



Comparing forest product harvest rates and livelihood activities among migrant and Indigenous households in the Congo Basin

Jessica L'Roe^{a,*}, Grayson Shanley Barr^a, Diane Detoeuf^b, Michelle Wieland^c, Bernard Ikati^d, Moïse Enduyi Kimuha^d, François Sandrin^c, Delphin Bilua^d, Gerard Bondeko^e, Yves Londza^e, Parfait Bakabana^e, Germain Mavah^e, Ben Evans^e, David Wilkie^b

^a Middlebury College, VT, USA

^b Wildlife Conservation Society, NY, USA

^c Wildlife Conservation Society, Africa Program, Kigali, Rwanda

^d Wildlife Conservation Society, Democratic Republic of the Congo

^e Wildlife Conservation Society, Republic of the Congo

ARTICLE INFO

Keywords:

Forest dependence

Protected areas

Migration

Off-farm income

Indigenous peoples

Conservation policy

ABSTRACT

Understanding uneven patterns of forest use and tracking changes in the composition of forest residents are both important for sensitive forest policy and management. With increases in migration streams in several tropical forest regions, we need corresponding information about how new immigrants are influencing human-environment relations in sites of ecological significance. We use data from over 6500 household surveys collected by the Wildlife Conservation Society in three sites in Central Africa: the forests surrounding Nouabalé-Ndoki National Park and Lac Télé Community Reserve in the Republic of Congo, and the Okapi Wildlife Reserve in the Democratic Republic of Congo. We compare household characteristics, livelihoods, and forest use among recent migrants (arriving within the past decade), longer-established households, and households belonging to an Indigenous group. We find that recent migrants are less likely to engage in forest-harvest-based livelihoods and harvest several types of forest foods and fibers less frequently than other households. Recent migrants also tend to be wealthier, younger, and over-represented in salaried jobs. Meanwhile, Indigenous households are 3 to 16 times more likely to participate in a forest-based livelihood, depending on the site. Other consistent predictors of forest harvest include village, age of the household head, household size, whether a household is female-headed (–), and wealth (–). Many trends hold broadly across all three sites, but there are also site-specific patterns related to differences in remoteness and economic opportunities. We conclude with reflections about what the changing make-up of forest-proximate communities might mean for forest management and governance.

1. Introduction

1.1. Forest harvest and migration

Forests support human prosperity in a multitude of ways, from regulating climate, to providing food and fiber resources, to sustaining culturally significant activities (Miller and Hajjar, 2020). One key way that people depend on forests is through direct harvest of forest

products. These often support forest-proximate households by supplementing diets and material requirements and providing a safety net in times of short-fall or crisis (Shackleton et al., 2011). Because forest harvest can affect forest composition (Ticktin, 2004), understanding this form of reliance is especially important when forests are managed to preserve wildlife populations while also supporting human livelihoods. In this study, we explore how changes in the human communities near forests may affect the patterns of forest product harvest.

* Corresponding author.

E-mail addresses: jlroe@middlebury.edu (J. L'Roe), gshanleybarr@middlebury.edu (G. Shanley Barr), ddetoeuf@wcs.org (D. Detoeuf), mwieland@wcs.org (M. Wieland), bikati@wcs.org (B. Ikati), menduyi@wcs.org (M. Enduyi Kimuha), fsandrin@wcs.org (F. Sandrin), dbilua@wcs.org (D. Bilua), gbondeko@wcs.org (G. Bondeko), ylondza@wcs.org (Y. Londza), pbakabana@wcs.org (P. Bakabana), gnavah@wcs.org (G. Mavah), bjevens@wcs.org (B. Evans), dwilkie@wcs.org (D. Wilkie).

<https://doi.org/10.1016/j.forpol.2023.103089>

Received 31 May 2023; Received in revised form 30 September 2023; Accepted 10 October 2023

Available online 27 October 2023

1389-9341/© 2023 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC license (<http://creativecommons.org/licenses/by-nc/4.0/>).

In the past three decades, we have learned much about *who* harvests forest products. For instance, harvest of particular resources is often gendered, with access rules negotiated under uneven power relations (Rocheleau and Edmunds, 1997; Mogotsi et al., 2016). Some types of forest harvest activities, such as hunting, tend to be performed by specialists, while others, like fuelwood collection, are practiced more broadly within communities (Coomes and Barham, 1997; Bakkegaard et al., 2017). Households with relatively more assets often extract more from forests while those with fewer resources may rely more on forest-based income (Coomes et al., 2004; Jagger et al., 2022). Sociodemographic characteristics are often correlated with the degree to which people use forest resources (e.g., McElwee, 2008; Dash and Behera, 2016; Mushy et al., 2020).

The contribution of forest products to local livelihoods differs from place to place. For example, forest products from the dry forests of Ethiopia contribute an average 17% of household income (Teshome et al., 2015), while forest products are responsible for over 70% of household income in parts of the Peruvian Amazon (L'Roe and Naughton-Treves, 2014). Sites vary in geographic factors like forest extent and population density (Cooper et al., 2018), socio-political factors governing forest access (Ribot et al., 2010), and economic factors influencing access to markets and opportunities for alternative income streams (Coomes et al., 2016). This study explores patterns of participation in forest harvest in three sites in Central Africa's Congo Basin, a region that is under-represented in literature on forests and livelihoods (Miller and Hajjar, 2020), especially given the ecological importance of its forests (Bele et al., 2015).

The forests of the Congo Basin represent substantial components of global biodiversity (Mittermeier et al., 2003) and carbon stocks (Saatchi et al., 2011). For many households in the Congo Basin, forests also directly underpin livelihood strategies (Endamana et al., 2019). Engagement with forest resources typically complements small-scale agricultural activities and often involves collection of non-timber forest products (NTFPs) including food, medicinal plants, fuelwood, and construction materials, as well as hunting and fishing. Logging is a prevalent economic activity (Ndoye and Tieguhong, 2004). The forests of the Congo Basin are also home to several groups of Indigenous Peoples, including the Ba'Aka groups in the west and the Mbuti, Efe, and Ba'Twa in the east (Hewlett, 2014). These groups have been traditionally characterized as semi-nomadic hunter-gatherers, foragers, and forest peoples in contrast with more sedentary communities of Bantu and Sudanic-speaking farmers and fishers. However, Indigenous groups have become more sedentarized in response to sometimes coercive social and governmental pressures (IWGIA, 2014). Both Indigenous and non-Indigenous households engage in harvest of forest resources, swidden agriculture, and non-farm livelihoods.

The impact of *changes* in the people living near forests is a topic of growing importance. In a recent horizon scanning exercise, a panel of forest policy experts identified changing rural demographics and a growing middle-class in low-income countries as two of five trends likely to have substantial impacts on forest-livelihood links in the future (Oldekop et al., 2020). Broadly, forest-proximate communities tend to reside in areas more remote from market centers, with lower value for agriculture and lower population densities (Sunderlin et al., 2008). However, expanding populations, increasing land competition, and migration are all acting to change the character of forest-proximate communities. In Sub-Saharan Africa (SSA), there is a strong tide of urbanization (De Brauw et al., 2014; Güneralp et al., 2017). There are also counter-streams of migrants to rural landscapes where land is more accessible for small holders (Jones et al., 2018; Salerno et al., 2014) and urban-based investors (Jayne et al., 2014). Intra-regional rural migration is also increasing, as people follow economic opportunities (e.g., mining), flee regions that have become unsafe due to violent conflict, or seek relief from environmental crises (Morrissey, 2014). As these trends lead to changes in the households residing near forests, more empirical information is needed about how forest use of migrants may differ from

that of longer-established populations, and how this varies in different contexts (Rasmussen et al., 2017).

Recent work suggests that migration in SSA is indeed contributing to changes in local use of forest resources, but the pathways and direction of the change can vary. In a study in Uganda, migrants were more likely to hunt and contribute to deforestation than long-term residents (Zommers and MacDonald, 2012). In Madagascar, migrants were found to have no higher propensity to clear forests than pre-existing residents, but they did expand the demand for agricultural land on forest margins by augmenting population densities (Jones et al., 2018). Near Mt. Cameroon, Indigenous households rely to a much greater extent on non-timber forest products for subsistence and have a much wider breadth and depth of knowledge of plant species in comparison to migrant households (Laird et al., 2011). These cases highlight the importance of the context and motivations driving migration in mediating outcomes for forests - i.e., whether people are "pushed" into more remote areas by competition, conflicts, or crises in neighboring regions or "pulled" to forested regions by perceived availability of forest resources or other economic opportunities.

A subset of forests worth special consideration are those that contain or comprise protected areas (PAs). Migration to sites in and around PAs represents a potential cause for concern for sensitive species and habitats, particularly when accompanied by additional extractive pressure, forest disturbance, or land clearing that can lead to habitat fragmentation (DeFries et al., 2005). Some of the most significant pressures on forests in the Congo Basin are related to the expansion of mining and logging roads in formerly unfragmented and relatively inaccessible regions (Rainey et al., 2010; Mogba and Freudenberger, 1998). In addition to direct impacts from logging, these roads increase poaching, commercial hunting (Abernethy et al., 2013), and provide means for smallholders to access land for agriculture in interior forested regions (Tyukavina et al., 2018). Protected areas can represent additional amenities and disamenities that could both attract or discourage migrants, depending on the circumstances (Coad et al., 2008; Wittemyer et al., 2008; Pullin et al., 2013). On the one hand, PAs can offer economic opportunities and protect resources critical for forest-based livelihoods. However, PAs can also restrict access to land and forest resources or increase the likelihood of human-wildlife conflict. Migrants are likely to have different relationships with forest resources in and around protected areas if they are attracted to the region by the resources themselves, attracted by employment or other economic opportunities associated with conservation efforts, or pushed into the area in search of available land for agriculture (Zommers and MacDonald, 2012). The extent to which in-migration represents a threat to the ecological integrity of protected areas and forests is a function of both the rates of in-migration *and* the motivations and activities of new immigrants.

In many regions, there is a question of temporal scale and a complex socio-political history informing established-outsider relations and who is considered a recent immigrant (Lacassagne, 2016). Human settlement in the Congo Basin has occurred in many waves over thousands of years and current residents reflect diverse processes and legacies (Gondola, 2002). In this study, we compare forest use and livelihoods of households arriving within the previous decade (since 2010) with longer-established households (those arriving any time prior to 2010). We also explore the extent to which differences represent continuing divergence in cultural traditions following much earlier waves of migration by comparing households with Indigenous heads to households with non-Indigenous heads. In the Congo Basin, groups of Indigenous Peoples have lived in the area for generation upon generation, for many thousands of years (Boyette et al., 2022; Hewlett, 2014). In both the Congo and the DRC, Indigenous groups are legally defined and include a suite of ethnic groups that have historically been collectively known as pygmies (Law No. 22/030 on the protection and promotion of the rights of indigenous pygmy peoples, 2022; Law No. 5-2011 promoting and protecting indigenous populations, 2011). Both new

migrants and Indigenous Peoples are relative minorities in our study sites; the majority of households do not fall in either category. In a sense, we examine different ends of a spectrum - those with relatively new ties to these regions and those with very deep ancestral ties.

