chiefdom *increases* because it *intensifies the political competition* among them as the legitimate political candidates to stand at elections that were introduced by the British indirect colonial rule. Olson's stationary bandit model cannot describe well the rivalries of the ruling families as part of their political competition. By citing Burrows (1976), Açemoğlu et al. (2014) suggest that the intensity of competition and conflict among the ruling families per chiefdom is an increasing function of the number of ruling families:

> *"Of the sixteen chiefdoms in Kenema district [...] Simbaru is the only chiefdom [...] boasting only one ruling family; as might be expected, its politics are characterised by widespread consensus and little overt conflict. In Dodo and Nomo [each with 2 families], family rivalries are muted. At the other end of the spectrum, Nongwa [4 families], Gaura [5 families], Tunkia [3 families] and Lower Bambara [2 families] are examples of intense ruling house conflict; all other aspects of local political interaction are remaindered subordinate to the demands of this basic cleavage in these chiefdoms."*

A higher number of ruling families per chiefdom *weakens* chiefs' power and intensifies their conflict (Açemoğlu et al., 2014). The latter can accelerate deforestation (González and Miguel, 2015; Kikuta, 2020). In the same direction points the evidence by Klopp (2012) on Kenya and by Sanford (2020), based on a broad sample of 136 countries that more contested competitive elections in weakly institutionalised democracies exacerbate deforestation. Sanford (2020) suggests that *"[p]oliticians facing a competitive election offer voters access to forested areas for small-scale farming or commercial use of timber in exchange for electoral support"* (1). According to Burrows (1976), cited by Açemoğlu et al. (2014), an analogy between political parties and ruling families in Sierra Leone can be made. Hence, the validity of the argument of Sanford (2020) about political behaviour harming forests can be extended to traditional chiefs. Against this background, I expect that weaker traditional chiefs, reflected by a higher number of ruling families per chiefdom, due to the intensification of political conflict among them, could be motivated to use forests for political purposes that exacerbate deforestation. This leads to hypothesis 1.

> **HYPOTHESIS 1**: Weaker traditional chiefs should **positively** covary with contemporary deforestation.

Trust, power and deforestation

Trust is famously defined by Rousseau et al. (1998) as *"a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behaviour of another"* (395). Repeated interaction can create trust and facilitate outcomes such as collective action that require cooperation (Ostrom, 1990). The growing literature on various facets of trust as explanatory variables for pro-environmental attitudes, policies, and the quality of the natural environment also builds on the assumption that trust incentivises willingness to cooperate with other people and cooperation-based outcomes (Svendsen and Svendsen, 2009; Aklin and Mildenberger, 2020).

In a cross-national analysis of 52 countries, Sønderskov (2008) reports evidence that generalised trust, defined as the expectation that a general member of society is trustworthy, is associated with higher membership in environmental organisations, measured as the answer to the

question *"Do you belong to a conservation, environmental, or animal rights group?"* in the fourth European and World Values Survey (EWVS) from 1999 to 2002. Carattini et al. (2015) contribute to this body of work by highlighting the positive role of generalised trust for the mitigation of carbon dioxide emissions in a sample of 29 European countries. Jo (2021) complements this line of research by studying how trust affects firms' compliance decisions as part of the European Union Emissions Trading System. She reports evidence that trust beneficially affects compliance and that this pattern varies depending on the country where the corporate headquarters is located.

Trust is a relevant factor to consider in the context of forest management because it explains the participation in collective action and voluntary associations in order to protect forests as a common pool resource (Ostrom, 2008). The traditional overexploitation of this type of resource by individuals to their own advantage without considering the collective interest is captured by Garet Hardin's (1968) famous article, 'The Tragedy of the Commons'. Murtazashvili et al. (2019) are the only authors so far to have studied the association between deforestation and trust. They find that higher generalised trust as a key independent variable covaries with lower deforestation as a dependent variable in a global sample of 94 countries.

In addition to the understanding commonly accepted in the literature that trust facilitates cooperation-based outcomes, Murtazashvili et al. (2019) highlight three channels that may explain the link between deforestation and trust. Firstly, societies with higher levels of trust tend to have higher legal compliance—for example, through avoidance of illegal logging, which could be beneficial for forest management. Secondly, higher trust may lead to more efficient responses to unexpected shocks of forest governance. Thirdly, trust mirrors corruption in society, and the latter causes deforestation (Burgess et al., 2012). Murtazashvili et al. (2019) explain further that when trust is lower, governments are more likely to engage in dishonest activities that can be expected to accelerate deforestation.

The overview of the empirical studies so far suggests that generalised trust has a pro-environmental effect in a variety of settings that study the quality of the natural environment, policies, and attitudes. Fairbrother et al. (2019) studied political trust as a form of relational trust toward known others as opposed to generalised trust toward unknown and distant others. Based on multilevel models and data on 42,401 individuals from 23 European countries, the authors showed that survey respondents with higher political trust tended to support fossil fuel taxes on condition that they were aware of the consequences of anthropogenic climate change.

Repeated interaction between traditional chiefs and their communities is a further context in which relational trust develops and cooperation-based outcomes are facilitated (Ostrom, 1990). My expectation is that higher trust in chiefs is beneficial to forests and is associated with less

deforestation. The logic is as follows. Although the authority of traditional chiefs to determine multiple aspects of socioeconomic life creates rent-seeking opportunities for them, they have incentives to self-regulate the quality of their governance not to fall below a certain threshold that is perceived as *acceptable* by their community because, due to their embeddedness, they depend on the local population for income-earning opportunities; their misconduct may create public discontent and, possibly, *a decrease of trust in them*, leading to their displacement by members of other families with legitimacy to rule the chiefdoms (Açemoğlu et al., 2014). This fact implies that chiefs may have personal motivation—although with a variable degree of personal compliance—to manage efficiently natural resources, to monitor that forest overexploitation does not happen, and to be responsive to the demands of their communities, including concerning forest sustainability. These arguments motivate hypothesis 2.

HYPOTHESIS 2: Higher trust in chiefs should **negatively** covary with contemporary deforestation.

Rather than based on democratic principles, the relationship between communities in Sierra Leone and their chiefs is based on asymmetric power dependence (Açemoğlu et al., 2014). The more powerful the chiefs are, the less powerful is the population in their chiefdom. At the same time, variation in power is shown to explain variation in trust. Concretely, lower-power individuals tend to perceive their relationships as more trustworthy because they place higher importance on them and behave cooperatively (Schilke et al., 2015). A higher number of ruling families per chiefdom, proxied by fam_num_ln, implies lower power concentration for the respective chiefs and higher power concentration for the respective community, which implies that trust in chiefs should drop, according to the argument of Schilke et al. (2015). Açemoğlu et al. (2014) suggests the same logic with direct reference to the chiefdoms in Sierra Leone: when the number of chiefs per district grows, people become less dependent on chiefs' role for the allocation of resources and services, and find it less valuable to invest in social capital and interactions with their leaders. Similarly to the more general case of social interaction described by Schilke et al. (2015), trust in traditional chiefs in Sierra Leone can be expected to drop and, hence, is partially mediated or explained by the decrease of chiefs' power, reflected by higher values of the variable fam_num_ln. These arguments produce hypothesis 3.

HYPOTHESIS 3: Traditional chiefs' power **partially mediates** the negative association between local community's trust in chiefs and deforestation.

Technically, hypothesis 3 consists in comparing estimates of trust in chiefs from (i) regression specifications of deforestation measures on trust in chiefs and district fixed effects (Table A.4.2)

with (ii) estimates of trust in chiefs from regression specifications of deforestation measures on trust in chiefs, district fixed effects and fam_num_ln as a mediating variables (Table A.4.3).

4.3. Data and methods

Dependent variable

The dependent variable is various deforestation rates, compiled on the basis of Version 1.7 of the high-resolution data of Hansen et al. (2013). They are defined at a spatial resolution of 1 arc-second per pixel, which corresponds to approximately 30 meters per pixel at the equator. Hansen et al. (2013) considers as forest only vegetation that is taller than 5 meters in height. Their dataset provides baseline forest cover for 2000 and when it dropped to zero in the period 2001–2019. Hansen's et al. dataset has been frequently used in previous literature (Bare et al., 2015; Larcom et al., 2016; Leblois et al., 2017; Abman, 2018; Alesina et al., 2019; Abman and Carney, 2020a,b; Abman and Lundberg, 2020) because its "*coverage is global, the method is accurate, and the data are not susceptible to interference from parties that seek to conceal or misrepresent information*" (Sanford (2020), 14).

I use the methodology detailed in Leblois et al. (2017) to calculate various deforestation rates. The key independent variables are cross-sectional, which motivates the decision to use aggregate and not annual measures of deforestation. Specifically, I calculate the deforestation rates as aggregate percentage loss (2007–2019)[6] of forest cover for each chiefdom in Sierra Leone, provided that they dropped to zero for grid cells with more than 20 percent, 30 percent, 40 percent, 50 percent, and 60 percent forest cover in 2000. The deforestation rates or thresholds calculated in this way allow "*to examine varying forms of land use change and forest ecosystems in tropical regions*" (Bare et al. (2015), 4). Throughout the text, the five thresholds at which the dependent variable is measured are denoted by $dfo_{20\%}$, $dfo_{30\%}$, $dfo_{40\%}$, $dfo_{50\%}$, $dfo_{60\%}$. Figures B.4.1 and B.4.2 illustrate the aggregate percentage loss (2007–2019) for the 20 percent and 60 percent deforestation thresholds. Figure D.4.1 shows that the probability distribution of all deforestation thresholds is approximately symmetric about the mean. This means that observations cluster around the mean with higher probability, and hence resemble the Gaussian distribution which commonly occurs

[6]The key independent variable on trust in chiefs in hypothesis 2 originates from the National Public Services Survey of Sierra Leone conducted in 2007. Reed and Robinson (2013) and Açemoğlu et al. (2014) undertook their surveys of Sierra Leone's chieftaincies in 2011. However, the number of ruling families as the key independent variable in hypothesis 1 has remained unchanged since approximately 1920 (Açemoğlu et al., 2014). Therefore, it is justified to aggregate deforestation over the longer period 2007–2019 rather than over 2011–2019.

for independent and identically distributed random variables. Therefore, no logarithmic or other transformations of the deforestation rates are undertaken either as part of the estimation of the baseline specifications or as part of the robustness checks.

Independent variables

The set of independent variables consists of two groups. The first proxies chiefs' power in chieftaincy *c*. It originates from Açemoğlu et al. (2014). They were the first to undertake a detailed reconstruction via surveys of the oral history of each of the 149 chieftaincies in Sierra Leone. The surveys were implemented by research team members who were native speakers of the local language, who visited each ruling family, conducted extensive interviews, and cross-checked their results both among them and with written historical sources (Reed and Robinson, 2013). Relying on Açemoğlu et al. (2014), I operationalise chiefs' power with the logarithm of the number of ruling families in each chiefdom (fam_num_ln). This measure reflects the concentration of chiefs' political power. In a chiefdom with more ruling families, there will be higher political competition, and hence less concentrated political power, or, equivalently, weaker chiefs (Açemoğlu et al., 2014). I complement the dataset with an amalgamation index that equals one if a chieftaincy has been merged with another.