In this analysis, we explore the role of migration in changing the composition of forest residents and local relationships with forest extraction. Specifically, we use data from over 6500 household surveys from >50 villages across three sites around protected forests in the Congo Basin to address the following research questions:

- 1) To what extent, and in what ways, are recent immigrant households different from the other households in the landscape?
- 2) How does migrant status compare with other traditional predictors of participation in forest harvest and forest-based livelihoods?
- 3) How sensitive are these patterns to the particular context of each landscape?

1.2. Study sites

The three sites we describe are locations within the Congo Basin where the Wildlife Conservation Society (WCS) has conducted extensive social surveys since 2015 to monitor human well-being around protected areas. Two, the Nouabalé-Ndoki National Park and the Lac Télé Community Reserve, are in the northern Republic of Congo, while the third, the Okapi Wildlife Reserve, is in the northeastern Democratic Republic of Congo (DRC) (Fig. 1). We outline key points contextualizing livelihoods, migration, and forest use for each site below.

1.2.1. The Okapi Wildlife Reserve in the DRC's Ituri Forest (Ituri)

The Okapi Wildlife Reserve (OWR) is located in the Ituri Forest of the Democratic Republic of Congo. It is ~14,000 km² and was gazetted in 1992 to protect significant populations of imperiled large-bodied wildlife such as okapis, chimpanzees and forest elephants (Brown, 2010). The reserve contains an interior core area where no extraction is allowed



Fig. 1. The three Congo Basin sites included in this analysis. Protected areas are shown in transparent green; white dots indicate villages where surveys were conducted. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(IUCN category II) and delineates zones for community agriculture, hunting, and resource gathering. Indigenous Mbuti and Efe Peoples live within and around the reserve, along with smallholder farmers from various Bantu and Sudanic-speaking ethnic groups (Brown, 2010). Farmers grow a mix of crops like cassava, peanuts, maize, and beans, in a combination of home gardens and shifting agricultural fields outside village centers (Brown, 2010; Kabuanga et al., 2021). Smallholders often source firewood, construction materials, and sometimes foods like wild greens, honey, and bushmeat from the surrounding forest (Terashima, 1998). It is estimated that the forest in and around the OWR provides livelihood opportunities for >100,000 people, ~27,000 of whom live inside the reserve (WCS, 2020). Villages are located along a road that bisects the reserve and a secondary road along the reserve's eastern border (see Fig. 1). Most of the the region's population is concentrated in a few urban centers (Mamabasa, Niania, Wamba, Mungbere) outside the reserve. The Ituri Forest represents one of the largest forest blocks in Central Africa, however, the area has become a settlement frontier and human populations are increasing rapidly given the region's proximity to more densely populated parts of the DRC and to places experiencing high levels of conflict, including the neighboring North Kivu province (Yanggen et al., 2010; Brown, 2010). Migrants to this landscape come in search of arable land, employment opportunities, regional stability, and market access. These trends have been especially evident since the 1980's with the liberalization of mining, two civil wars, and the reconstruction of the road that forms the Reserve's eastern boundary (Dazé and Crawford, 2016; Yanggen et al., 2010). There has also been a sharp rise in artisanal mining and poaching, some of which is associated with continued presence of militarized groups (IUCN, 2020). The Wildlife Conservation Society has been working in the Ituri Region for decades and now co-manages the Okapi Wildlife Reserve in partnership with the Congolese government. WCS activities in the region have focused on zoning, governance, wildlife monitoring, and a host of community-support initiatives including agroforestry projects such as the production of shade cacao for export.

1.2.2. The Lac Télé Community Reserve in the Republic of Congo (Lac Télé)

The Lac Télé Community Reserve is located between the Sangha and Oubangui Rivers in the Republic of Congo. The 4400 km² reserve was established in 2001 and is composed primarily of wet and seasonally inundated forest. It hosts the highest known densities of endangered western lowland gorillas (Rainey et al., 2010) and conserves part of the world's largest tropical peatland (Dargie et al., 2017). About 20,000 people live in 27 villages within and around the reserve, located on the few available raised areas along the shores of rivers to facilitate access but avoid seasonal flooding. The community reserve (IUCN category VI) includes zones allowing sustainable use of natural resources by local communities along with a zone of more strict protection. Most households are part of the long-established Bomitaba ethnic group, not considered Indigenous but with rights to traditional community territories in and around the reserve. In addition to the Bomitaba, there are also a smaller number of Ba'aka and Bakoulou Indigenous People, along with recent immigrants to the reserve (Yanggen et al., 2010). Immigrants primarily come for access to natural resources, though immigration to the reserve is comparatively low as there are limited employment opportunities, swamp forests have reduced value for timber exploitation, and there is limited permanently dry land for agriculture (Ekhasa and Oyo, 2012). In this wet landscape, fishing is one of the primary livelihood strategies and the source of 91% of the protein consumed by local communities (Yanggen et al., 2010). Most households practice small-scale agriculture (the main staple crop is manioc) along with NTFP collection, hunting, and minor commerce (ibid). Due to the seasonal flooding of forests and relative absence of roads, the Lac Télé Reserve is comparatively less affected by deforestation (Ekhasa and Oyo, 2012). The reserve's major current management challenges include declining fish stocks with increased commercial fishing, as well as wildfire, commercial hunting, and wildlife trafficking (ibid). The WCS

has been working in collaboration with the government in the region to assist in ensuring effective law enforcement, improve the well-being of reserve inhabitants, and support sustainable use and management of natural resources.

1.2.3. The Nouabalé-Ndoki National Park in the Republic of Congo (Ndoki)

Located in the north-western Congo Basin, Nouabalé-Ndoki National Park is a part of the larger Sangha Tri-National Forest Landscape, a trans-boundary conservation area that encompasses three contiguous national parks at the intersection of Cameroon, Central African Republic, and the Republic of Congo (Yanggen et al., 2010). The 4300 km² Nouabalé-Ndoki National Park was established in 1993. No resource extraction is permitted within the park (IUCN category II), and logging concessions, community hunting, and rural development interventions are located in the extensive forest outside the park's borders (Yanggen et al., 2010). Nouabalé-Ndoki National Park is unique in the contiguity and quality of its humid tropical forest ecosystem. Because of this, and the very low human population density in the surrounding region, Ndoki is often considered the most 'pristine' contiguous block of rainforest in the Congo Basin (Poulsen et al., 2010). The park has never been logged, contains no roads within its borders, and has high levels of animal biodiversity with little to no human contact, including endangered species such as western lowland gorillas and chimpanzees (Poulsen et al., 2010). Most of the landscape around Ndoki is still roadless and heavily forested, but ongoing expansion of logging roads is making the park more accessible for elephant poaching and commercial bushmeat hunting, particularly for antelope and monkeys. Outside of the park, there are villages to the south along the Sangha River and to the northeast along the Motaba River. Households in the Ndoki landscape practice small-scale swidden agriculture of crops like manioc and maize, but to a lesser extent than households in the Ituri landscape. Ndoki households engage more in collection of forest resources, including hunting, fishing, and harvest of non-timber forest products for food, medicine, and fibers. The principal Indigenous groups in the region are the Mbendjele and Bangombe groups of the Ba'Aka People (Lewis, 2005), now living primarily in settled communities alongside other groups that have come to the area in historic waves of immigration from higher population density regions to the north and east. Upstream along Sangha River in the Central African Republic, the neighboring Dzanga-Sangha Protected Areas complex has experienced significant immigration over recent decades associated with economic opportunities from placer diamond mining, commercial forestry, and a settlement frontier advancing from the north to the south with expanding transportation infrastructure (Mogba and Freudenberg, 1998). In Ndoki, most recent migrants have come for economic opportunities provided by logging activities, and by the protected areas themselves, including work as employees supporting research, wildlife protection, and tourism. In 2014, the WCS entered a public/private partnership with the Congolese government to co-manage the protected area and has invested regionally in community conservation, research and monitoring, tourism development, and biodiversity protection efforts.

2. Methods

2.1. Data collection

Survey data was collected in three sites by national teams from the WCS using a survey instrument called the Basic Necessities Survey (BNS). The BNS is one of WCS's principal tools for monitoring well-being and assessing socio-economic trends in communities around protected areas (Detoef et al., 2020). The survey instrument is designed to take less than half an hour to administer and collects information about household demographics, access to goods and services, livelihoods, and use of forest resources (see Table 2 for a detailed description of measures used in this analysis). Surveys were conducted with an adult household

member in the local language (Lingala, Swahili, and others) by teams of WCS technicians. Multiple survey campaigns were conducted in each site – the largest and most populated site was the Ituri landscape in the DRC, where 4923 surveys were conducted in 4 rounds (2015, 2017, 2019, and 2021). In the less populated sites in the northern Republic of Congo, 839 surveys were conducted in 3 rounds around Nouabalé-Ndoki National Park (2018, 2020, and 2022), and 791 in the communities in and around Lac Télé Community Reserve (2015, 2018, and 2021). Within each protected area landscape, WCS first selected a stratified sample of villages to capture variation in livelihoods, ethnicity, and WCS activities in the region, and then within the selected villages, teams visited a random sample of at least 30 households. The BNS protocol specifies 30 households per village to capture representative means at the village level while considering the overall resources required for completing surveys across this geographically extensive landscape (Lakens, 2022). Campaigns within each landscape included different but overlapping selections of villages. In instances where the same villages were visited in repeated rounds, teams attempted to survey the same households, but replaced these with new households to reach the target sample size when original households were unable to be reached.¹ Since 2017, data has been recorded digitally with KoboToolbox. Survey methods were reviewed and approved by the Congolese governments and the WCS Institutional Review Board to ensure compliance with Congolese and US federal regulations to protect the rights of human subjects.

2.2. Key variables

The BNS survey instrument included two complementary opportunities to assess engagement with forest resources. The first draws from a module of questions about the forest resources that a household collects. The resource harvest questions were not open-ended; regional field teams developed a standard list of indicator resources for each landscape to ensure that all households were prompted with the same information and limit potential bias from differences in respondents' recall. Lists contained ~5 items from the following general categories, based on the teams' knowledge of commonly collected non-timber forest products: fuelwood, bushmeat, wrapper leaves (*Marantaceae*), *Gnetum* / Eru / wild greens, polewood, lianas / rattan palm vine (*Eremospatha*), fish, fruit, honey, and mushrooms. Households were asked how frequently they collect each resource type in a given week. Households were not asked to specify where they collect forest resources (e.g., inside or outside the PAs); all the indicators could be legally collected in forests nearby. Distinct but overlapping lists were used in different campaigns; early years (2015) asked about more types of resources. Strongly seasonal resources (like fruits, mushrooms, and honey) were dropped from later years (after 2017) due to concerns that the timing of campaigns would not consistently align with seasonal availability and affect interpretation of temporal trends in harvesting. See Appendix Table 1 for an overview of indicator resources. Although this data in no way captured all the specific forest resources used by residents of these landscapes, we used the indicators to glean comparative information about the relative frequencies of forest harvest across different types of households, based on the sum of resource-trips per week.² Fig. 2 depicts the number of surveys mentioning each resource type. Fuelwood was the most commonly harvested resource, but also one of the least specific, so we also ran robustness checks without fuelwood to make sure results were not driven solely by this resource.

¹ This means that the sampling design is biased in a way that will underestimate the proportion of very recent immigrants in the subset of villages with multiple rounds of surveys.