The second key independent variable in this study is trust in chiefs in each chieftaincy. Since none of trust's dimensions are directly observable, the only available approach is to approximate them with individuals' perceptions derived from surveys (Carattini et al., 2015). For the purposes of this article, I operationalise trust with interviewees' answer to statement C.16c of the 2007 National Public Services Survey of Sierra Leone (Decentralization Secretariat, Republic of Sierra Leone, 2011; Açemoğlu et al., 2014): *"In your opinion, do you believe chiefdom officials or do you have to be careful dealing with them?"* Similarly to Sønderskov (2008), Carattini et al. (2015) and Murtazashvili et al. (2019) who study generalised trust in different settings than mine, I define the variable for trust in chiefs as the share of people who replied in the affirmative to question C.16c. In order to have a more nuanced comparative perspective of trust as a multi-dimensional concept, I complement the analysis with answers to the same question with respect to trust in people from own town/neighbourhood (C.16a); in people from outside of own town/neighbourhood (C.16b), referred to from here on as 'outsiders'; in local councillors (C.16e); in central government officials (C.16f); and in NGOs/donor projects (C.16g).

The comparison of estimates of trust in people from own town/neighbourhood versus outsiders is intended to capture possible social differentiation due to various identities and group affiliations (Baldassarri and Abascal, 2020) and related favouritism (Habyarimana et al., 2007). I

consider trust in various levels of local and central authorities because Horning (2018) has demonstrated that conservation of forests in Africa is only possible if there is simultaneous alignment between the interests of local and national decision-making actors. In addition, the recent survey article by Dinesen and Sønderskov (2021) suggests that institutional quality may have a positive association with generalised trust. Against this background, it can be expected that better quality central and local governmental institutions in Sierra Leone, which could consist of higher responsiveness to/willingness for alignment with the interests and requests of the electorate for better environmental quality, should be rewarded by citizens with higher trust. Next, by building on the logic of the literature on trust and environmental quality, higher trust in local or central government can be expected to be associated with less deforestation. Subsequently, I compare the estimates of trust in local and central government with those of trust in chiefs, because this approach yields useful insights into how to shape future policy decisions that benefit forest management. Finally, exploration of trust in NGOs and donors is relevant because of Africa's dependence on foreign aid and because the latter is also shown to influence deforestation (Bare et al., 2015).

Figures B.4.3 and B.4.4 in the Appendix visualise the geographic distribution of the log-transformed number of ruling families and trust in chiefs, respectively. These figures confirm that chieftaincies with higher values of either of these variables are not clustered in any particular area of Sierra Leone. Some of them are close to the capital Freetown, which is the largest city and a major port on the Atlantic Ocean, others are located in border regions, and still others are situated in the interior of the country. Furthermore, Açemoğlu et al. (2014) mitigate endogeneity concerns by providing evidence that the log-transformed ruling families are not meaningfully associated with the pre-colonial economic development of Sierra Leone. Traditional chiefs in their contemporary form should be understood as shaped to a considerable extent by the British indirect colonial rule and its 1896 policy that replaced the traditionally ruling kings and queens with paramount chiefs (Conteh, 2013; Açemoğlu et al., 2014; Van der Windt and Voors, 2020).

Control variables

As part of the control variables, I include a set of geographic characteristics that are potentially correlated with forest management and historical development. The first takes into account the fact that colonial practices have brought unprecedented ecological changes to the native ecosystems (Crosby, 2004; Galor and Özak, 2016; Lewis and Maslin, 2018). The colonisers replaced the traditional crop rotation agriculture with cash crops for export (Crosby, 2004). This change in the natural environment is reflected in the post-1500CE variant of the high-resolution, global Caloric Suitability Index (CSI) developed by Galor and Özak (2015, 2016) and Galor et al. (2016) that I

use. Unlike the measure of suitability of land for agriculture (Ramankutty et al., 2001), the CSI more fully captures the large crop variation and is based on potential crop yields, which mitigates endogeneity concerns (Galor and Özak, 2015).

I complement these data with geographic and historical development controls from Açemoğlu et al. (2014) that are known from broader contexts in the related literature to capture the degree of geographic and economic heterogeneity, as well as the opportunity cost of keeping land as forest cover or using it for other economic activities (Abman, 2018; Asher et al., 2020; Ricart-Huguet, 2021a,b): distance to coast (in kilometres), distance to river (in kilometres), distance to 1907 railroad (in kilometres), and minimum distance to Bo, Freetown, or Kenema (in kilometres). I also include an indicator of whether the respective district received mining permission during Sierra Leone's mining expansion in the 1930s, because in such regions chiefs are allowed to request direct payments from miners (Açemoğlu et al., 2014). For this reason, they could have an economic interest in allowing forest land to be cleared and used for mining activities.

I complement the regression specifications with a variable that captures essential 1895 trade routes (Mitchell, 1962; Açemoğlu et al., 2014), considering the possibility that they influenced the diffusion of colonial investments and regional economic disparities in the subsequent post-colonial period (Ricart-Huguet, 2021b). More populated districts may exert higher pressure on the natural environment. Therefore, it is appropriate to account for demographics. I account for the population in 1963 (Açemoğlu et al., 2014) in the regression specifications because its contemporary values may be bad controls in the sense of Angrist and Pischke (2008) and Cagé and Rueda (2016).

Empirical Strategy

In order to test the formulated three hypotheses, I estimate variants of the following regression specification:

$$\text{dfo}_{h\%\,ic} = \alpha_1 + \alpha_2 \text{fam_num_ln}_{ic} + \alpha_3 \text{trust_chiefs}_{ic} + \alpha_4 \text{amalgamation}_{ic} + X'_{ic}\alpha_5 + \text{District}_i + \epsilon_{ic}, \quad (1)$$

where $\text{dfo}_{h\%}$ are deforestation thresholds for $h = [20\%, 30\%, 40\%, 50\%, 60\%]$, aggregated over the period 2007-2019, in chiefdom c within district i. The coefficient of interest for hypothesis 1 is α_2. I expect it to be positive, which would imply that a higher number of ruling families corresponding to weaker chiefs, due to the competition and conflict among them, will resort to the allocation of forests for political purposes, and this may exacerbate deforestation. Hypothesis 2 is tested via the coefficient α_3. I expect it to have a negative sign because, as the literature

review revealed, various dimensions of trust have a beneficial effect on the environmental quality, attitudes, and membership in environmental organisations. A combination of the two sets of independent variables, fam_num_ln and trust_chiefs, is used to test hypothesis 3. This consists of comparing the magnitude of the estimates of trust_chiefs with and without the inclusion of fam_num_ln.

To reduce selection bias, all regression estimates presented in the article are from models including district fixed effects District_i for $i = 1, \cdots, 12$ that to a large extent eliminate variation attributable to confounding factors. I also take into account the possibility for within-group correlation of the regression residuals and on analogy to the study of Burgess et al. (2015) on Sierra Leone cluster the standard errors at the district level. This strategy of adjusting the standard errors reflects the assumption that the error terms are independent among districts but correlated among chiefdoms.

Since the inclusion of subnational fixed effects is not sufficient to mitigate possible spurious correlations, I account for eight historical and geographic correlates of economic development and forest management with the vector X. These variables are the CSI (Galor and Özak, 2015, 2016; Galor et al., 2016); population in 1963; distance to coast (km); distance to river (km); distance to 1907 railroad (km); minimum distance to Bo, Freetown, or Kenema (km); an indicator of whether the respective district received mining permission during Sierra Leone's mining expansion in the 1930s; and essential 1895 trade routes (Mitchell, 1962). Some regression specifications contain additional variables from the NPS survey to account for interviewees' trust in people from own town/neighbourhood, in outsiders, in local councillors, in central government officials, and in NGOs/donor projects. Although the dependent variable is longitudinal, the key independent variables are cross-sectional. Therefore, like other contributions on the legacies of the past (Michalopoulos, 2012; Açemoğlu et al., 2014; Galor and Özak, 2015, 2016; Galor et al., 2016; Larcom et al., 2016), I implement a cross-sectional setting and discuss the results of the estimation in the next section.

4.4. Results

The results are organised as follows. Estimates of the 30 percent deforestation threshold, representative of statistically significant deforestation measures, are presented for all hypotheses in Table 4.1. Additional results for the 20 percent, 40 percent, 50 percent, and 60 percent deforestation thresholds in Tables A.4.1–A.4.3 of the Appendix complement Table 4.1 and are estimated using identical regression models.

I begin by estimating the relationship between the measures of deforestation and chiefs' power, proxied by the log-transformed number of ruling families. The results are presented in columns 1–4 of Table 4.1 and in Table A.4.1. As predicted by hypothesis 1, the association between the log-transformed number of ruling families and deforestation is positive and remains statistically significant when the regression specifications contain district fixed effects without controls, when controls are added and after taking into account whether the chiefdom has been amalgamated. The coefficient of the indicator for amalgamation has a positive sign and is statistically significant, which implies that this administrative measure is detrimental to forests. Overall, a higher number of ruling families in a given chiefdom accelerates deforestation, which may be explained with the suggested by Açemoğlu et al. (2014) sharpened political competition and conflict among them and the reported evidence that these factors accelerate deforestation in other settings without a focus on traditional chiefs (Klopp, 2012; Burgess et al., 2015; Kikuta, 2020; Sanford, 2020).

I implement a standard variance decomposition (Nunn and Wantchekon, 2011; Cagé and Rueda, 2016) in order to gain insights about the explanatory power of the independent variables. Part A of Table A.4.4 in the Appendix contains the results concerning hypothesis 1. I find that the independent variables and the controls together explain between 10.30 and 19.00 percent of the total variation of the 20–60 percent deforestation thresholds. Of these percentage bounds, between 2.63 and 22.33 percent are explained by the log-transformed number of ruling families and the amalgamation indicator.

Columns 5 and 6 of Table 4.1 and Table A.4.2 contain the regression results for hypothesis 2. The coefficients for trust in chiefs are negative and statistically significant for all deforestation thresholds higher than 20 percent, hence providing support for hypothesis 2. An increase of trust in chiefs by one unit is associated with an average decrease in deforestation of 4.7, 5.6, 6.1, and 11.2 percent respectively for the 30, 40, 50 and 60 percent deforestation thresholds, while keeping all other variables in the regression fixed. The variance decomposition for hypothesis 2 is presented in Part B of Table A.4.4. The independent variable trust in chiefs and the controls together explain between 10.50 and 17.90 percent of the total variation of the deforestation measures. Of these percentage bounds, between 3.68 and 21.90 percent is explained by trust in chiefs.