² Because more than one forest resource could be harvested on a given trip, this is not exactly the same as asking "how many times do you collect forest resources per week?"

The second measure of forest use also focused on extraction but drew on a different set of questions about the livelihood activities of the household. Survey respondents could list up to 4 income-generating livelihood activities, considering all members of the household. This was a semi-open-ended question, where field technicians coded respondent's answers into a long menu of options. During analysis, we further classified these specific livelihoods into major categories (Table 1). The category of 'forest-based livelihoods' included hunting, fishing, plant collection, and logging work. If households mentioned any of these among their four livelihood activities, they were considered as engaging in a forest-based livelihood.

Our key predictor variables were whether a household had recently arrived in the landscape, and whether the household head (HH) was Indigenous. The former was produced from a question about the year that the household head arrived in the community. Because the birth year of the head or respondent was often recorded as an arrival year in cases where the household had not migrated, we used a binary indicator for whether the arrival year was after 2010. We also performed robustness checks with a 2015 threshold. Our binary Indigenous indicator refers to whether the head of the household identified themselves as a member of an Indigenous group. In addition to these factors associated with longevity in the landscape, we attend to other household characteristics thought to be correlated with forest use, including measures of labor availability, gender of household head, stage in household life cycle, and asset-based wealth. Table 2 describes each variable included in the analysis.

2.3. Analysis

For each of our study variables (Table 2), we first compared the means of recently migrated households to other households in the landscape with bivariate tests, assuming unequal variance. We used nonparametric rank tests as a robustness check for variables with skewed distributions, like the frequency of harvesting forest resources. We summarized livelihood data within each broad category (from Table 1) to examine which livelihoods were over- or under-represented among newly arrived households compared to the entire sample. We then did the same for Indigenous households.

Because many household demographic and livelihood characteristics differed according to respondents' migrant or Indigenous status, we moved to a regression framework to model the effect of being a newly arrived or Indigenous household on harvest frequency and participation in forest-based livelihoods, controlling for additional factors that differ across the groups. We built models with the general structure below:

Frequency of Harvest or Participation in Forest-Based Livelihood = $\beta_1 \text{Household Arrived after 2010} + \beta_2 \text{HH is Indigenous} + \beta_3 \text{HH is Female} + \beta_4 \ln(\text{Wealth Score}) + \beta_5 \text{HH Age} + \beta_6 \text{Age}^2 + \beta_7 \text{Household Size} + \beta_8 \text{Dependency Ratio} + \beta_9 \text{Village Fixed Effects} + \beta_{10} \text{Survey Campaign Fixed Effects}$.

Models focused on the role of different household characteristics in predicting forest use, taking temporal and spatial variation into account. We used tobit models for the harvest frequency outcome because it was strongly left-censored at 0 (i.e., many households never harvested forest resources). We used both logistic models and linear probability models for the binary outcome of participation in a forest-based livelihood.³ All models used robust standard errors. We included fixed effects for each village within the wider landscapes, as well as fixed effects for each separate survey campaign. These helped to account for the fact that surveys were not always administered in the same villages in each

³ The logistic model excludes two villages (Djoubé and Gbagbali) in Ndoki because they predict success perfectly (i.e., all surveyed households participate in a forest-based livelihood) and two villages (Brazza and Teturi) in Ituri because they predict failure perfectly (i.e., no surveyed households participate in a forest-based livelihood).

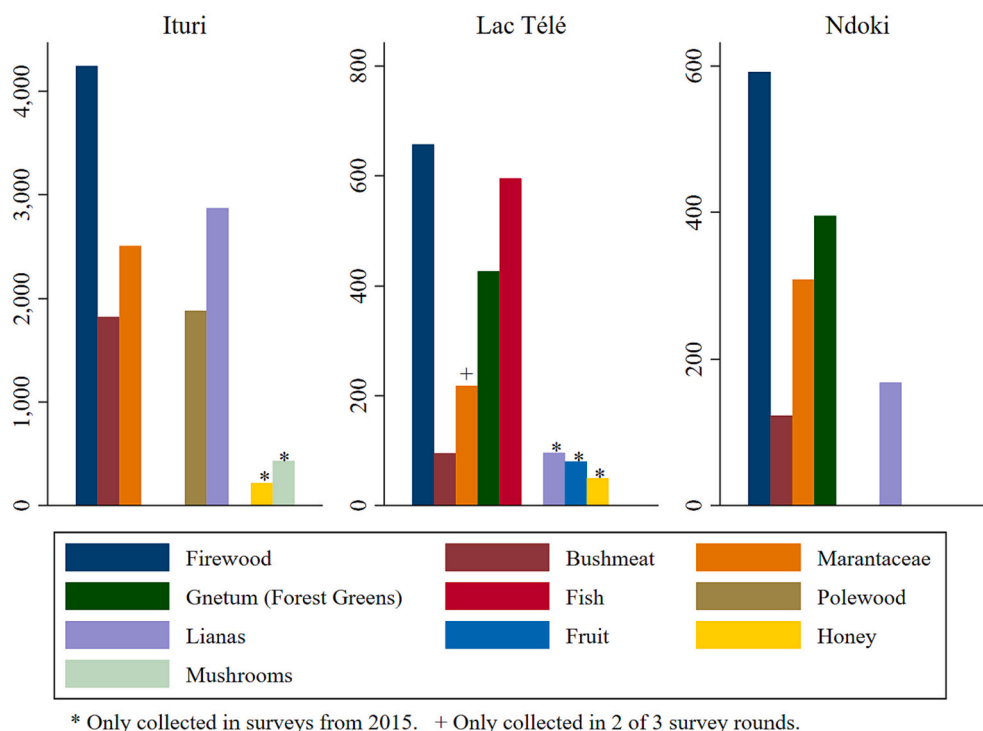


Fig. 2. The number of surveys reporting collection of each type of forest resource, across all campaigns within a given landscape. Firewood was the most common and bushmeat was the least common of the consistently repeated indicators. Note that some resources (indicated with a star) weren't asked about in every campaign.

Table 1

Livelihood Categories with Member Elements.

Forest-Based	Agriculture	Salaried Employment	Hourly Employment	A Trade or a Craft
Hunting	Agriculture	Employee	Hourly wage work	Alcohol brewer
Fishing	Livestock rearing	Teacher	Church work*	Artisan
Collecting forest products	Subsistence farming	Official	House cleaning	Tailor
Timber harvesting	Market gardening	Nurse		Carpenter
Trade in fish and bushmeat		Police		Mechanic
Charcoal making		Military		Mason
				Baker
Mining	Transportation	Commerce	Unemployed	Hairdresser
Mining	Boat driver	Shop owner	No work	Blacksmith
	Driver	Local businessman	Retired	Electrician
	Moto-taxi driver		Student	Painter
	Porter			

Activities are arranged within each category in descending order of frequency.

* Church work includes a variety of paid and unpaid activities and can be more associated with social standing than financial gain; we list it with other low-compensation work though it isn't hourly, per se.

successive round, and there was substantial variation in resource use and livelihood activities between villages. It also ameliorated issues with forest resource indicator lists containing somewhat different members in earlier and later years; hence we control for different years but do not interpret year coefficients as time-trends. Robustness checks included using landscape-level fixed effects (with standard errors clustered by village) rather than village-level fixed effects, and separately examining particular forest resources and livelihoods. Firewood and bushmeat were the only forest resources that were asked about in every round and landscape. Since they are procured and used in very different ways, we built more specific models predicting collection of firewood, collection of every indicator other than firewood, and collection of bushmeat. Hunting was one of the most common forest-based livelihoods, was consistently reported across campaigns, and is of particular interest for

wildlife conservation, so we examined this separately as well. Finally, we built models for each landscape separately, to assess how relationships varied across sites.

3. Results

3.1. Descriptive differences in recent migrant households

Overall, migration rates in our sample were relatively high; of the 6553 surveys from all three sites, 18.4% (1208) reported an arrival year of 2010 or later, and 7.5% (493) reported arrivals since 2015. Average characteristics of recently arrived households and longer-established households differed along many of the variables that we measured. Table 3 summarizes results of bivariate tests for differences between the

Table 2
Overview of Variables Included in Analysis.

Variable	How Measured
Newly arrived households	Arrival year was simplified into a binary variable indicating whether households arrived in the community after 2010. Surveys collected a continuous 'year of arrival in the community', but this was registered as a birth year for households that had not migrated, so we used a recent threshold to confidently distinguish newly arrived households.
Ethnicity of household head	This was collected as a categorical variable but simplified into a binary indicator of Indigenous and non-Indigenous households. Indigenous groups in these three landscapes include Ba'Aka, Bakoulou, Mbuti, and Efe peoples and non-Indigenous groups include a variety of Bantu and Sudanic-speaking ethnicities.
Gender of household head	The gender of the respondent-identified head of household. Males are typically heads except in cases where male heads have died or left the household.
Age of household head	We use the age of the head of household as an indicator of the household's life-stage. We include age-squared in regressions to account for non-linear effects of age when household heads become elderly.
Household size	Measured as the number of people living in a household, where household is defined as 'those who eat around the same fire'. Household size was used in combination with dependency ratio as an indicator of labor availability, mobility, and resource demand.
Dependency ratio	Calculated as the number of household members who are under 15 and over 65 years of age, divided by the total household size.
Wealth index	A household wealth score was generated from the sum of the goods that a household owned from a fixed list of assets, weighted by the quantity and price of each item, and indexed to 2015 USD. We used the natural-log transformed wealth index in analyses to handle its right-skewed distribution.
Natural resource collection	Households reported their weekly frequency of collecting each of a fixed list of general types of forest resources commonly harvested in each landscape. Listed resources included things like firewood, bushmeat, wrapper-leaves, wild greens, poles, and lianas (see Appendix Table 1). We use the total number of resource-trips per week, summed across these indicators.
Household practices a forest-based livelihood	Respondents could list up to four income-generating livelihoods from all members of the household. See Table 1 for all livelihoods mentioned. We created a binary indicator for whether any of a household's livelihoods were forest-based (includes hunting, fishing, and collection of forest products).

Table 3
Differences Between Recent Migrant and Longer Established Households.

	Ituri			Lac Télé			Ndoki		
	Migrant	Estab.	Diff.	Migrant	Estab.	Diff.	Migrant	Estab.	Diff.
NR Collection Trips	6.5	8.6	-2.1***	8.0	10.6	-2.6***	3.9	7.0	-3.2***
Practices a Forest-based Livelihood	15%	35%	-20.3%***	91%	84%	6%	48%	75%	-27%***
Age of Household Head	40.5	45.5	-5.0***	45.4	49.5	-4.0	39.7	45.3	-5.6***
Household Size	5.3	5.4	-0.097	6.8	6.67	0.11	5.2	5.7	-0.6**
Dependency Ratio	0.40	0.43	-0.02*	0.42	0.44	-0.02	0.41	0.45	-0.04*
Household Head is Female	26%	24%	2%	42%	35%	7%	17%	14%	3%
Household Head is Indigenous	3%	17%	-14.0%***	5%	13%	-7.7%**	15%	38%	-22.7%***
Wealth Score	5.3	5.0	0.3***	6.5	6.8	-0.3*	7.3	6.8	0.5***
Sample Size	831	4052		74	717		290	549	

Statistical significance based on two-side tests for difference in means with unequal variance.

*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$.

two groups. While most households in each of these forested landscapes collected at least one of the indicator resources at least once a week, forest product collection frequencies were lower by about 2 to 3 resource-trips per week for migrants in all three landscapes. The largest difference was in Ndoki, where on average, migrant households collect forest resources about half as often as longer-established households. Similarly, a lower proportion of migrant households reported forest-based livelihoods, with differences of 20 to 25 percentage points in Ituri and Ndoki. Lac Télé was the exception. There, fishing is the dominant livelihood and there were no significant differences in participation in this livelihood between recently arrived and longer-established households.

Newly arrived and longer-established households differed in several other ways besides their direct engagement with forest resources (Table 3). Newly arrived households tended to be younger and have fewer dependents. Wealth scores were significantly different between newly arrived and longer-established households, but these differences weren't uniform in direction. New immigrants have higher wealth scores in Ituri and Ndoki and lower scores in Lac Télé.

In bivariate tests comparing Indigenous respondents to non-Indigenous respondents, Indigenous respondents harvested forested resources significantly more frequently, were more likely to practice forest-based livelihoods, and tended to have lower wealth scores (Appendix Table 2).

For a finer-scale descriptive comparison of livelihood activities across groups with different migrant and Indigenous status, the relative proportions of migrant or Indigenous households participating in each

livelihood category is summarized in Fig. 3. Overall, migrants were overrepresented in livelihoods that require higher education (e.g., nurses and teachers). Meanwhile, they were under-represented in forest-based livelihoods. In contrast, Indigenous Peoples were strongly over-represented in forest-based livelihoods and lower-compensation hourly labor, while under-represented in mining, transportation, and commerce-based livelihoods.

3.2. Modeling predictors of harvesting forest resources

The signal of lower direct forest use among recent migrant households and higher use among Indigenous households remained consistent when controlling for covarying differences across households and villages (Tables 4 and 5). Newly arrived households took approximately one less resource-trip per week.⁴ This effect was twice as large when the model did not include fixed effects for each village, indicating that there was substantial spatial clustering within landscapes in both the locations of new immigrants and locations of heavier forest resource use. The depressing effect of being a new immigrant was weaker (but still significant) when firewood was the only resource considered. Meanwhile the effect was stronger for non-firewood resources, including bushmeat (Table 4). Households with Indigenous heads made over 4 more resource trips per week, and these tended to be for forest resources other

⁴ Robustness checks using a 2015 rather than a 2010 threshold performed very similarly, but with a slightly larger effect size for recent immigrants.

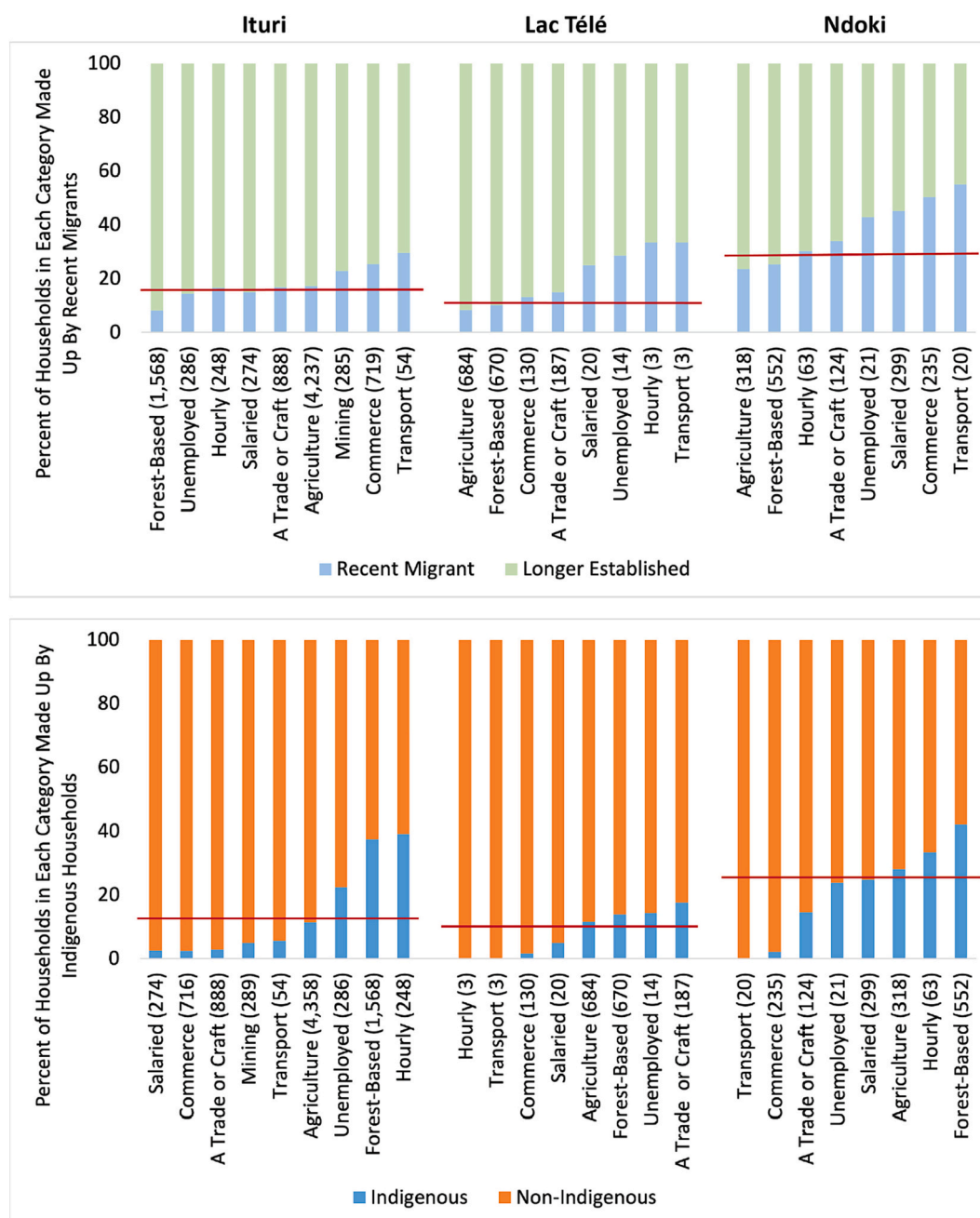


Fig. 3. Comparison of the relative frequency of participation in different livelihood categories between migrant and non-migrant households (top) and Indigenous and non-Indigenous respondents (bottom). The red lines indicate the overall proportion of migrant or Indigenous households in the sample. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

than firewood. Patterns in forest-based livelihoods (Table 5) were similar to patterns in resource harvest frequency (Table 4); migrants had a lower probability of participating in forest-based livelihoods (about half as likely) while Indigenous households had a much higher probability (over 14 times more likely). Effects were significant across all model specifications and were largest without village-level controls, again indicating spatial concentrations in forest-based livelihoods.

Other factors beyond migrant status were also important predictors of forest resource harvest. The village in which a household was located was one of the strongest. Coefficients for individual villages are not shown (there are over 70 villages represented in this data), but effects were often large and significant (e.g., participating in forest-based livelihoods was over 20 times as likely in some villages, and some villages predicted participation in forest-based livelihoods perfectly).

Controlling for these village effects, at the household level, the age and gender of the head of household were associated with influences similar in magnitude to that of migrant status. Households with older heads harvested more frequently until this slowed and reversed as heads became elderly. A change of one standard deviation in the age of a household head corresponded to a change in approximately 1 resource-trip per week. On average, female-headed households harvested about 1 resource-trip per week less than male-headed households (though this varied with landscape, see section 3.3) and were only 0.2 times as likely to participate in forest-based livelihoods. Forest harvest increased with household size; an increase of one standard deviation in household size corresponded to an additional 0.6 resource-trips per week. The ratio of dependents to adults did not impact the forest harvest measures used here. Wealth was a consistent negative predictor of forest use, though

Table 4
Forest Resource Harvest Frequency Regression Models.

	Village Controls	No Vill. Controls	Firewood Only	Non-Firewood Resources	Bushmeat Only
Recent Immigrant ^a	−0.9***	−2.0***	−0.2**	−1.0***	−0.7***
HH is Indigenous ^a	4.4***	4.4***	1.1***	3.9***	1.9***
HH is Female ^a	−0.9***	−1.2***	−0.1	−1.00***	−1.0***
Ln(WealthScore) ^b	−0.3***	−0.6***	−0.1***	−0.3***	0.1 [†]
HH Age ^c	1.2**	1.3**	0.5**	0.8*	0.1
HH Age Squared ^c	−1.3**	−1.5**	−0.5**	−1.0**	−0.4
Household Size ^c	0.6***	0.2*	0.3***	0.4***	−0.1*
Dependency Ratio ^c	0.1	0.1	0.1	0.1	0.0
Village Controls	Yes	No - only landscape	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes
Mean of Outcome Var.	8.2	8.2	3.5	4.7	0.6
Adj. R ²	0.11	0.06	0.11	0.12	0.19
Sample Size	6491	6491	6490	6491	6491

[†] p < 0.10

* p < 0.05

** p < 0.01

*** p < 0.001

Tobit regressions take into account the outcome censored at 0.

^a Coefficients represent the difference in weekly resource-trips associated with this category, compared to other households.

^b Coefficients can be interpreted as the change in weekly resource-trips associated with a 1% increase in wealth score.

^c Coefficients expressed in terms of change in weekly resource-trips associated with a change of 1 std. deviation in the predictor.

Table 5
Forest-based Livelihood Regression Models.

	Participating in any forest-based livelihood			Hunting, specifically
	Logit Model ^a	LP Model	No Village Controls	
Recent Immigrant ^b	0.55***	−0.08***	−0.14***	−0.08***
HH is Indigenous ^b	14.11***	0.41***	0.38***	0.38***
HH is Female ^b	0.19***	−0.20***	−0.24***	−0.17***
Ln(WealthScore) ^c	0.82***	−0.02***	−0.03***	−0.02***
HH Age ^d	1.22	0.02	0.05	0.02
HH Age Squared ^d	0.67 [†]	−0.05 [†]	−0.08*	−0.04
Household Size ^d	1.12**	0.01*	−0.01	0.01
Dependency Ratio ^d	0.99	−0.002	−0.004	−0.007
Village Controls	Yes	Yes	No - only landscape	Yes
Year Effects	Yes	Yes	Yes	Yes
Mean of Outcome		0.43	0.43	0.23
Adj. R ²	(0.39)	0.45	0.34	0.37
Sample Size	6202	6491	6491	6489

[†] p < 0.10

* p < 0.05

** p < 0.01

*** p < 0.01

^a Coefficients of the logit model are expressed as odds-ratios - a change in the predictor means the household is X times as likely to participate in that livelihood. Coefficients >1.0 mean more likely and < 1.0 mean less likely. Coefficients for the other three linear probability models are changes in the probability of participating in that livelihood.

^b Coefficients represent the difference associated with this category, compared to other households.

^c Coefficients can be interpreted as the change associated with a 1% increase in wealth score.

^d Coefficients for are expressed in terms of a change of 1 standard deviation in the predictor.

Table 6
Descriptive Statistics for Each Landscape.