Table 4.1: Regression estimates for the 30% deforestation threshold (dfo30)

	dfo30	dfo30	dfo30	dfo30	dfo30	dfo30	dfo30
	H1	H1	H1	H1	H2	H2	H3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
fam_num_ln	3.133**	2.625**	2.753	1.549*			3.192***
	(1.057)	(0.975)	(1.560)	(0.835)			(1.011)
amalgamation			0.962	2.634*			
			(1.688)	(1.238)			
trust_chiefs					-0.076**	-0.047*	-0.079**
					(0.036)	(0.023)	(0.035)
Controls	no	yes	no	yes	no	yes	no
District FE	yes	yes	yes	yes	yes	yes	yes
N	145	144	145	144	145	144	145
adj. R^2	0.387	0.552	0.383	0.555	0.435	0.542	0.395

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. The table reports OLS estimates. Clustered standard errors at the district level in parentheses. The controls in all regression specifications are: Caloric Suitability Index, population in 1963, distance to coast (km), distance to river (km), distance to 1907 railroad (km), minimum distance to Bo, Freetown or Kenema (km), an indicator whether the respective district has received a mining permissions during Sierra Leone's mining expansion in the 1930s, as well as essential trade routes in 1895. H1, H2 and H3 stands for hypothesis 1, 2, and 3, respectively.

Trust in chiefs may be a function of the number of ruling families because it determines their power (Açemoğlu et al., 2014) and the latter determines trust (Schilke et al., 2015). Therefore, Table A.4.5 presents regression results of trust in chiefs on chiefs' power and the full set of controls in the analysis. Neither the log-transformed number of ruling families nor the amalgamation indicator are statistically significant and, hence, endogeneity concerns can be mitigated. An interesting result is that the coefficient of Caloric Suitability Index is negative and statistically significant. It can be linked to the study of Raz (2021), who finds that soil heterogeneity lowers the importance of moral foundations. They are derived from individual answers to questions of Graham et al. (2011) that measure virtues such as fairness, reciprocity, leadership and followership, individualising versus binding distinction, and striving to live a more noble life. Although the coefficient of the distance to the nearest railroad in Table A.4.5 is statistically significant, it is at the 10 percent level and is unlikely to be economically important.

The coefficient plots in Figures A.4.1–A.4.4 in the Appendix compare the 90 percent confidence interval estimates of trust in chiefs versus trust in people from own town/neighbourhood,

outsiders, local councillors, central government officials, and NGOs/donors, based on clustered standard errors at the district level, all controls, and district fixed effects. The figures show that apart from trust in chiefs, the only other trustworthy sources perceived by the interviewees are NGOs and donors in general. This result remains consistently statistically significant for all deforestation thresholds and has a negative association with deforestation. In comparison to the results about trust in chiefs, an increase of trust in NGOs/donors by one unit is associated with a greater average decrease in deforestation of 7.89, 8.42, 8.22, 6.77 and 12.18 percent respectively for the 20, 30, 40, 50 and 60 percent deforestation thresholds, keeping all other variables in the regression fixed.

The results in Figures A.4.1–A.4.4 about trust in both central and local state officials are indicative of possible inefficiencies that trigger deforestation. Concretely, the lack of statistical significance between all deforestation measures and these dimensions of trust suggests that it may be due to central and local governments' lack of or low quality response to the electorate's requests for a cleaner natural environment. These arguments find support in the study by Ribot (2010), who noted with respect to forest management in Africa that central-level regulation has not changed its original purpose to favour foreign (colonial) and local elites and exclude people outside these circles. The authors observe further that *"[i]n most cases, local authorities do not represent the local population or their space of discretion is so narrow that they have little effect on management"* (1).

Columns 5 and 7 of Table 4.1 contain the regression estimates that allow to assess hypothesis 3 for the 30 percent deforestation threshold. By comparing these two specifications, it can be noted that the inclusion of the log-transformed ruling families explains 3.80 percent of trust in chiefs, and hence confirms the expectation of this hypothesis. The analogous comparison of the specifications in the lower panel of Table A.4.2 with those in Table A.4.3 suggests that the log-transformed number of ruling families explains 4.17, 2.33, 1.18, 2.50 percent of the relationship between trust in chiefs for the 20, 40, 50, 60 percent deforestation thresholds, respectively. Since chiefs' power only weakly mediates the relationship between trust in chiefs and deforestation, this can be interpreted as beneficial to forests because it means that all chiefs in Sierra Leone, if willing to address deforestation, for instance, through the commonly applied local co-production of goods via community contributions (Baldwin, 2016) and the becoming increasingly popular decentralisation strategies (Ribot et al., 2010), have the potential to succeed because of the trust that their communities consistently place in them.

My main empirical strategy includes estimation of the three hypotheses with district fixed effects, with and without a set of controls. However, it is still possible that omitted variables that

affect deforestation or chiefs' power and social perceptions about them bias the results. I implement Oster's coefficient stability test (Oster, 2019) in order to assess this possibility. It consists in defining a maximum R^2_{max} in a hypothetical regression with all observed and unobserved controls assumed to be included. The maximum R^2_{max} defined in this way must be higher than the estimates obtained from the regression models in Tables 4.1, A.4.1 and A.4.2.[7] A rule of thumb for the choice of a value of R^2_{max} does not exist. The R^2_{max} implemented in the social sciences literature varies between an increase in the observed R^2 with 0.1, or 10 percent (Ricart-Huguet, 2021a), and setting to 1 as the most stringent variant (González and Miguel, 2015). I select this most conservative value and the close to it 0.7 and 0.8. Table C.4.1 contains the results of the coefficient stability test. It shows that some of the confidence bounds for the estimated regression coefficients of trust in chiefs include 0 only for the unlikely to be achieved in practice values of $R^2_{max} = 1$.

The Sierra Leone Civil War took place between 1991 and 2002, during which the Revolutionary United Front (RUF), with support from the National Patriotic Front of Liberia (NPFL), intervened in Sierra Leone with the goal to overthrow the government (Sesay et al., 2021). What could be the potential impact of civil war on deforestation and what roles do the chiefs play? Burgess et al. (2015) address the first part of this question. They study the association between civil war and deforestation in Sierra Leone as a mean shift in remotely sensed forest cover data from the University of California, Berkeley between two points in time: 1990, right before the beginning of the war; and 2000, close to the end of civil conflict. Burgess et al. (2015) found that chiefdoms where attacks and battles were more intensive experienced significantly lower deforestation in comparison to their more peaceful counterparts. The authors explain that these results occurred due to the forceful disruption of agricultural activity from the civil war.

Burgess et al. (2015) do not focus on chiefs in their study on the link between civil war and deforestation. However, an analysis of chiefs' role in the Sierra Leone Civil War and its impact on deforestation is a relevant inquiry not only because of chiefs' ample authority to influence local socio-economic life but also because of evidence that suggests that they are motivated to intervene when calamities and conflicts occur. For instance, Van der Windt and Voors (2020) show that more powerful chiefs have had less Ebola cases, and that some of them undertook active disease prevention measures such as the dissemination of health information and building of task forces. Furthermore, Richards (2003) provides qualitative evidence that some chiefs have used tactics to drive the military conflict away from their chiefdoms, mentioning cases of traditional leaders' success by linking it to their power. The author also suggests that the traditional divide

[7] Oster's coefficient stability test allows only a single regression coefficient to be tested. Therefore, it is not possible to assess the results for hypothesis 3 via this test.

of the country between the elderly and youth as insiders to outsiders, respectively, to the power structure of the chieftaincy (Açemoğlu et al., 2014) sharpened during the Sierra Leone Civil War. As a result of the erosion of chiefs' authority among the young rural Sierra Leoneans, "*[c]hiefs were no longer in a position easily to impose on young men as in the days before the war*" (Richards (2003), 31). A consequence of this phenomenon could be an increase of deforestation because I found that it is positively associated with weaker chiefs, but I cannot test my theory because the unique kind of data on chiefs by Açemoğlu et al. (2014) is cross sectional, and I am not aware of the existence of alternative appropriate data.

4.5. Conclusion

Deforestation is a persistent environmental problem in Sierra Leone and has far-reaching consequences. I provide evidence for the important role that traditional chiefs play in contemporary deforestation in Sierra Leone. Locations with weaker chiefs experience higher deforestation. I explain this finding through sharpened conflict and competition for power among chiefs and forests being used for political purposes. I also provide evidence that locations with higher trust in chiefs have lower deforestation and that chiefs' power only weakly moderates the association between trust and deforestation. The findings imply that chiefs, due to the consistent trust that they enjoy in their communities, are important partners to win for the introduction of policies that aim at improving local forest management, including through the co-production of goods via community contributions commonly applied in the country (Baldwin, 2016) and the increasingly popular forestry decentralisation strategies (Ribot et al., 2010).

The observed global trend toward decentralisation, starting from the 1980s and 1990s, rests on broad agreement in practitioners' circles that it should facilitate environmentally sustainable development away from poverty (Crawford and Hartmann, 2008; Capistrano, 2009). Decentralisation processes taking two main forms—administrative and democratic decentralisation—have also affected the forest sector in Africa (German et al., 2009). There is a broad consensus that administrative decentralisation is the weaker form because of the strong upward accountability preserved toward various forms of central and more local state authorities; in contrast, democratic decentralisation aims to increase downward accountability (German et al., 2009).

Ribot et al. (2010) define the conditions for existence of democratic decentralisation as a prerequisite for improved forest management compared to its previous, highly centralised form. Firstly, the transfer of power should be done in a meaningful way. Secondly, it should be done in favour of local representative authorities. Ribot (2009) clarifies the concept by emphasising

that democratic decentralisation cannot exist if the mode of representation of the community is defined separately for each project, intervention, or state measure. It is essential to include the entire population in the decision-making process Ribot (2009). Based on a broad survey of democratic decentralisation cases concerning forest management in Africa, Ribot et al. (2010) conclude that it rarely represents the local population, or has insufficient discretionary power.

State constitutions that create upward accountability of the local level to political parties, ministers, and legislatures work against democratic decentralisation because they do not account for the interests of the local population in a credible way (Ribot et al., 2010). Henn (2018) develops this argument further by hypothesising that chiefs can be regarded as an institutional extension of the state apparatus when their status is formalised. A good proxy of the latter is if their authority derives from the state constitution (Albertus and Menaldo, 2014; Henn, 2018).

Sierra Leone is not an exception to the tendency toward chiefs' institutional extension that hampers the democratic decentralisation of forest management. Concretely, according to Article 72, Paragraph 5 of the Constitution of Sierra Leone, *"Parliament shall make laws for the qualifications, election, powers, functions, removal and other matters connected with Chieftaincy"*. My finding that a higher number of chiefs accelerates deforestation could be explained by the imbalance that consists in local power being allocated without representation, departing from democratic decentralisation. Based on success stories and lessons learnt from the democratic decentralisation of forest management, possible policy solutions to consider are to create rules that benefit the poorest and most vulnerable and not to create inequality by taking into account the interests of only some strata of society (Ribot et al., 2010).

A possible future research direction relates to the finding of this article that higher trust in NGOs and donors is related to less deforestation in Sierra Leone. However, as far as conservation aid is concerned, Bare et al. (2015) reports evidence that it accelerated deforestation in 42 sub-Saharan African countries between 2000 and 2013. Baldwin and Raffler (2019) discuss the relevance for development practitioners, such as donors, NGOs, and experts working on institutional reforms, questioning whether and how to work with traditional authorities. The authors argue that practitioners typically exclude customary authorities from their projects and more rarely seek to achieve cooperative solutions by involving traditional leaders.