	Ituri	Lac Télé	Ndoki
Arrived since 2010	17.1%	9.4%	34.6%
Arrived since 2015	6.0%	4.7%	19.3%
Indigenous	15.1%	12.4%	30.0%
Avg. resource-trips per week	8.2	10.4	6.0
Participate in forest-based livelihoods	31.9%	84.7%	65.8%
Sample size	4923	791	839

more so for resource harvest than forest-based livelihoods. A 10% increase in a household's wealth score corresponded to 3 fewer resource-trips per week. As with other factors, the impact of wealth was stronger in models that did not account for village-level variation. Negative

wealth effects were also concentrated in forest resources that were neither firewood nor bushmeat (e.g., palm leaves, lianas, polewood, etc.). In fact, wealth was a weakly positive predictor of bushmeat harvest frequency.

3.3. Variation across landscapes

We now turn to the question of how sensitive the overall trends were to particular landscape contexts. The frequency of recent immigrants varied strongly across landscapes, with substantially lower rates in Lac Télé and higher rates in Ndoki (Table 6). The proportion of the population in Ndoki that was Indigenous was also about twice as large compared to the other two sites. Collection of indicator forest resources was high across landscapes, highest in Lac Télé and lowest in Ndoki,

Table 7
Predictive Models for Each Landscape.

	Forest Resource Harvest Frequency (Tobit Models ^a)			Participation in Forest-Based Livelihoods (Logistic Models ^b)		
	Ituri	Lac Télé	Ndoki	Ituri	Lac Télé	Ndoki
Arrived after 2010 ^c	−0.6**	−1.3 [†]	−0.6	0.5***	1.6	0.5***
HH is Indigenous ^c	3.7***	4.7***	7.7***	16.0***	3.0*	7.2***
HH is Female ^c	−1.2***	−1.0*	1.5*	0.2***	0.2***	0.5**
Ln(WealthScore) ^d	−0.3**	−0.6*	−0.4*	0.8***	0.8 [†]	0.8 [†]
HH Age ^e	1.2**	0.01	0.6	1.3	0.5	2.0
HH Age Squared ^e	−1.3**	−0.5	−0.5	0.6 [†]	1.6	0.4
Household Size ^e	0.4***	1.1***	1.2***	1.1	1.4**	1.2 [†]
Dependency Ratio ^e	0.05	0.2	0.03	0.98	1.1	1.1
Village Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Controls	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R ²	0.13	0.05	0.13	0.35	0.24	0.24
# Left-Censored Obs.	568	60	229			
Sample Size	4861	791	839	4682 ^f	791	729 ^f

[†] $p < 0.10$

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$.

^a Coefficients of the tobit regressions are expressed as changes in the weekly harvest frequency associated with a change in the predictor variables. Tobit regressions take into account the outcome censored at 0 - i.e., households that did not collect these resources at all.

^b Coefficients of the logistic models are expressed as odds-ratios - a change in the predictor means the household is X times as likely to participate in that livelihood. Coefficients >1.0 mean more likely and < 1.0 mean less likely.

^c Coefficients represent the difference associated with this category, compared to other households.

^d Coefficients can be interpreted as the change associated with a 1% increase in wealth score.

^e Coefficients for are expressed in terms of a change of 1 standard deviation in the predictor.

^f Sample sizes are smaller because 2 villages in Ituri predict failure perfectly and 2 villages in Ndoki predict success perfectly.

bearing in mind that the lists of indicator resources varied from one landscape to the next. Perhaps more tellingly, 73% of Ndoki surveys reported collection of at least one of the indicator resources, compared to 88% in Ituri and 92% in Lac Télé. On average, participation in forest-based livelihoods was substantially lower in Ituri, where agricultural livelihoods were more prevalent, and higher in Lac Télé, where fishing was the dominant forest-based livelihood.

In general, newly arrived households took approximately one less resource-trip per week (between 0.6 and 1.3, depending on the landscape) and the difference was most significant in Ituri where the sample size was largest (Table 7). Newly arrived households were about half as likely to have a member that practiced a forest-based livelihood in Ituri and Ndoki, but migrant status was not a significant predictor of practicing a forest-based livelihood in Lac Télé, where almost all households fished. Having an Indigenous household head was a strong positive predictor of harvest frequency and forest-based livelihoods in all landscapes.

'Village' was a stronger predictor of forest harvest frequency in Ituri and Ndoki and a weaker predictor in Lac Télé, where villages were all located along or inside the reserve. Wealth was a consistent negative predictor of forest extraction across outcomes and landscapes, though the relationship was only weakly significant in landscapes with smaller sample sizes (Table 7). Being a female-headed household had a generally negative effect except for resource harvest frequency in Ndoki, where it was instead a significant positive predictor. Household size generally had a significant and positive effect on harvest frequency and increased the chance of having a household member that participates in a forest-based livelihood. The effects of the age of the head of household were less consistent - most of the overall impacts on resource harvest are concentrated in Ituri. Age effects in Lac Télé and Ndoki are not significant.

4. Discussion

4.1. Characteristics of recent migrants

Average characteristics of recent migrants in these sites differ significantly from longer-established households along several dimensions. Recently arrived households are generally younger, wealthier, have fewer dependents, and are more likely to have sources of off-farm income. The finding that migrant households tend to have younger heads concurs with established migration theory positing that propensities to migrate are highest when people are initially setting up households and mobility is easier (Jasso, 2003). Age of the household head, household size, and dependency ratio were all identified as determinants of recent rural migration in Tanzania (Duda et al., 2018). Youths often out-migrate because they will not inherit family land (Yeboah et al., 2019). The finding that migrant households tend to be wealthier than longer-established households is more surprising. If people migrate to forested areas seeking refuge from conflict or economic insecurity elsewhere, or if their claims to land resources are newest and least secure, the expectation is that new migrants would be more vulnerable than longer-established households (e.g., Naughton-Treves, 1997). Sampling bias is a potential issue here, as more desperate migration situations are less likely to be captured representatively in a household survey campaign. For example, young men moving to a region like Ituri to mine or extract natural resources (potentially illegally) are often less well off (Maclin et al., 2017). On the other hand, migration has long been theorized as a positively selected process, whereby those who move tend to be the ones with the financial, social, or cultural resources to do so, while relatively less privileged counterparts remain stuck (Ravenstein, 1885). Further, because forested landscapes tend to be more remote, households that arrive from elsewhere may tend to have higher material wealth relative to the receiving region. The recent

immigrants captured in our sample are over-represented in salaried jobs, business and commerce, and occupations that require technical skills and higher education. This is consistent with recent empirical studies reporting an increased propensity for migration among households with a higher education level, while households involved in the agricultural sector and those with subsistence-based livelihoods are less likely to migrate (Flahaux and De Haas, 2016; Duda et al., 2018).

4.2. Predictors of forest harvest

Although newly arrived households may have more wealth and household labor availability, on average, the additional assets and labor are not invested in additional forest resource collection. Migrant households are less likely to be engaged with forest resources compared to longer-established households, at least with respect to the indicators in this study. The strength of the negative effect of migrant status varied with the type of forest resource: it was weaker for firewood - a daily necessity that can be harvested from many different sources, and stronger for resources like bushmeat that require more specialized knowledge to find and collect.

Many of the characteristics that differ between migrant and longer-established households are themselves important predictors of forest harvest and livelihoods. This means that recent immigrants might have different patterns of forest extraction because of their “newness” in the landscape (i.e., through effects mediated by knowledge and access to resources) but they also might have different patterns simply because they tend to be younger or wealthier, etc. In models controlling for other characteristics affecting forest harvest, migrant status remains a significant predictor but is not the strongest determinant of forest use. Foremost, both harvest frequency and forest-based livelihoods vary spatially within landscapes and are concentrated in certain regions and villages. This could correspond to uneven patterns in distribution of forest resources, uneven patterns in availability of other sources of income and substitute products, or uneven distribution of any other factor affecting resource extraction.

Among household-level factors, whether a household head was Indigenous was associated with the largest and most consistent effects. Indigenous-headed households harvest forest resources much more frequently and are overwhelmingly more likely to practice a forest-based livelihood compared to other households in the landscape. The average differences in forest relations between Indigenous and non-Indigenous groups in these sites is also underestimated in this study due to the limited way that we measured forest use - either according to a few of the most common general types of resources or based on a narrow concept of livelihood as something that generates income. We don't capture flora and fauna that are harvested sporadically for medicinal or other purposes, nor any interactions with the forest that are not harvest-based (spiritual, cultural, etc.). Moreover, the Indigenous groups in our study are the descendants of peoples who lived in these forests prior to the advent of agriculture and their culture continues to be strongly entwined with the forest (Boyette et al., 2022). Studies from very different parts of the world also report strong associations between indigeneity and forest use (Coulibaly-Lingani et al., 2009; Torres et al., 2018; Nguyen et al., 2019).

Wealth is also an important confounding variable - migrant status loses some of its significance when controlling for the fact that recent immigrants tend to be wealthier. As expected, wealthier households were less likely to engage in forest-based livelihoods and harvested NTFPs less frequently. However, there were particular resources, like bushmeat, where this was not true. Because of the potential impact on wildlife populations, bushmeat is a category of forest-based resource with considerable dedicated investigation, and several other studies have reported nuanced relationships between wealth and use of bushmeat (e.g., Bakkegaard et al., 2017; Brashares et al., 2011; Foerster et al., 2012).

Having a female head affected forest harvest roughly as much as

being a new migrant. While we observe a signal that female-headed households are less likely to participate in forest-based livelihoods and generally harvest less frequently, this is likely sensitive to which resources are chosen as indicators. Harvest of forest resources in Sub-Saharan Africa is often gendered, and highly specific to particular kinds of resources (Angelsen et al., 2014; Timko et al., 2010). Furthermore, our surveys allow us to distinguish forest resource use trends for female-headed households, but not for women in general. Signals associated with female-headed households may result as much from labor or shock effects (i.e., from a recent death or separation) as from gender differences in resource use.

Other factors associated with household composition and lifecycle stage were sometimes important. As expected, more household members tend to increase the chance that someone in the house participates in a forest-based livelihood and the frequency with which resources are gathered, though this does not hold for bushmeat or hunting. Meanwhile, the ratio of dependents to prime-aged adults was never a significant predictor. This is somewhat surprising given the effect on labor availability in a household but could be partially due to the fact that the age of household head covaries with dependency ratio and partially to the fact that children and elderly household members are also involved in harvest of NTFPs.

It is worth considering whether recent immigrants represent a different “type” of household, with respect to their engagement with forests, or if they are simply households at an earlier stage of the process of forming ties to the forest landscape. Ecological knowledge, cultural value, and customary access rights are all lowest when households are freshly arrived in a new location, so we might expect the difference between recent immigrants and longer-established households to “wear off” over time. Differences in forest use between Indigenous households and non-Indigenous households are extremely marked, even when non-Indigenous households have lived their whole lives in the communities, and even when controlling for the wealth differences that accompany ethnic discrimination. This speaks to a cultural transmission of forest-based lifeways that doesn't simply accrete over time by virtue of a household spending more time in the landscape. Many have expressed concern that knowledge of forest-based lifeways is eroding everywhere, including among successive generations of Indigenous Peoples, as a result of broader social changes (e.g., Laird et al., 2011; Parrotta et al., 2016). What we measure in this study is the fact that a distancing from forest-based livelihoods and less incorporation of forest-products into daily life is not solely a function of changes among the population in situ, but also a function of flows of new people into the landscape.