Against this background, it will be relevant to analyse the relationship between chiefs' power and the trust in them on the one hand and donors' cooperation strategy on the other, and how this influences the effect of forest conservation aid on forests. A salient feature of traditional leaders to consider in this regard is their embeddedness in the local community (Baldwin, 2014; Van der Windt and Voors, 2020). Therefore, practitioners should not undertake any reforms to

alter chiefs' embeddedness, because this will diminish their communities' trust in them and may lead to negative outcomes (Baldwin and Raffler, 2019), including for forest management.

Appendix to Chapter 4

A. Additional results

Table A.4.1: Regression estimates of deforestation on chief's power

	dfo20	dfo20	dfo30	dfo30	dfo40	dfo40	dfo50	dfo50	dfo60	dfo60
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
fam_num_ln	2.435**	1.517*	2.625**	1.549*	2.503**	1.109	1.955*	0.450	3.434***	2.507*
	(0.832)	(0.690)	(0.975)	(0.835)	(1.060)	(0.846)	(1.047)	(0.830)	(1.020)	(1.193)
amalgamation		2.248*		2.634*		3.411**		3.681**		2.269
		(1.139)		(1.238)		(1.434)		(1.579)		(1.583)
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
District FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
N	144	144	144	144	144	144	144	144	144	144
adj. R^2	0.587	0.650	0.552	0.555	0.525	0.533	0.499	0.510	0.325	0.325

	dfo20	dfo20	dfo30	dfo30	dfo40	dfo40	dfo50	dfo50	dfo60	dfo60
fam_num_ln	3.075**	2.882*	3.133**	2.753	2.892**	2.167	2.171**	1.222	3.896***	3.179*
	(0.996)	(1.471)	(1.057)	(1.560)	(1.046)	(1.612)	(0.912)	(1.501)	(1.203)	(1.595)
amalgamation		0.487		0.962		1.832		2.398		1.812
		(1.512)		(1.688)		(1.968)		(2.033)		(1.684)
Controls	no	no	no	no	no	no	no	no	no	no
District FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
N	145	145	145	145	145	145	145	145	145	145
adj. R^2	0.430	0.426	0.387	0.383	0.354	0.353	0.324	0.325	0.248	0.245

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. This table provides a comparison of the main results for the 30 percent deforestation threshold in columns 1–4 of Table 4.1 and the 20, 40, 50 and 60 percent deforestation thresholds. Below each coefficient is reported in parentheses its standard error adjusted for clustering within districts. When controls are used, they are the same as the listed in Table 4.1.

Table A.4.2: Regression estimates of deforestation on trust in chiefs

	dfo20	dfo30	dfo40	dfo50	dfo60
	(1)	(2)	(3)	(4)	(5)
trust_chiefs	-0.038	-0.047*	-0.056**	-0.061*	-0.112**
	(0.024)	(0.023)	(0.026)	(0.033)	(0.041)
Controls	yes	yes	yes	yes	yes
District FE	yes	yes	yes	yes	yes
N	144	144	144	144	144
adj. R^2	0.578	0.542	0.519	0.499	0.327
	dfo20	dfo30	dfo40	dfo50	dfo60
trust_chiefs	-0.069*	-0.076**	-0.084**	-0.084***	-0.117***
	(0.041)	(0.036)	(0.034)	(0.030)	(0.036)
Controls	no	no	no	no	no
District FE	yes	yes	yes	yes	yes
N	145	145	145	145	145
adj. R^2	0.473	0.435	0.410	0.389	0.313

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. This table provides a comparison of the main results for the 30 percent deforestation threshold in columns 5–6 of Table 4.1 and the 20, 40, 50 and 60 percent deforestation thresholds. Below each coefficient is reported in parentheses its standard error adjusted for clustering within districts. When controls are used, they are the same as the listed in Table 4.1.

Table A.4.3: Regression estimates of deforestation on trust in chiefs and power of chiefs

	dfo20	dfo30	dfo40	dfo50	dfo60
	(1)	(2)	(3)	(4)	(5)
trust_chiefs	-0.072	-0.079**	-0.086**	-0.085**	-0.120**
	(0.040)	(0.035)	(0.033)	(0.028)	(0.041)
fam_num_ln	3.129***	3.192***	2.957**	2.235**	3.985***
	(0.973)	(1.011)	(0.993)	(0.885)	(1.265)
Controls	no	no	no	no	no
District FE	yes	yes	yes	yes	yes
N	145	145	145	145	145
adj. R^2	0.437	0.395	0.364	0.334	0.272

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. This table provides a comparison of the main results for the 30 percent deforestation threshold in column 7 of Table 4.1 and the 20, 40, 50 and 60 percent deforestation thresholds. Below each coefficient is reported in parentheses its standard error adjusted for clustering within districts.

Table A.4.4: Variance decomposition

Part A: Hypothesis 1	dfo20	dfo30	dfo40	dfo50	dfo60
A.1 Full regression specification					
adj. R^2	0.589	0.555	0.533	0.510	0.325
Δ(A.1-A.2)	17.40%	18.30%	19.00%	19.00%	10.30%
A.2 Regressions with fixed effects					
adj. R^2	0.415	0.372	0.343	0.320	0.222
A.3. Regressions with fam_num_ln, amalgamation and fixed effects					
adj. R^2	0.426	0.383	0.353	0.325	0.245
Δ(A.3-A.2)	1.10%	1.10%	1.00%	0.50%	2.30%
Δ(A.3-A.2)/Δ(A.1-A.2)	6.32%	6.01%	5.26%	2.63%	22.33%
Part B: Hypothesis 2	**dfo20**	**dfo30**	**dfo40**	**dfo50**	**dfo60**
B.1 Full regression specification					
adj. R^2	0.578	0.542	0.519	0.499	0.327
Δ(B.1-B.2)	16.30%	17.00%	17.60%	17.90%	10.50%
B.2 Regressions with fixed effects					
adj. R^2	0.415	0.372	0.343	0.320	0.222
B.3 Regressions with trust_chiefs and fixed effects					
adj. R^2	0.421	0.379	0.352	0.329	0.245
Δ(B.3-B.2)	0.60%	0.70%	0.90%	0.90%	2.30%
Δ(B.3-B.2)/Δ(B.1-B.2)	3.68%	4.12%	5.11%	5.03%	21.90%

This table contains variance decomposition results. They consist in calculations that involve adj. R^2 from several sets of regression specifications. The standard errors are clustered at the district level in all regression specifications. The results for hypothesis 1 are presented in rows A.1–A.3. Row A.1 contains the adj. R^2 of the estimation of the full regression specification (fam_num_ln, amalgamation, controls and fixed effects). Row A.2 contains the estimates of regression specifications that only contain district fixed effects. Row A.3 contains estimates of regression models that contain fam_num_ln, amalgamation and district fixed effects. The variables in the full regression specification A.1 explain between 10.30% and 19.00% of the total variation of the deforestation measures. The result $\Delta_{\%}$(A.3–A.2)/$\Delta_{\%}$(A.1–A.2) is the variance decomposition that corresponds to hypothesis 1. It is calculated as the ratio of the percentage difference between adj. R^2 of (A.3–A.2) and (A.1–A.2). It explains from 2.63% to 22.33% of the explanatory power of the full regression specification A.1. The calculation steps (B.1–B.3) concerning hypothesis 2 with main independent variable trust in chiefs (trust_chiefs) are analogous. All variables in the regression model B.1 are able to explain between 10.50% and 17.90% of the total variation of the deforestation measures. Of these percentages, between 3.68% and 21.90% are explained by trust in chiefs. This result is presented in row $\Delta_{\%}$(B.3-B.2)/$\Delta_{\%}$(B.1-B.2). It can be noted that the measures for chiefs' power and trust in chiefs have significantly higher explanatory power for the high deforestation 60% threshold.

Table A.4.5: Determinants of trust in chiefs

fam_num_ln	3.832
	(2.926)
amalgamation	-6.110
	(5.414)
caloric_suitability_index	-0.024**
	(0.009)
min_dist	0.057
	(0.089)
mitchell_km	-0.081
	(0.105)
mining_1930	-9.523
	(5.530)
population_1963	-0.000
	(0.000)
river_dist	-0.053
	(0.189)
coast_dist	0.013
	(0.076)
rail_dist	0.173*
	(0.090)
N	144
adj. R^2	0.052

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Clustered standard errors at the district level in parentheses. The variables are as follows: fam_num_ln – for the log-transformed number of ruling families, amalgamation – for the value of chiefdom's amalgamation indicator, caloric_suitability_index – for Caloric Suitability Index, coast_dist – for distance in kilometres to nearest coast, river_dist – for distance in kilometres to nearest navigable river, rail_dist – for distance in kilometres to nearest railroad, mining_1930 – for mining permission in 1930, population_1963 – for population in 1963, mitchell_km – for distance in kilometres to 19th century trading route (Mitchell, 1962), min_dist – minimum distance to Bo, Freetown or Kenema (km).

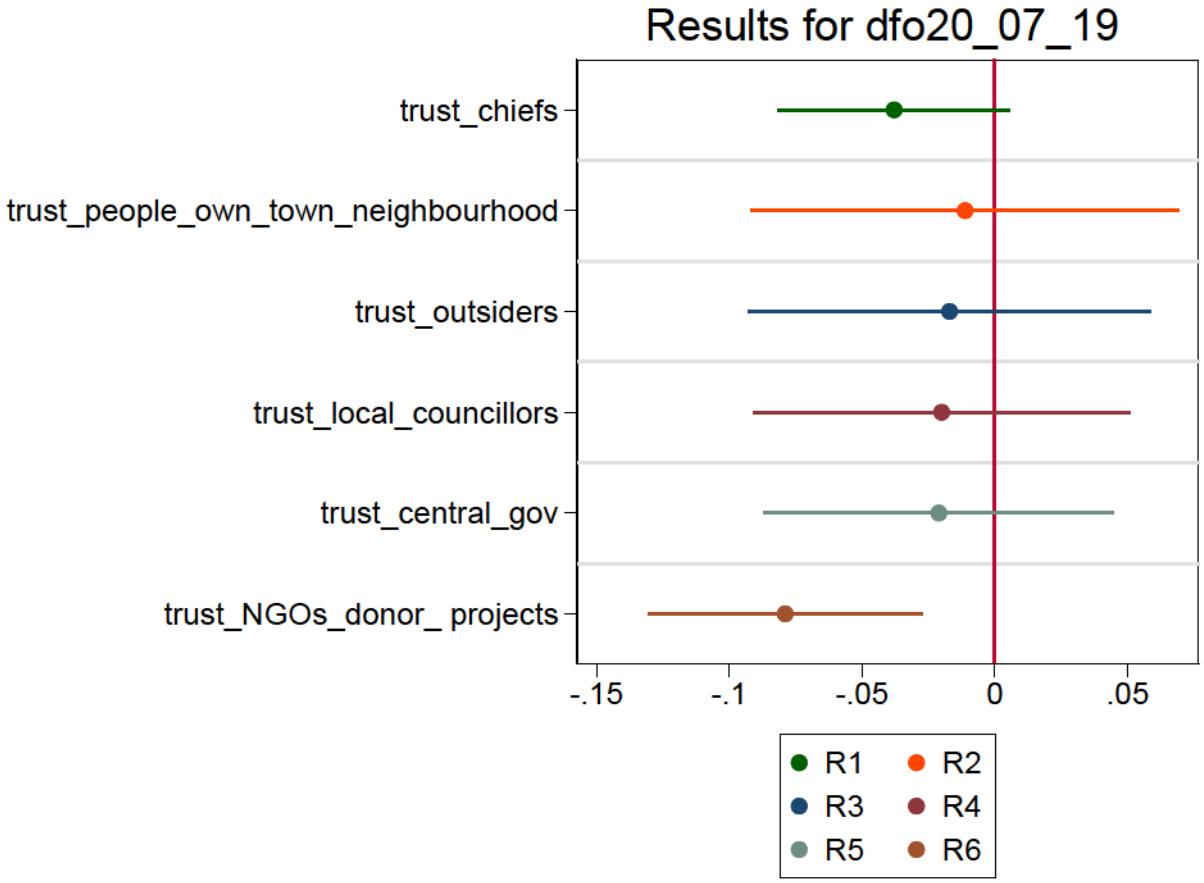


Figure A.4.1: Regression coefficient plots of various dimensions of trust for the 20% deforestation threshold in Sierra Leone

The graph reports OLS estimates. All point estimates are represented with their 90% confidence intervals. Standard errors are adjusted for one-way clustering at the district level. The key independent variables are: trust_chiefs – for the percentage of respondents who trust chiefs, trust_people_own_town_neighbourhood – for the percentage of respondents who trust people from own town/neighbourhood, trust_outsiders – for the percentage of respondents who trust outsiders, trust_local_councillors – for the percentage of respondents who trust local councillors, trust_central_gov – for the percentage of respondents who trust central government officials, trust_NGOs_donors – for the percentage of respondents who trust NGOs/donor projects. The used controls are: Caloric Suitability Index, population in 1963, distance to coast (km), distance to river (km), distance to 1907 railroad (km), minimum distance to Bo, Freetown or Kenema (km), an indicator whether the respective district has received a mining permissions during Sierra Leone's mining expansion in the 1930s, and essential trade routes in 1895.

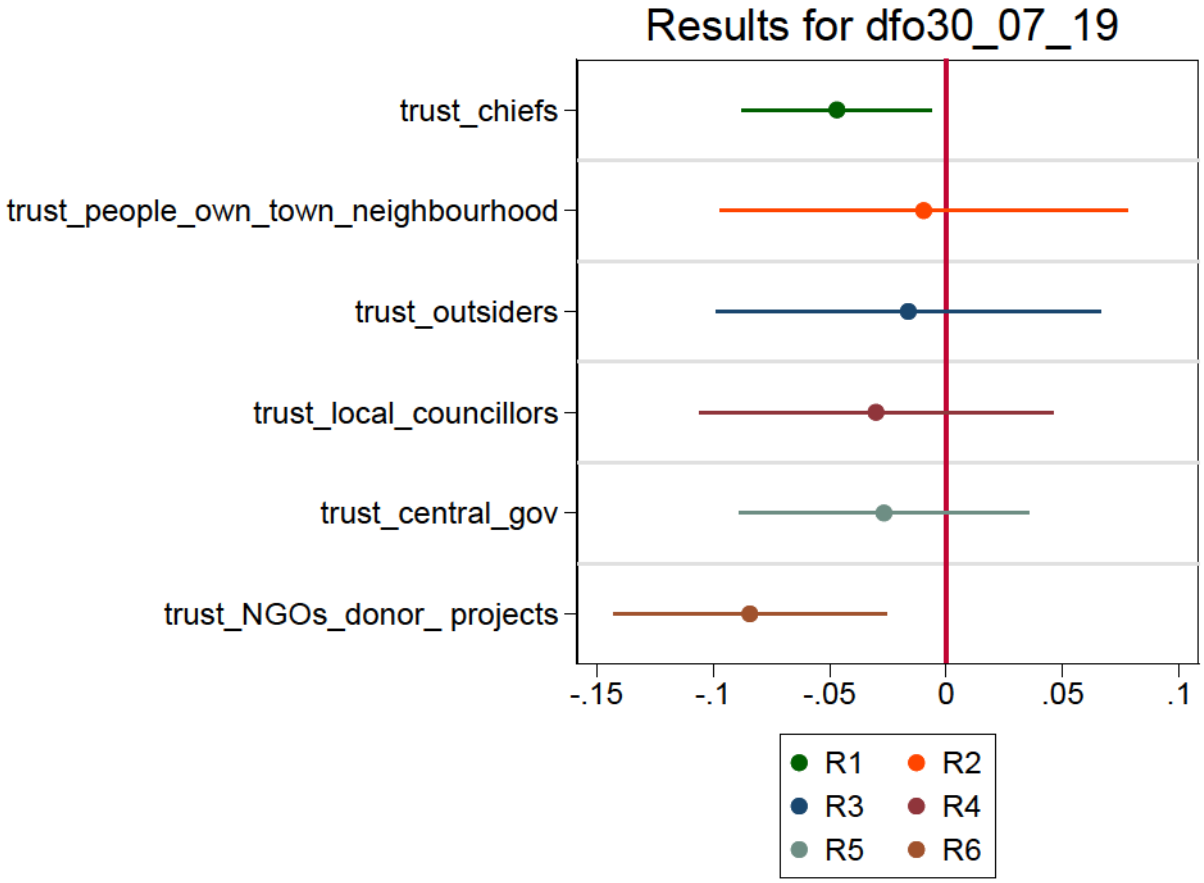


Figure A.4.2: Regression coefficient plots of various dimensions of trust for the 30% deforestation threshold in Sierra Leone

The graph reports OLS estimates. All point estimates are represented with their 90% confidence intervals. Standard errors are adjusted for one-way clustering at the district level. The key independent variables are: trust_chiefs – for the percentage of respondents who trust chiefs, trust_people_own_town_neighbourhood – for the percentage of respondents who trust people from own town/neighbourhood, trust_outsiders – for the percentage of respondents who trust outsiders, trust_local_councillors – for the percentage of respondents who trust local councillors, trust_central_gov – for the percentage of respondents who trust central government officials, trust_NGOs_donors – for the percentage of respondents who trust NGOs/donor projects. The used controls are: Caloric Suitability Index, population in 1963, distance to coast (km), distance to river (km), distance to 1907 railroad (km), minimum distance to Bo, Freetown or Kenema (km), an indicator whether the respective district has received a mining permissions during Sierra Leone's mining expansion in the 1930s, and essential trade routes in 1895.

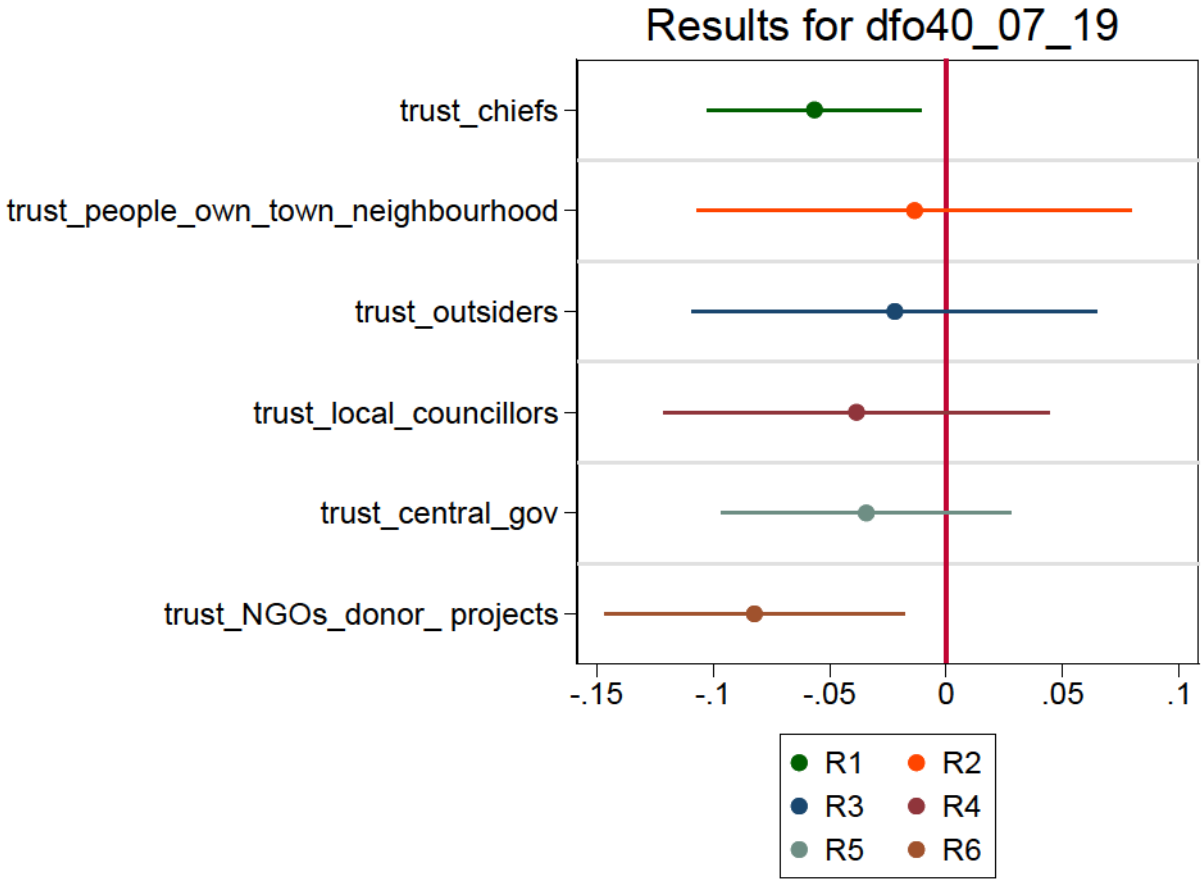


Figure A.4.3: Regression coefficient plots of various dimensions of trust for the 40% deforestation threshold in Sierra Leone

The graph reports OLS estimates. All point estimates are represented with their 90% confidence intervals. Standard errors are adjusted for one-way clustering at the district level. The key independent variables are: trust_chiefs – for the percentage of respondents who trust chiefs, trust_people_own_town_neighbourhood – for the percentage of respondents who trust people from own town/neighbourhood, trust_outsiders – for the percentage of respondents who trust outsiders, trust_local_councillors – for the percentage of respondents who trust local councillors, trust_central_gov – for the percentage of respondents who trust central government officials, trust_NGOs_donors – for the percentage of respondents who trust NGOs/donor projects. The used controls are: Caloric Suitability Index, population in 1963, distance to coast (km), distance to river (km), distance to 1907 railroad (km), minimum distance to Bo, Freetown or Kenema (km), an indicator whether the respective district has received a mining permissions during Sierra Leone's mining expansion in the 1930s, and essential trade routes in 1895.