4.3. Different patterns across landscapes

Although the three sites in our study are all located within forested regions of the Congo Basin, migration rates and forest harvest measures varied substantially between sites. Forest resource dependence was highest in Lac Télé, absolute number of migrants was highest in Ituri, and the relative rate of migration was highest in Ndoki. The cases of Ndoki and Lac Télé provide an interesting comparison, since they are essentially neighbors in the northeastern Congo. In the Ndoki landscape, the majority of those moving to the surveyed communities are coming specifically for salaried opportunities associated with the National Park and logging companies. Given the very low existing population density, employment rates are actually quite high and provide an alternative to agricultural and NTFP-based livelihoods. WCS employs up to 80% of households in some of the communities. The aberrant signal of greater frequency of harvest of NTFPs among female-headed households here may be because women are less likely to be employed by the park and logging companies, so are more likely to rely on forest resources.

Our data does not specify *where* households are newly arrived from. In Ndoki, many people have moved to the villages where employment programs are headquartered from neighboring villages within the same region. This could partially account for the higher rate of ‘recent

immigrants' there, but it represents a process of local sorting that differs from inter-regional migration. It is also worth noting that even though newly arrived households in Ndoki are less likely to participate in forest-(extraction)-based livelihoods, those working as park rangers or supporting research and tourism still have livelihoods based on the presence of the forest. In the Lac Télé Community Reserve, forest use rates are higher in general, migration rates are lower, and migrants are not as different from longer-established households in terms of wealth and forest use. In Lac Télé, there is less research and tourism infrastructure, far fewer opportunities for PA-based employment compared to Ndoki National Park, and agricultural options are more limited in the swampy landscape compared to a site like Ituri; thus, fishing and extraction of other forest resources are the primary livelihood options available for migrants and non-migrants alike. In Ituri, while there are some opportunities for PA-based employment in a few of the villages, these do not make up a significant fraction of the employment opportunities in the landscape. Many of the professional and commerce-associated jobs are held by recent immigrants, including traders and businesspeople that have left less stable regions nearby.

Zommers and MacDonald (2012) outline models describing different mechanisms behind migration to protected forests. There is an "attraction" model, in which people settle near protected areas specifically because conservation efforts provide economic, social benefits, and infrastructure for surrounding communities. This is contrasted with a "frontier engulfment" model, in which people settle near forests because of logging opportunities, which is subsequently followed by land conversion for agricultural purposes, ultimately leaving only protected forest remaining. In this study, the Ndoki case most closely approximates the attraction model, with people moving closer to protected areas to take advantage of the economic benefits that can be associated with parks, which in this case are employment benefits more than income from forest resources. At the same time, Ndoki fits early stages of the "frontier engulfment" model as other migrant streams are turning informal logging camps into more permanent villages in remote areas. The Lac Télé case also fits the "frontier" scenario, where some respondents migrated to the area because fish stocks are more plentiful in the more remote wetland complex than closer to major markets. Our measured immigration rates to Lac Télé were lower, but importantly, many who come to fish or extract resources commercially may not set up residence in the region and thus will not be captured in the sample. Finally, although still highly forested, Ituri is most aligned with a frontier engulfment model where much of the migration to the region is associated with the search for access to agricultural land and mining opportunities, in addition to fleeing conflict, as opposed to seeking benefits from forest extraction or park-based opportunities per se. Some of the clearest examples of frontier engulfment come from PAs in more densely populated landscapes in and around Africa's rift valley just to the east of Ituri (Mulley and Unruh, 2004; Zommers and MacDonald, 2012).

4.4. Implications

The impacts of human migration on forests extend well beyond differences in the propensity of recently immigrated residents to extract forest products. Migrants attracted to forested sites for employment or other benefits can also have a secondary effect of clearing land around forests for agriculture (Jones et al., 2018). Additionally, households that earn income in other ways and then purchase bushmeat or forest-based building materials in markets are 'using' forest resources just as much as the person who directly collects them (Tieguhong and Zwolinski, 2009). In regions like Ituri, migrants clear a large amount of land for agriculture, and even when migration is concentrated in urban centers the increased urban demand increases commercial harvest in the region. Those extracting resources for commercial sale in these sites are not necessarily local residents, and hence won't be captured even among the newly arrived group. Just a few commercial hunters or loggers can have

a large impact on sensitive species, even if most households do not harvest them directly (Coomes et al., 2004). For these reasons, it is important not to assume that the trends described here lead to reduced pressure on natural resources.

It is important to understand who relies on forests, and how, in order to craft fair and effective forest policy. It is also important to keep in mind that forest-proximate communities may be changing. Migration is predicted to increase in response to climate change and environmental shocks, particularly towards areas with available land and natural resources (Morrissey, 2014; Duda et al., 2018). Better understanding the ways that new households influence forest-proximate communities can inform natural resource management. To the extent that direct engagement with forest resources increases value for richly diverse forests, less use of forests by local residents could heighten ambivalence about what happens to forested land unless engagement with forests continues in other forms. In places where rights are contested and communities that share forested land are in flux, it is important to be aware of trends in which forest extraction is becoming concentrated within specific groups while opportunities for alternative income sources are concentrated among others. This has implications both for identification of the relevant stakeholders in forest resource management and for the design of any projects aiming to boost local incomes. Organizations working to support conservation and livelihoods often wish to ensure that local rights holders are fundamental beneficiaries of conservation. In situations where there are large flows of new immigrants and immigrants are less interested in extracting forest products, policies that strictly regulate forest harvest to protect sensitive species may become less of a source of friction with neighboring residents. On the other hand, such policies could aggravate rifts between longer-established and newer residents if longer-established and Indigenous households are among those whose livelihoods would be most affected by restrictions. Preserving local and Indigenous access to forest resources is a priority for many conservation organizations, and Indigenous rights to land can facilitate conservation of forest communities and Indigenous culture in the face of migration pressure (Ricketts et al., 2010; Blackman et al., 2017). Future research should focus on the ways that different streams of immigrants may impact forest governance.

In summary, migration to forested landscapes will likely increase as agricultural land becomes less available elsewhere and newly arrived households will influence receiving communities. We find that recent immigrants differ from longer-established residents in both the ways they harvest forest resources and in the livelihood activities they pursue. They also differ in characteristics such as wealth and age, factors that themselves influence propensity to harvest forest resources. Households belonging to an Indigenous group tended to have patterns of livelihoods and forest harvest that were inverse to those of new migrants. There were differences across sites within the Congo Basin, with some attracting wealthier and more educated migrants into the non-extractive sector while others had limited economic opportunities outside of forest-based extraction. Findings from this study suggest ways migration may change human communities living within these forests and should help to inform forest management and conservation strategies.

CRedit authorship contribution statement

Jessica L'Roe: Conceptualization, Methodology, Formal analysis, Writing – original draft, Funding acquisition. **Grayson Shanley Barr:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization. **Diane Detoeuf:** Conceptualization, Methodology, Supervision, Software, Data curation, Writing – review & editing. **Michelle Wieland:** Conceptualization, Methodology, Supervision, Validation, Funding acquisition. **Bernard Ikati:** Supervision, Software, Investigation, Data curation. **Moïse Enduyi Kimuha:** Software, Investigation, Data curation. **François Sandrin:** Supervision, Project administration, Software, Data curation. **Delphin Bilua:** Investigation, Data curation. **Gerard Bondeko:** Supervision, Software, Investigation,

Data curation. **Yves Londza**: Software, Investigation, Data curation. **Parfait Bakabana**: Supervision, Investigation, Data curation. **Germain Mavah**: Supervision, Project administration. **Ben Evans**: Supervision, Project administration, Writing – review & editing. **David Wilkie**: Conceptualization, Methodology, Validation, Funding acquisition.

Declaration of Competing Interest

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

Data availability

The data that has been used is confidential.

Acknowledgements

Our gratitude goes first to the Local Communities and Indigenous

Peoples in the Republic of Congo and Democratic Republic of Congo for their participation in the Basic Necessities Survey. We would like to thank the WCS staff working on the ground who assisted with the data collection and provided insights on the results, including Odette Angauko Sukari, Junior Nzala Nkulu, Aymard Nkounkou, Fredant Selat, François Mossoula, Benjamin Ngampamou, Gracia Ngohouani, Rodrigue Mouanda, and Morgane Cournarie. We would also like to thank Annika Hoerner and Eli Richardson for help with data preparation, and Pete Nelson for feedback on an early version of the manuscript. Financial support for survey campaigns was provided by USAID as part of the CARPE program (WCS cooperative agreement numbers AID- 660-A-13-00003, 4, 7) and the Sustainable Wildlife Management Programme of the European Union and the Organisation of African, Caribbean and Pacific States. This material is based upon work supported by the National Science Foundation under Grant No. 2117404.

Appendix A. Appendix

Table A1
Indicator Natural Resources.

Indicator Resource	Description	Ituri	Lac Télé	Ndoki
Firewood	Dead wood from many species used as fuel for cooking.	2015, 2017, 2019, 2021	2015, 2018, 2022	2018, 2020, 2022
Bushmeat	Wild animals hunted for food; many species including ungulates, primates, and rodents	2015, 2017, 2019, 2021	2015, 2018, 2022	2018, 2020, 2022
Fish	Many species; used for food.	X	2015, 2018, 2022	X
Marantaceae	A plant family whose leaves are used as wrappers for cooking, roofing, and basket weaving.	2015, 2017, 2019, 2021	2018, 2022	2018, 2020, 2022
Lianas	Vines, including <i>Eremospatha</i> rattan palm vines, used for weaving and as a construction material.	2015, 2017, 2019, 2021	2015	2018, 2020, 2022
Gnetum / Eru	A vine with leaves that are consumed as forest greens in soups and stews and are also used for medicinal purposes.	X	2015, 2018, 2022	2018, 2020, 2022
Polewood	Small trees harvested for construction material.	2015, 2017, 2019, 2021	X	X
Honey	Seasonally collected from wild hives.	2015	2015	X
Fruit	Many species; seasonally collected for food.	X	2015	X
Mushrooms	Many species; seasonally collected for food.	2015	X	X

Table A2
Descriptive Differences between Indigenous and Non-Indigenous Households.

	Ituri			Lac Télé			Ndoki		
	Indig.	Non-Indig.	Diff.	Indig.	Non-Indig.	Diff.	Indig.	Non-Indig.	Diff.
Natural Resource Collection Trips	12.1	7.5	4.6***	15.8	9.6	6.2***	11.5	3.6	6.0***
Practices a Forest-based Livelihood	79%	23%	56%***	95%	83%	12%***	92%	55%	38%***
Age of Household Head	42.5	45.1	-2.5***	49.9	49.0	0.9	43.0	43.6	-0.6
Household Size	4.2	5.6	-1.4***	6.2	6.8	-0.6*	5.3	5.6	-0.3
Dependency Ratio	0.35	0.44	-0.1***	0.4	0.5	-0.1**	0.4	0.5	-0.04**
Household Head is Female	16%	26%	-10%***	34%	36%	-3%	17%	14%	-3%
Household Arrived After 2010	4%	19%	-16%***	4%	10%	-6%***	17%	42%	-24%***
Wealth Score	4.1	5.3	-1.2***	5.4	6.9	-1.6***	5.8	7.5	-1.8
Sample Size	741	4182		98	639		252	587	

Statistical significance based on two-side tests for difference in means with unequal variance.