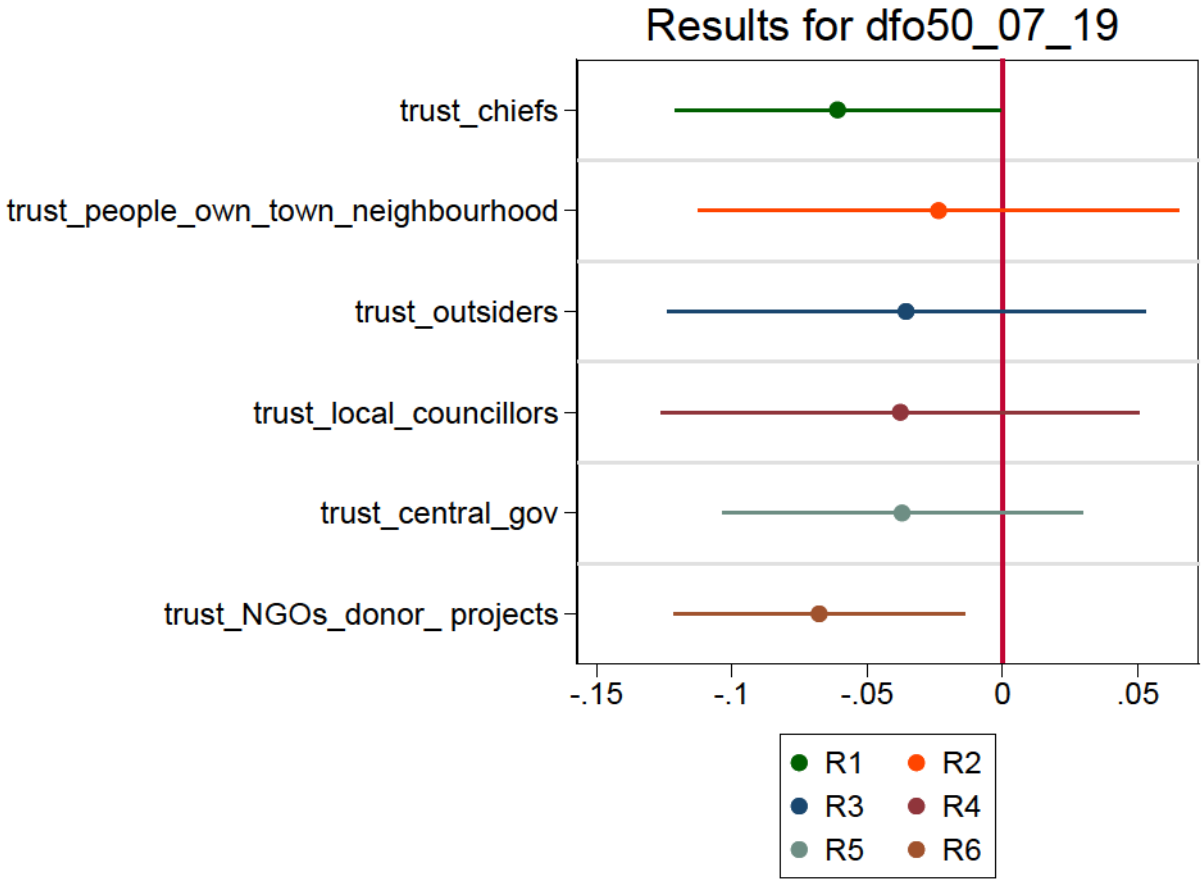


Figure A.4.4: Regression coefficient plots of various dimensions of trust for the 50% deforestation threshold in Sierra Leone

The graph reports OLS estimates. All point estimates are represented with their 90% confidence intervals. Standard errors are adjusted for one-way clustering at the district level. The key independent variables are: trust_chiefs – for the percentage of respondents who trust chiefs, trust_people_own_town_neighbourhood – for the percentage of respondents who trust people from own town/neighbourhood, trust_outsiders – for the percentage of respondents who trust outsiders, trust_local_councillors – for the percentage of respondents who trust local councillors, trust_central_gov – for the percentage of respondents who trust central government officials, trust_NGOs_donors – for the percentage of respondents who trust NGOs/donor projects. The used controls are: Caloric Suitability Index, population in 1963, distance to coast (km), distance to river (km), distance to 1907 railroad (km), minimum distance to Bo, Freetown or Kenema (km), an indicator whether the respective district has received a mining permissions during Sierra Leone's mining expansion in the 1930s, and essential trade routes in 1895.

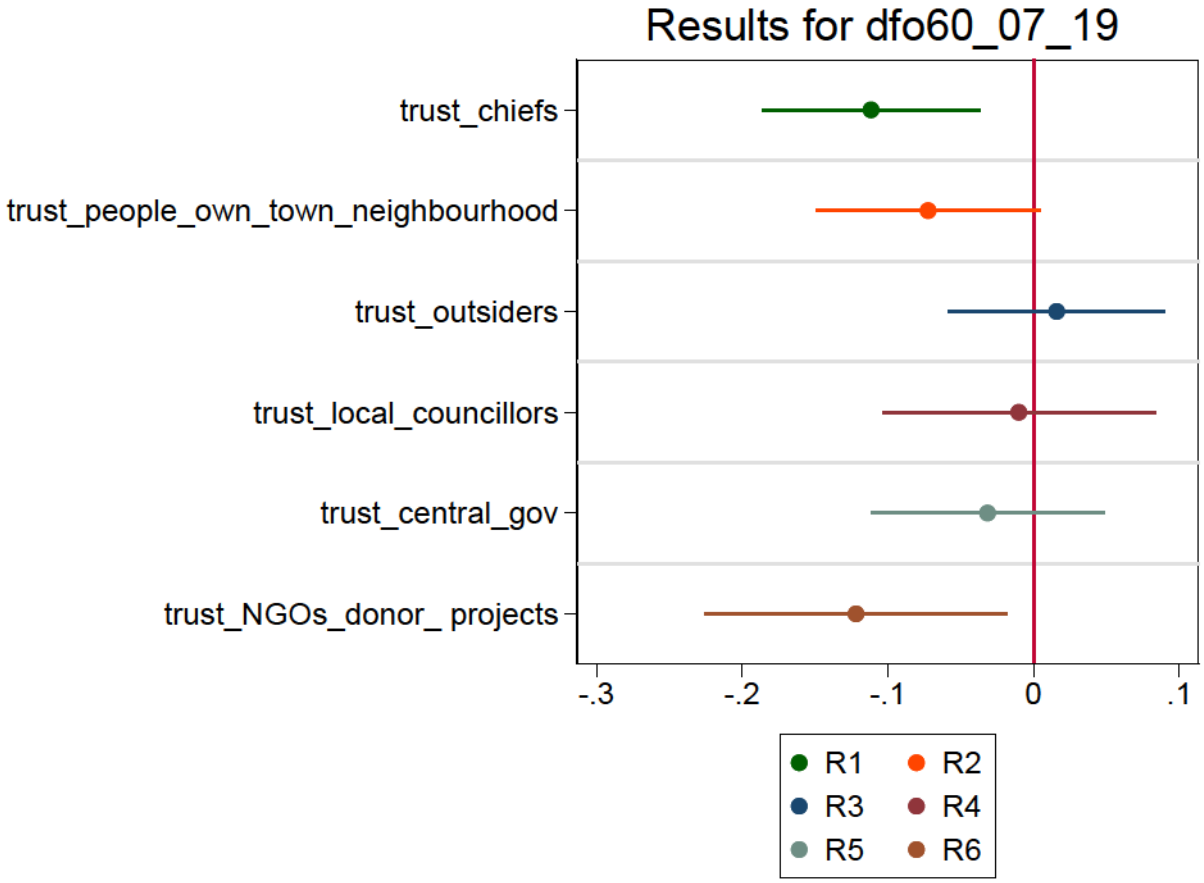


Figure A.4.5: Regression coefficient plots of various dimensions of trust for the 60% deforestation threshold in Sierra Leone

The graph reports OLS estimates. All point estimates are represented with their 90% confidence intervals. Standard errors are adjusted for one-way clustering at the district level. The key independent variables are: trust_chiefs – for the percentage of respondents who trust chiefs, trust_people_own_town_neighbourhood – for the percentage of respondents who trust outsiders, trust_outsiders – for the percentage of respondents who trust people from outside own town/neighbourhood, trust_local_councillors – for the percentage of respondents who trust local councillors, trust_central_gov – for the percentage of respondents who trust central government officials, trust_NGOs_donors – for the percentage of respondents who trust NGOs/donor projects. The used controls are: Caloric Suitability Index, population in 1963, distance to coast (km), distance to river (km), distance to 1907 railroad (km), minimum distance to Bo, Freetown or Kenema (km), an indicator whether the respective district has received a mining permissions during Sierra Leone's mining expansion in the 1930s, and essential trade routes in 1895.

B. Maps of key variables in the analysis

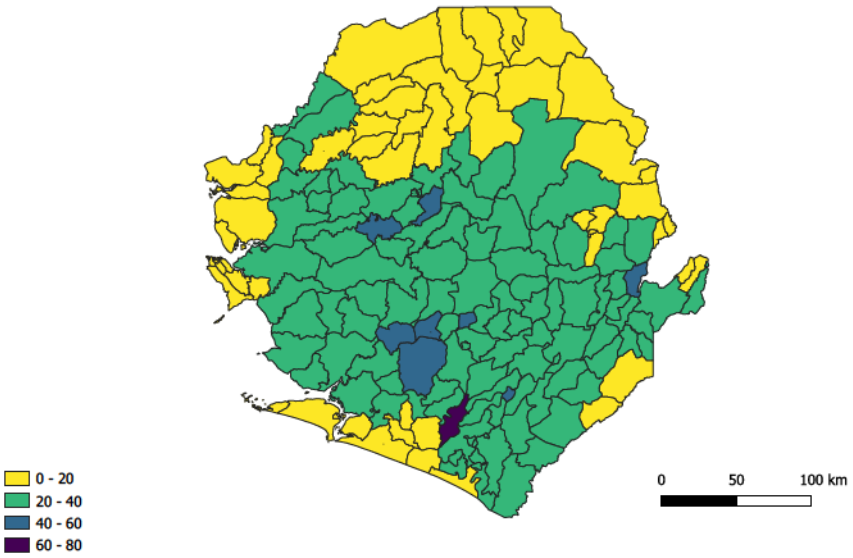


Figure B.4.1: Map of aggregate deforestation (2007-2019) for the 20% deforestation threshold in Sierra Leone

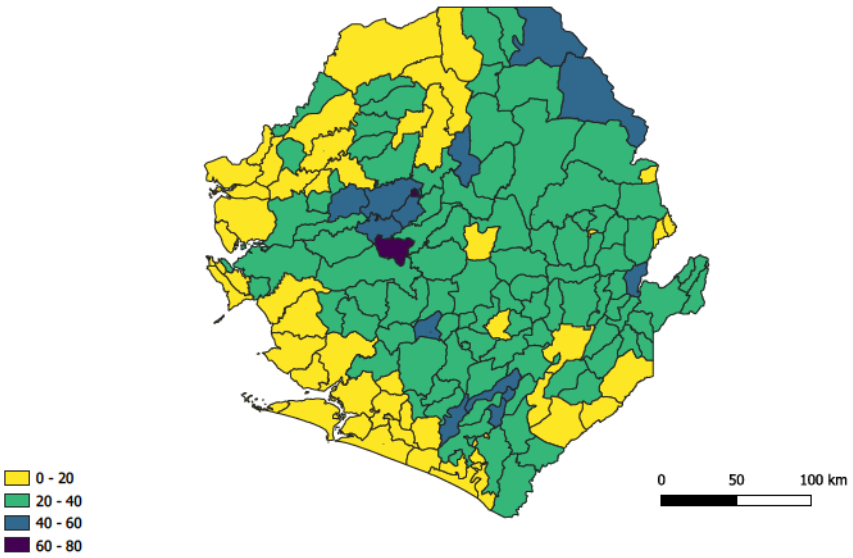


Figure B.4.2: Map of aggregate deforestation (2007-2019) for the 60% deforestation threshold in Sierra Leone

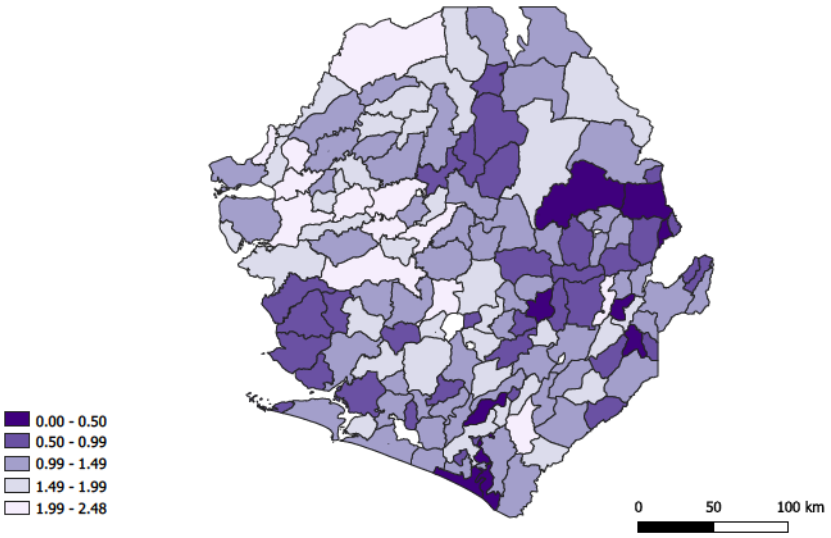


Figure B.4.3: Map of the log-transformed number of ruling families in Sierra Leone

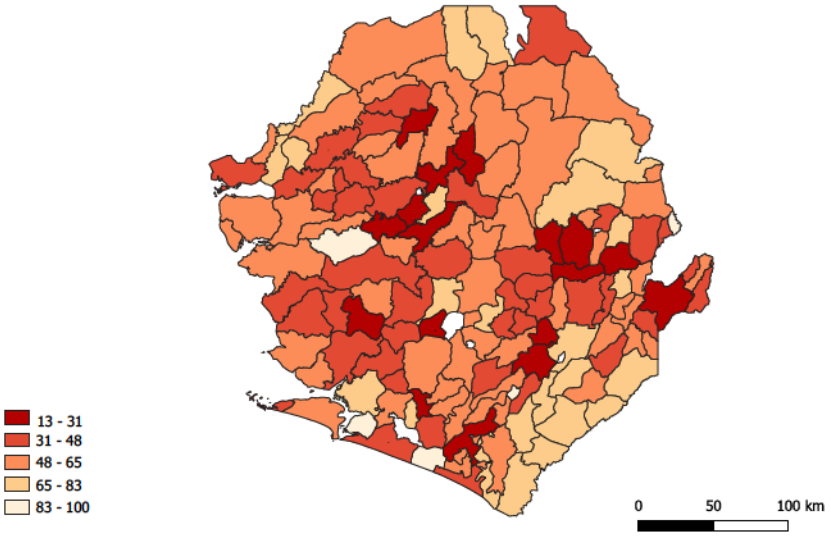


Figure B.4.4: Map of trust in chiefs in Sierra Leone

C. Coefficient stability test

Table C.4.1: Results from coefficient stability tests for the main regression specifications in Tables A.4.1–A.4.2

	$R^2_{max} = 0.7$	$R^2_{max} = 0.8$	$R^2_{max} = 1$
fam_num_ln, dfo20	[2.435, 2.224]	[2.435, 1.840]	[2.435, 1.074]
fam_num_ln, dfo30	[2.625, 2.379]	[2.625, 2.091]	[2.625, 1.517]
fam_num_ln, dfo40	[2.503, 2.273]	[2.503, 2.061]	[2.503, 1.637]
fam_num_ln, dfo50	[1.955, 1.805]	[1.955, 1.691]	[1.955, 1.462]
fam_num_ln, dfo60	[3.434, 2.250]	[3.434, 1.827]	[3.434, 0.982]
trust_chiefs, dfo30	[-0.047, -0.031]	[-.047, -0.014]	[-0.047, 0.019]
trust_chiefs, dfo40	[-0.056, -0.039]	[-0.056, -0.024]	[-0.056, 0.007]
trust_chiefs, dfo50	[-0.061, -0.045]	[-0.061, -0.033]	[-0.061, -0.008]
trust_chiefs, dfo60	[-0.112, -0.099]	[-0.112, -0.094]	[-0.112, -0.085]

This table contains the confidence bounds of the estimates of coefficient stability tests: (1) with $R^2_{max} = 0.7$; (2) of Baird et al. (2008) with $R^2_{max} = 0.8$, and (3) of González and Miguel (2015) with $R^2_{max} = 1$. The lower bound is derived from the regression models in columns 1, 3, 5, 7 and 9 in the upper panel of Table A.4.1 and in the upper panel of Table A.4.2. The upper bound is calculated by using the indicated R^2_{max} in the columns of Table C.4.1 and the workflow of González and Miguel (2015).

Each notation for the pair independent variable–dependent variable indicates estimates from a separate coefficient stability test. For example, the notation for the pair fam_num_ln, dfo20 refers to estimates from a coefficient stability test with a key independent variable the log-transformed number of ruling families, fam_num_ln, and the 20 percent deforestation threshold, dfo20, as the dependent variable.

D. Descriptive statistics, histograms and correlations

Table D.4.1: Descriptive statistics

	Count	Mean	SD	Min	Max
Deforestation, 20% threshold	145	25.97	10.99	3.25	61.46
Deforestation, 30% threshold	145	27.80	11.21	3.88	62.25
Deforestation, 40% threshold	145	29.65	11.46	3.50	63.08
Deforestation, 50% threshold	145	31.04	11.01	3.23	64.42
Deforestation, 60% threshold	145	26.17	11.02	1.69	61.97
Trust in chiefs	145	51.33	16.28	13.33	100.00
Trust in people from own town/neighbourhood	145	78.80	16.46	20.00	100.00
Trust in outsiders	145	40.25	18.07	6.67	100.00
Trust in local councillors	145	30.92	17.72	3.33	100.00
Trust in central government	145	36.20	19.71	5.00	100.00
Trust in NGOs/donor projects	145	48.46	18.36	6.67	100.00
Ln(Number of ruling families)	145	1.23	0.56	0.00	2.48
Amalgamation	145	0.31	0.46	0.00	1.00
Caloric Suitability Index	145	2750.19	231.01	2530.64	3618.84
Min. distance: Bo, Kenema, Makeni, Freetown	145	78.96	43.09	7.49	211.21
Distance (km) to 19^{th} century trade route	145	20.43	20.11	0.00	94.87
Mining permission in 1930	145	0.18	0.38	0.00	1.00
Population in 1963	144	13346.56	9435.81	980.00	47853.00
Distance (km) to nearest navigable river	145	9.15	7.14	0.09	36.54
Distance (km) to coast	145	105.73	65.06	3.11	250.40
Distance (km) to railroad	145	43.63	29.79	0.06	133.79

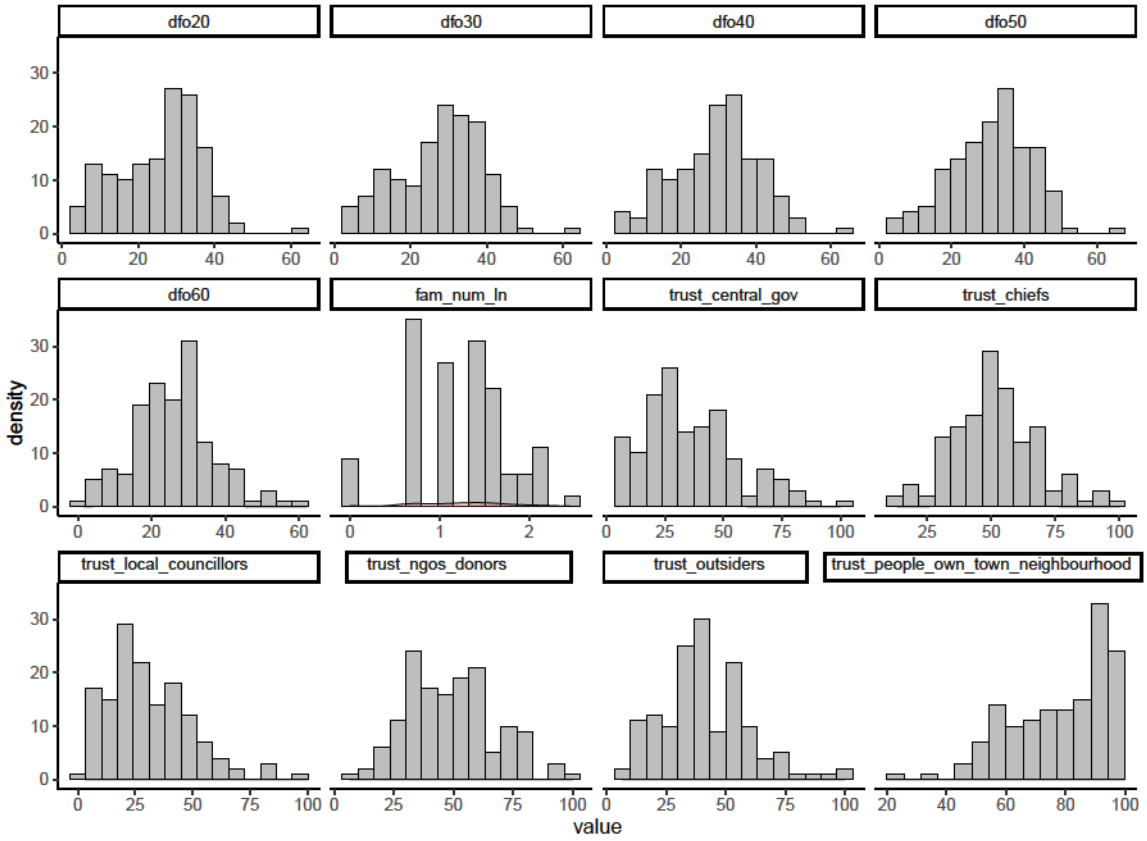


Figure D.4.1: Histograms of the dependent and independent variables

Notations: dfo20–dfo60 stands for the 20%–60% aggregate deforestation thresholds for the period 2007-2019, trust_chiefs – for the percentage of respondents who trust chiefs, trust_people_own_town_neighbourhood – for the percentage of respondents who trust people from own town/neighbourhood, trust_outsiders – for the percentage of respondents who trust outsiders, trust_local_councillors – for the percentage of respondents who trust local councillors, trust_central_gov – for the percentage of respondents who trust central government officials, trust_ngos_donors – for the percentage of respondents who trust NGOs/donor projects, fam_num_ln – for the log-transformed number of ruling families.