*, p < 0.05, **, p < 0.01, ***, p < 0.001.

References

- Abernethy, K.A., Coad, L., Taylor, G., Lee, M.E., Maisels, F., 2013. Extent and ecological consequences of hunting in central African rainforests in the twenty-first century. *Philos. Trans. R. Soc. B* 368 (1625), 20120303. <https://doi.org/10.1098/rstb.2012.0303>.
- Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N.J., Bauch, S., Börner, J., Smith-Hall, C., Wunder, S., 2014. Environmental income and rural livelihoods: a global-comparative analysis. *World Dev.* 64, S12–S28. <https://doi.org/10.1016/j.worlddev.2014.03.006>.
- Bakkegaard, R.K., Nielsen, M.R., Thorsen, B.J., 2017. Household determinants of bushmeat and eru (*Gnetum africanum*) harvesting for cash in the Democratic Republic of Congo. *Environ. Dev. Sustain.* 19, 1425–1443.
- Bele, M.Y., Sonwa, D.J., Tiani, A.M., 2015. Adapting the Congo Basin forests management to climate change: linkages among biodiversity, forest loss, and human well-being. *Forest Policy Econ.* 50, 1–10.
- Blackman, A., Corral, L., Lima, E.S., Asner, G.P., 2017. Titling indigenous communities protects forests in the Peruvian Amazon. *Proc. Natl. Acad. Sci.* 114 (16), 4123–4128. <https://doi.org/10.1073/pnas.1603290114>.
- Boyette, A.H., Lew-Levy, S., Jang, H., Kandza, V., 2022. Social ties in the Congo Basin: insights into tropical forest adaptation from BaYaka and their neighbours. *Philos. Transact. Royal Soc. B: Biol. Sci.* 377 (1849), 20200490. <https://doi.org/10.1098/rstb.2020.0490>.
- Brashares, J.S., Golden, C.D., Weinbaum, K.Z., Barrett, C.B., Okello, G.V., 2011. Economic and geographic drivers of wildlife consumption in rural Africa. *Proc. Natl. Acad. Sci.* 108 (34), 13931–13936. <https://doi.org/10.1073/pnas.1011526108>.
- Brown, E.L., 2010. Okapi faunal reserve, Ituri-Epulu-Aru landscape, Democratic Republic of the Congo. In: Yanggen, D., Angu, K., Tchamou, N. (Eds.), *Landscape-Scale Conservation in the Congo Basin: Lessons Learned from the Central African Regional Program for the Environment (CARPE)*. International Union for the Conservation of Nature, Gland, Switzerland. <https://portals.iucn.org/library/efiles/documents/2010-037.pdf>.
- Coad, L., Campbell, A., Miles, L., Humphries, K., 2008. The Costs and Benefits of Protected Areas for Local Livelihoods: A Review of the Current Literature. Working Paper. UNEP World Conservation Monitoring Center, Cambridge UK.
- Coomes, O.T., Barham, B.L., 1997. Rainforest extraction and conservation in Amazonia. *Geogr. J.* 180–188.
- Coomes, O.T., Barham, B.L., Takasaki, Y., 2004. Targeting conservation–development initiatives in tropical forests: insights from analyses of rain forest use and economic reliance among Amazonian peasants. *Ecol. Econ.* 51 (1–2), 47–64.
- Coomes, O.T., Takasaki, Y., Abizaid, C., Arroyo-Mora, J.P., 2016. Environmental and market determinants of economic orientation among rain forest communities: evidence from a large-scale survey in western Amazonia. *Ecol. Econ.* 129, 260–271. <https://doi.org/10.1016/j.ecolecon.2016.06.001>.
- Cooper, M., Zvoleff, A., Gonzalez-Roglich, M., Tussime, F., Musumba, M., Noon, M., Alele, P., Nyiraturza, M., 2018. Geographic factors predict wild food and nonfood NTFP collection by households across four African countries. *Forest Policy Econ.* 96, 38–53. <https://doi.org/10.1016/j.forpol.2018.08.002>.
- Coulibaly-Lingani, P., Tigabu, M., Savadogo, P., Oden, P.-C., Ouadba, J.-M., 2009. Determinants of access to forest products in southern Burkina Faso. *Forest Policy Econ.* 11 (7), 516–524. <https://doi.org/10.1016/j.forpol.2009.06.002>.
- Dargie, G.C., Lewis, S.L., Lawson, I.T., Mitchard, E.T.A., Page, S.E., Bock, Y.E., Ifo, S.A., 2017. Age, extent and carbon storage of the Central Congo Basin peatland complex. *Nature* 542 (7639). <https://doi.org/10.1038/nature21048>. Article 7639.
- Dash, M., Behera, B., 2016. Determinants of household collection of non-timber forest products (NTFPs) and alternative livelihood activities in Similipal Tiger Reserve, India. *Forest Policy Econ.* 73, 215–228.
- Dazé, A., Crawford, A., 2016. Human Migration and Ecosystems: Insights from the Great Lakes Region of East and Central Africa. IISD, Canada. <https://policycommons.net/artifacts/614618/human-migration-and-ecosystems/1594948/>.
- De Brauw, A., Mueller, V., Lee, H.L., 2014. The role of rural–urban migration in the structural transformation of sub-Saharan Africa. *World Dev.* 63, 33–42.
- DeFries, R., Hansen, A., Newton, A.C., Hansen, M., 2005. Increasing isolation of protected areas in tropical forests over the past twenty years. *Ecol. Appl.* 15 (1), 19–26.
- Detoef, D., Wieland, M., Wilkie, D., 2020. Guide 2.0 to the Modified Basic Necessities Survey: Why and How to Conduct Digital-Based BNS in Conservation Landscapes. Wildlife Conservation Society. <https://doi.org/10.19121/2020.Report.38385>.
- Duda, I., Fasse, A., Grote, U., 2018. Drivers of rural-urban migration and impact on food security in rural Tanzania. *Food Sec.* 10, 785–798.
- Ekhassa, B., Oyo, P., 2012. “Lac Télé-Lac Tumba Landscape”. *Climate Change and Forests in the Congo Basin (COBAM)*. CIFOR. <http://www.jstor.com/stable/resrep01915>.
- Endamana, D., Shepherd, G., Akwah Neba, G., Angu Angu, K., Ntumwel Bonito, C., Eyong Ako, C., 2019. Rapid assessment of the value of forest income for people in Central Africa. *J. Sustain. For.* 38 (4), 343–368. <https://doi.org/10.1080/10549811.2018.1549499>.
- Flahaux, M.-L., De Haas, H., 2016. African migration: trends, patterns, drivers. *Comp. Migrat. Stud.* 4 (1), 1. <https://doi.org/10.1186/s40878-015-0015-6>.
- Foerster, S., Wilkie, D.S., Morelli, G.A., Demmer, J., Starkey, M., Telfer, P., Steil, M., Lewbel, A., 2012. Correlates of Bushmeat hunting among remote rural households in Gabon, Central Africa. *Conserv. Biol.* 26 (2), 335–344. <https://doi.org/10.1111/j.1523-1739.2011.01802.x>.
- Gondola, D., 2002. *The History of Congo*. Bloomsbury Publishing USA.
- Güneralp, B., Lwasa, S., Masundire, H., Parnell, S., Seto, K.C., 2017. Urbanization in Africa: challenges and opportunities for conservation. *Environ. Res. Lett.* 13 (1), 015002.
- Hewlett, B.S. (Ed.), 2014. *Hunter-Gatherers of the Congo Basin: Cultures, Histories and Biology of African Pygmies*. Transaction Publishers.
- IUCN, 2020. Okapi Wildlife Reserve: 2020 Conservation Outlook Assessment. World Heritage Outlook. IUCN, p. 13. <https://worldheritageoutlook.iucn.org/explore/sites/wdpaid/124389>.
- IWGIA, 2014. Country Technical Note on Indigenous Peoples' Issues: The Republic of Congo. IFAD, p. 38. https://www.ifad.org/documents/38714170/40224547/congo_ctn.pdf/25612f61-03f1-4cbd-a983-bc3f0ef9154?e=1651742303250.
- Jagger, P., Cheek, J.Z., Miller, D., Ryan, C., Shyamsundar, P., Sills, E., 2022. The role of forests and trees in poverty dynamics. *Forest Policy Econ.* 140, 102750.
- Jasso, G., 2003. Migration, human development, and the life course. In: Mortimer, J.T., Shanahan, M.J. (Eds.), *Handbook of the Life Course*. Springer US, pp. 331–364. <https://doi.org/10.1007/978-0-306-48247-2.16>.
- Jayne, T.S., Chapoto, A., Sitko, N., Nkonde, C., Muyanga, M., Chamberlin, J., 2014. Is the scramble for land in Africa foreclosing a smallholder agricultural expansion strategy? *J. Int. Aff.* 67 (2), 35.
- Jones, J.P., Mandimbiniaina, R., Kelly, R., Ranjatson, P., Rakotojoelina, B., Schreckenberger, K., Poudyal, M., 2018. Human migration to the forest frontier: implications for land use change and conservation management. *Geo. Geogr. Environ.* 5 (1), e00050.
- Kabuanga, J.M., Kankonda, O.M., Saqalli, M., Maestripieri, N., Bilintoh, T.M., Mweru, J.-P.M., Liama, A.B., Nishuli, R., Mané, L., 2021. Historical changes and future trajectories of deforestation in the Ituri-Epulu-Aru landscape (Democratic Republic of the Congo). *Land* 10 (10). <https://doi.org/10.3390/land10101042>. Article 10.
- Lacassagne, A., 2016. The complexities of the established-outside relations in Canada: re-integrating socio-historical analysis and engaging with some post-colonial thoughts. *Hist. Soc. Res. Historische Sozialforschung* 41 (3 (157)), 81–100.
- Laird, S.A., Awung, G.L., Lysing, R.J., Ndivé, L.E., 2011. The interweave of people and place: biocultural diversity in migrant and indigenous livelihoods around Mount Cameroon. *Int. For. Rev.* 13 (3), 275–293.
- Lakens, D., 2022. Sample size justification. *Collabra Psychol.* 8 (1), 33267. <https://doi.org/10.1525/collabra.33267>.
- Law No. 22/030 on the protection and promotion of the rights of indigenous pygmy peoples. <https://www.leganet.cd/Legislation/Droit%20Public/DH/Loi%2022.030%20du%2015%20juillet%202022.html>, July 15, 2022.
- Law No. 5-2011 promoting and protecting indigenous populations. <https://pcpacongo.files.wordpress.com/2016/04/loi-05-2011-peuples-autochtones.pdf>, February 25, 2011.
- Lewis, J., 2005. Whose Forest is it anyway? Mbendjele Yaka pygmies, the Ndoki forest and the wider world. In: Widlok, T., Tadesse, W.G. (Eds.), *Property and Equality: Volume II: Encapsulation, Commercialization, Discrimination*. Berghahn Books, pp. 56–78.
- L'Roe, J., Naughton-Treves, L., 2014. Effects of a policy-induced income shock on forest-dependent households in the Peruvian Amazon. *Ecol. Econ.* 97, 1–9. <https://doi.org/10.1016/j.ecolecon.2013.10.017>.
- Maclin, B.J., Kelly, J.T.D., Perks, R., Vinck, P., Pham, P., 2017. Moving to the mines: motivations of men and women for migration to artisanal and small-scale mining sites in eastern Democratic Republic of the Congo. *Res. Policy* 51, 115–122. <https://doi.org/10.1016/j.resourpol.2016.12.003>.
- McElwee, P.D., 2008. Forest environmental income in Vietnam: household socioeconomic factors influencing forest use. *Environ. Conserv.* 35 (2), 147–159. <https://doi.org/10.1017/S0376892908004736>.
- Miller, D.C., Hajjar, R., 2020. Forests as pathways to prosperity: empirical insights and conceptual advances. *World Dev.* 125, 104647.
- Mittermeier, R.A., Mittermeier, C.G., Brooks, T.M., Pilgrim, J.D., Konstant, W.R., da Fonseca, G.A.B., Kormos, C., 2003. Wilderness and biodiversity conservation. *Proc. Natl. Acad. Sci.* 100 (18), 10309–10313. <https://doi.org/10.1073/pnas.1732458100>.
- Mogba, Z., Freudenberger, M., 1998. Human migration in the protected zones of Central Africa: The case of the Dzanga-Sangha special reserve. In: Eves, H.E., Hardin, R., Rupp, S. (Eds.), *Resource Use in the Trinational Sangha River Region of Equatorial Africa: Histories, Knowledge Forms, and Institutions*, vol. 102. Yale School of Forestry and Environmental Studies, Bulletin Series, pp. 59–97.
- Mogotsi, I., Lendelvo, S., Angula, M., Nakanyala, J., 2016. Forest resource management and utilisation through a gendered lens in Namibia. *Environ. Nat. Res. Res.* 6 (4), 79. <https://doi.org/10.5539/enrr.v6n4p79>.
- Morrissey, J., 2014. Environmental change and human migration in sub-Saharan Africa. In: Piguet, E., Laczo, F. (Eds.), *People on the Move in a Changing Climate: The Regional Impact of Environmental Change on Migration*. Springer, Netherlands, pp. 81–109. <https://doi.org/10.1007/978-94-007-6985-4.4>.
- Mulley, B.G., Unruh, J.D., 2004. The role of off-farm employment in tropical forest conservation: labor, migration, and smallholder attitudes toward land in western Uganda. *J. Environ. Manag.* 71 (3), 193–205. <https://doi.org/10.1016/j.jenvman.2004.02.002>.
- Mushi, H., Yanda, P.Z., Kleyer, M., 2020. Socioeconomic factors determining extraction of non-timber Forest products on the slopes of Mt. Kilimanjaro, Tanzania. *Hum. Ecol.* 48 (6), 695–707. <https://doi.org/10.1007/s10745-020-00187-9>.
- Naughton-Treves, L., 1997. Farming the forest edge: vulnerable places and people around Kibale National Park, Uganda. *Geogr. Rev.* 87 (1), 27–46.
- Ndoye, O., Tieguhong, J.C., 2004. Forest resources and rural livelihoods: the conflict between timber and non-timber Forest products in the Congo Basin. *Scand. J. For. Res.* 19 (sup004), 36–44. <https://doi.org/10.1080/14004080410034047>.
- Nguyen, T., Lawler, S., Paul, W., 2019. Socioeconomic and indigeneity determinants of the consumption of non-timber forest products in Vietnam's Bu Gia map National Park. *Int. J. Sustain. Develop. World Ecol.* 26 (7), 646–656. <https://doi.org/10.1080/13504509.2019.1649314>.