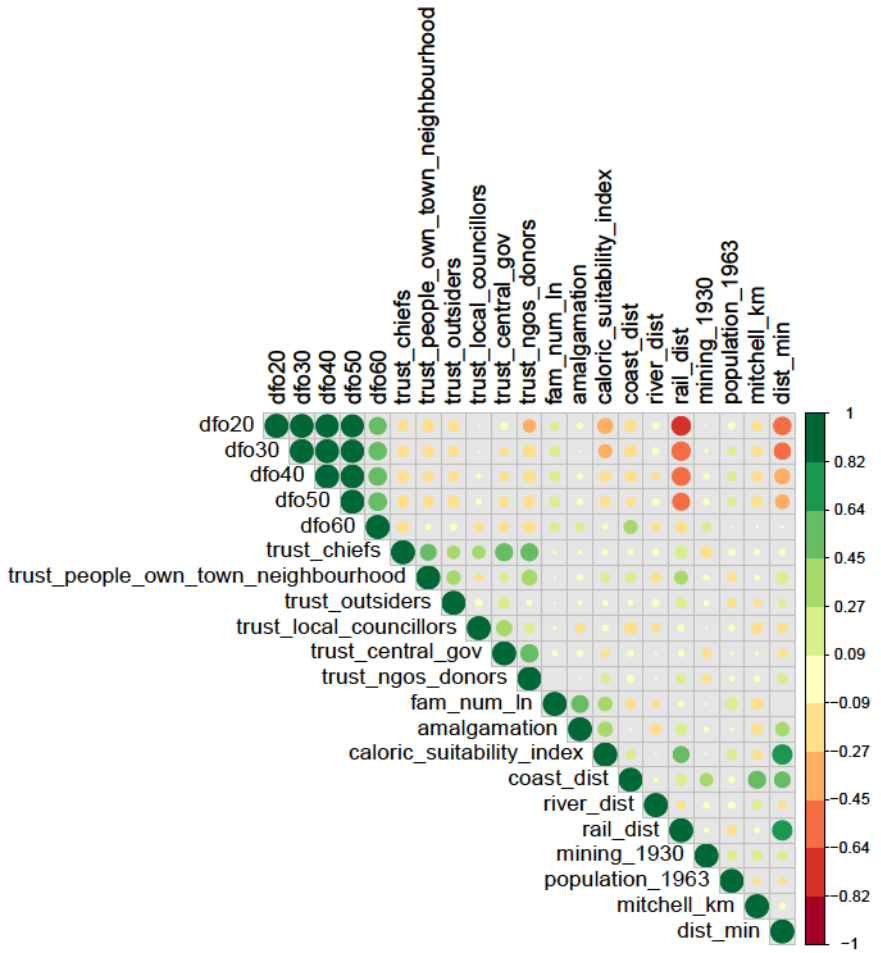


Figure D.4.2: Correlation plot of all variables

Notations: dfo20–dfo60 stands for the 20%–60% aggregate deforestation thresholds for the period 2007-2019, trust_chiefs – for the percentage of respondents who trust chiefs, trust_people_own_town_neighbourhood – for the percentage of respondents who trust people from own town/neighbourhood, trust_outsiders – for the percentage of respondents who trust outsiders, trust_local_councillors – for the percentage of respondents who trust local councillors, trust_central_gov – for the percentage of respondents who trust central government officials, trust_ngos_donors – for the percentage of respondents who trust NGOs/donor projects, fam_num_ln – for the log-transformed number of ruling families, amalgamation – for the value of chiefdom's amalgamation index, caloric_suitability_index – for Caloric Suitability Index, coast_dist – for distance in kilometres to nearest coast, river_dist – for distance in kilometres to nearest navigable river, rail_dist – for distance in kilometres to nearest railroad, mining_1930 – for mining permission in 1930, population_1963 – for population in 1963, mitchell_km – for distance in kilometres to 19th century trading route.

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5. Conclusions

5.1. Implications

The objective of this dissertation has been to study contemporary deforestation by focusing on its roots in the past that have continued to shape it till the present day through a process of path dependence. The first article, "Ethno-linguistic diversity: Understanding its significance to contemporary deforestation in Africa", has attempted to explain for the first time how the historical evolution captured by linguistic trees via cleavages of ethno-linguistic fractionalisation and polarisation as common diversity metrics relate to contemporary deforestation. Previous research shows that coarser linguistic divisions that date back thousands of years ago matter for contemporary redistribution and civil conflict; in contrast, however, cleavages that are finer and were formed more recently are found to matter for economic outcomes, usually pre-conditioned by cooperation and communication (Desmet et al., 2012). I find that both coarser and finer tiers of the linguistic trees of fractionalisation and polarisation for Africa accelerate its deforestation. This finding implies that deforestation in Africa may be partially rooted in past failures to cooperate and communicate and in distributional conflicts.

This result relates to a study by Aklin and Mildenberger (2020) that recently showed that the patterns of climate change policy are best modelled as distributive conflicts both within (level 1) and between countries (level 2). Although without focus on forest management, the findings by these authors are highly relevant for this setting because similar factors hold in this context, including their suggestion of level 1 distribution of costs and benefits and power asymmetries in which, as this dissertation has highlighted, elites and traditional authorities play a central role. The first article has shown that one of the factors that shapes level 1 of forest management is ethno-linguistic diversity through possible distributive struggles and communication problems. What public policy could be beneficial in such a situation? An inclusive policy that decreases the politicisation of ethnic identity could be an option (de la Cuesta and Wantchékon, 2016). A central element of such a policy could be to build a national educational system that is equally accessible

to all communities (de la Cuesta and Wantchékon, 2016; Baldassarri and Abascal, 2020).

The scientific evidence regarding the long-term effects of past education investments in growing. Cagé and Rueda (2016) show that individuals who live in greater proximity to early Protestant missionaries as principal providers of education in the British colonies of sub-Saharan Africa have higher civic and social capital scores. Woodberry (2012) finds that Protestant missions have significantly influenced the global spread of democracy. The second article in this dissertation, titled "Deforestation, political elites and colonial educational investments: Evidence from East and West Africa", contributes to this line of research by showing that colonial-era educational investments in sixteen former British and French colonies in sub-Saharan Africa play a durable role for their contemporary deforestation.

This article also breaks new ground by exploring the forest "footprints" of post-colonial political elites in a comprehensive quantitative manner. I show that the relative performance of military versus civilian governments differs, and I argue that a key mechanism for understanding this result is their unequal colonial-era education, which is shown to have long-term persistent effects into the current day and the fact that decision makers' educational background influences their policy decisions. The results of this article can thus inform policy decisions. Similarly to the first article, the second one suggests that a natural starting point for addressing Africa's deforestation problem at its roots is to provide more equal access to education, which could reduce the pressure of agriculture on forests as a traditional manner of subsistence in many low-income and developing countries (Dewees, 1995).

The third article, "Deforestation in Sierra Leone: Unpacking the role of traditional chiefs' power and social values", is the first attempt in the literature to assess the role of traditional chiefs' power and trust in chiefs regarding contemporary deforestation. I find that locations with less powerful traditional chiefs experience higher deforestation, a result that is explained by the intensified struggles for power in this setting. I also report consistent evidence that higher trust in chiefs leads to less deforestation for low, intermediate, and high deforestation thresholds. The implications of this article's findings are relevant in the context of the process of democratic decentralisation of forest management in Africa. Ribot et al. (2010) define two conditions for the existence of democratic decentralisation of forest management as a prerequisite for improved forest management compared to its previous highly centralised form. First, the transfer of power should be done in a meaningful way. Second, it should be done in favour of local representative authorities. Ribot (2009) clarifies further that democratic decentralisation cannot exist if the representation mode of the community is defined separately on a case-by-case basis for each project, intervention, or state measure. It is absolutely essential to include the whole population in the

decision-making process (Ribot, 2009).

These features of democratic decentralisation of forest management are highly relevant in the context of the strategy to resort to forest restoration as an approach to enhance biodiversity conservation and carbon removal. Africa is rich with good opportunities for forest restoration but there is a global tendency to ignore its social dimensions (Erbaugh et al., 2020). An approach to increase the beneficial impact of forest restoration is to empower the local population (Erbaugh et al., 2020), which is a step in the direction of democratic decentralisation. Strengthening chiefs' accountability to their communities as part of the process of democratic decentralisation of forest management in general, and as part of strategies such as forest restoration in particular, can help to address the systematic deforestation challenges in Africa.

5.2. Future work

Many traditional chiefs rule over regions with multiple ethnic groups in Africa. Further research could be undertaken to study in a large N setting if co-ethnicity with the customary chiefs accelerates deforestation through the mechanism of ethnic favouritism. Ribot (1993) reports evidence that patron-client networks that spread from the central to the local level in the essential for Senegal's economy charcoal sector contribute to deforestation. A research objective that deserves attention in a large-scale comparative setting is to study the interaction between political and economic elites and traditional leaders, as well as the general population. How have these networks evolved over time and affected the natural environment?

Paniagua (2018) shows that elites favour different policies depending on the level of their assets' diversification among sectors. Concerning traditional chiefs, Henn (2018) argues that they can be regarded as an institutional extension of the state apparatus in which their status is officially formalised, for example, in the constitution; in this case, the state and the chiefs work in symbiosis, complementing each other, and a stronger state translates into stronger chiefs. On the other hand, when chiefs are not integrated in the state structure, they compete with the state, and a stronger state decreases their power (Henn, 2018). Do political elites' cooperation strategies differ with respect to whether traditional leaders are (not) an integral part of the state apparatus and does this affect forests in Africa? These questions offer avenues for future research.

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- *Book chapter (2023):* Corporate Social Responsibility and Green Balanced Scorecards: Recent trends and future prospects (with Andreas Blumer), Encyclopaedia of CSR, Edward Elgar Publishing Limited.
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