- Oldekop, J.A., Rasmussen, L.V., Agrawal, A., Bebbington, A.J., Meyfroidt, P., Bengston, D.N., Blackman, A., Brooks, S., Davidson-Hunt, I., Davies, P., Dinsi, S.C., Fontana, L.B., Gumucio, T., Kumar, C., Kumar, K., Moran, D., Mwampamba, T.H., Nasi, R., Nilsson, M., Wilson, S.J., 2020. Forest-linked livelihoods in a globalized world. *Nat. Plants* 6 (12). <https://doi.org/10.1038/s41477-020-00814-9>. Article 12.
- Parrotta, J., Yeo-Chang, Y., Camacho, L.D., 2016. Traditional knowledge for sustainable forest management and provision of ecosystem services. *Int. J. Biodiversity Sci. Ecosystem Serv. Manag.* 12 (1–2), 1–4. <https://doi.org/10.1080/21513732.2016.1169580>.
- Poulsen, J.R., Clark, C.J., Curran, B.K., 2010. A Multi-Organizational Model of Land-Use Planning to Conserve Wildlife and Forest Resources in Forestry Concessions. Landscape-scale conservation in the Congo Basin: Lessons learned from the Central African Regional Program for the Environment (CARPE). <https://portals.iucn.org/library/efiles/documents/2010-037.pdf>.
- Pullin, A.S., Bangpan, M., Dalrymple, S., Dickson, K., Haddaway, N.R., Healey, J.R., Hauari, H., Hockley, N., Jones, J.P.G., Knight, T., Vigurs, C., Oliver, S., 2013. Human well-being impacts of terrestrial protected areas. *Environ. Evid.* 2 (1), 19. <https://doi.org/10.1186/2047-2382-2-19>.
- Rainey, H.J., Iyenguet, F.C., Malanda, G.-A.F., Madzoké, B., Santos, D.D., Stokes, E.J., Maisels, F., Strindberg, S., 2010. Survey of Raphia swamp forest, republic of Congo, indicates high densities of critically endangered western lowland gorillas. *Oryx* 44 (1), 124–132. <https://doi.org/10.1017/S003060530999010X>.
- Rasmussen, L.V., Watkins, C., Agrawal, A., 2017. Forest contributions to livelihoods in changing agriculture-forest landscapes. *Forest Policy Econ.* 84, 1–8.
- Ravenstein, E.Ge., 1885. The Laws of migration. *J. Stat. Soc. Lond.* 48 (2), 167–235.
- Ribot, J.C., Lund, J.F., Treue, T., 2010. Democratic decentralization in sub-Saharan Africa: its contribution to forest management, livelihoods, and enfranchisement. *Environ. Conserv.* 37 (1), 35–44. <https://doi.org/10.1017/S0376892910000329>.
- Ricketts, T.H., Soares-Filho, B., da Fonseca, G.A.B., Nepstad, D., Pfaff, A., Petsonk, A., Anderson, A., Boucher, D., Cattaneo, A., Conte, M., Creighton, K., Linden, L., Maretti, C., Moutinho, P., Ullman, R., Victorine, R., 2010. Indigenous lands, protected areas, and slowing climate change. *PLoS Biol.* 8 (3), e1000331. <https://doi.org/10.1371/journal.pbio.1000331>.
- Rocheleau, D., Edmunds, D., 1997. Women, men and trees: gender, power and property in forest and agrarian landscapes. *World Dev.* 25 (8), 1351–1371.
- Saatchi, S.S., Harris, N.L., Brown, S., Lefsky, M., Mitchard, E.T.A., Salas, W., Zutta, B.R., Buermann, W., Lewis, S.L., Hagen, S., Petrova, S., White, L., Silman, M., Morel, A., 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. *Proc. Natl. Acad. Sci.* 108 (24), 9899–9904. <https://doi.org/10.1073/pnas.1019576108>.
- Salerno, J.D., Mulder, M.B., Kefauver, S.C., 2014. Human migration, protected areas, and conservation outreach in Tanzania. *Conserv. Biol.* 28 (3), 841–850.
- Shackleton, S., Delang, C.O., Angelsen, A., 2011. From subsistence to safety nets and cash income: Exploring the diverse values of non-timber Forest products for livelihoods and poverty alleviation. In: Shackleton, S., Shackleton, C., Shanley, P. (Eds.), *Non-Timber Forest Products in the Global Context*. Springer, pp. 55–81. https://doi.org/10.1007/978-3-642-17983-9_3.
- Sunderlin, W.D., Dewi, S., Puntodewo, A., Müller, D., Angelsen, A., Epprecht, M., 2008. Why forests are important for global poverty alleviation: a spatial explanation. *Ecol. Soc.* 13 (2).
- Terashima, H., 1998. Honey and holidays: the interactions mediated by honey between Efe hunter-gatherers and lese farmers in the Ituri forest. *Afr Study Monogr* 25, 123–134.
- Teshome, B., Kassa, H., Mohammed, Z., Padoch, C., 2015. Contribution of dry forest products to household income and determinants of forest income levels in the northwestern and southern lowlands of Ethiopia. *Nat. Res. Forum* 6 (5), 331.
- Ticktin, T., 2004. The ecological implications of harvesting non-timber forest products. *J. Appl. Ecol.* 41 (1), 11–21. <https://doi.org/10.1111/j.1365-2664.2004.00859.x>.
- Tieguhong, J.C., Zwolinski, J., 2009. Supplies of bushmeat for livelihoods in logging towns in the Congo Basin. *J. Horticult. For.* 1 (5), 65–80.
- Timko, J.A., Waerber, P.O., Kozak, R.A., 2010. The socio-economic contribution of non-timber forest products to rural livelihoods in sub-Saharan Africa: knowledge gaps and new directions. *Int. For. Rev.* 12 (3), 284–294. <https://doi.org/10.1505/for.12.3.284>.
- Torres, B., Günter, S., Acevedo-Cabra, R., Knoke, T., 2018. Livelihood strategies, ethnicity and rural income: the case of migrant settlers and indigenous populations in the Ecuadorian Amazon. *Forest Policy Econ.* 86, 22–34. <https://doi.org/10.1016/j.forpol.2017.10.011>.
- Tyukavina, A., Hansen, M.C., Potapov, P., Parker, D., Okpa, C., Stehman, S.V., Kommareddy, I., Turubanova, S., 2018. Congo Basin forest loss dominated by increasing smallholder clearing. *Science. Advances* 4 (11), eaat2993. <https://doi.org/10.1126/sciadv.aat2993>.
- WCS, 2020. FY19 Annual Report for Central Africa Forest Ecosystems Conservation (CAFE): Ituri-Epulu-Aru Forest Landscape. Central Africa Regional Program for the Environment (CARPE) – USAID.
- Wittemyer, G., Elsen, P., Bean, W.T., Burton, A.C.O., Brashares, J.S., 2008. Accelerated human population growth at protected area edges. *Science* 321 (5885), 123–126. <https://doi.org/10.1126/science.1158900>.
- Yanggen, D., Angu, K., Tchamou, N., 2010. Landscape-Scale Conservation in the Congo Basin: Lessons Learned from the Central African Regional Program for the Environment (CARPE).
- Yeboah, F.K., Jayne, T.S., Muyanga, M., Chamberlin, J., 2019. Youth access to land, migration and employment opportunities: evidence from sub-Saharan Africa. *IFAD Resarc. Ser* 53, 50.
- Zommers, Z., MacDonald, D.W., 2012. Protected areas as frontiers for human migration. *Conserv. Biol.* 26 (3), 547–556.