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A look at Intact Forest Landscapes (IFLs) and their relevance in Central African forest policy

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ABSTRACT

Tropical forests are major providers of natural resources and ecosystem services but their ecological functions are at threat, due to increasing human pressure linked to economic development. The identification of priority areas for conservation is crucial for land use planning to ensure the protection of biodiversity and ecological function. Intact Forest Landscapes (IFLs), as defined by Greenpeace and World Resources Institute (WRI), are areas of the forest ecosystems not subjected to human activities. They have been identified by mapping human disturbances through remote sensing. Contrary to similar global-scale concepts, IFLs have been integrated into the standards of the certification body Forest Stewardship Council (FSC) and therefore have practical implications for forest management policies. The Motion 65, approved in the general assembly of FSC in 2014, mandates the protection of IFLs located in FSC certified logging concessions. Until the implementation of national standards, forestry operations are banished from 80% of the IFL area within each forest management unit. To trace the history and evaluate the suitability of IFLs in the Central African context, we searched for documents related to the IFL method, and related approaches focusing on the identification of areas devoid of human disturbances. The IFL method is simple and cost-effective and allows for a global assessment of the influence of human infrastructures and industrial exploitation on forests. However, the method does not consider the situation below the canopy and those forest components not visible by satellites. For example, hunting, one of the main threats faced by wildlife in Central African forests today, cannot be detected with satellite imagery. On the other hand, other anthropogenic activities which remote sensing may detect may be compatible with forest ecosystem conservation. To better tailor the IFL approach to Central African forests, we recommend (i) the consideration of wildlife communities in the intactness analysis, (ii) a thorough evaluation of the impacts of human activities on forest ecosystems, and (iii) the integration of local stakeholders and governments in the design of land management strategies to respond to social, economic and environmental needs.

1. Introduction

Tropical forests provide essential ecosystem services, such as carbon storage, mitigation of climate change and extreme weather patterns, and water cycling (Brandon, 2014; Gibson et al., 2011; Marquant et al., 2015; Putz et al., 2012). They host a high level of biodiversity and comprise pools of genetic resources for adaptation of plants and animals to environmental change (Brandon, 2014). At a local scale, tropical forests provide timber and non-timber forest products (NTFPs, such as food, pharmaceuticals and construction materials), that are directly used by human populations and contribute to incomes (Cotter et al., 2011; Gibson et al., 2011; Marquant et al., 2015; Putz et al., 2012). Therefore, the preservation of the remaining forested tropical landscapes is environmentally and economically essential.

Recent decades have seen a rapid decline in tropical forest cover (Zhuravleva et al., 2013). The four main drivers of deforestation, all linked to human activities, are identified as (i) expansion of agriculture, (ii) natural resource extraction, (iii) expansion of infrastructure, and

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(iv) urbanization (Heino et al., 2015; Gillet et al., 2016). Nowadays, even the most preserved and remote forests are threatened by anthropogenic activities (Potapov et al., 2012).

Considering the limited resources that are available to environmental conservation and the need to exploit natural resources to sustain human development, setting conservation priorities is a key process in landscape management (Powers et al., 2013). A crucial conservation priority has for long been to identify and secure areas that are least impacted by anthropogenic activities, leading to various concepts to quantify the human influence on nature (Bryant et al., 1997; McCloskey & Spalding, 1989; Myers et al., 2000; Myers, 2003; Sanderson et al., 2002). The concept of "intactness" led to the introduction, by the environmental NGO Greenpeace, of "Intact Forest Landscapes" (IFLs). IFLs were defined as large areas of forest ecosystems with no signs of significant human activity (Potapov et al., 2008). However, as the identification of high priority conservation areas is controversial (Innes and Kenneth, 2002), the method and criteria used to define "intactness" and subsequently IFLs are debatable.

More than a simple question of terminology, the identification of IFLs could have tremendous environmental and economic impacts when used for regional-scale decision making. In September 2014, the General Assembly of the Forest Stewardship Council (FSC) voted in favor of Motion 65. Initially proposed by Greenpeace, this motion requires the development of national indicators intended to ensure the protection of the vast majority of IFLs located in forest management units (FMUs) and areas within the control of FSC certificate holders (Rodrigues et al., 2014). It also states that "*if by the end of 2016 a relevant standard* (ensuring the maintenance of IFLs) *has not been implemented, a default indicator will apply that mandates the full protection of a core area of each IFL within the management unit. For this purpose, the core area of the IFL will be defined as an area of forest comprising at least 80% of the intact forest landscape falling within the FMU*". FSC traditionally defines High Conservation Value (HCV) forests as areas where adapted logging practices are implemented to ensure the protection of important environmental and social values in certified forests (FSC, 2015). Indeed, IFLs are associated with HCV forests of the second category (HCV2[1]) (FSC, 2015). Since the first approval of Motion 65 in September 2014, an advice note for the interpretation of its default clause has been published that allows forestry operations to take place in IFL until national standards become effective, if these operations do not impact more than 20% of the area of the IFL and do not reduce any IFL area below the 500 km^2 threshold (FSC, 2017). Therefore, the future management of IFLs within FSC FMUs is still unclear and will be ruled out by specific standards established at a national scale. The effects of Motion 65 on the timber sector, especially in FSC-certified logging concessions, could be far reaching if the strict protection of a large area of IFL is applied within FSC-certified FMUs as prescribed by the motion. Four regions, namely Brazil, Canada, Central Africa and Russia, are particularly affected because of their high coverage of both IFL and FSC-certified concessions (FSC, 2016; Potapov et al., 2008). In Quebec, FSC certificate holders have threatened to revoke their certification because of the reduction in timber supply that could result from a strict application of Motion 65 (Rotherham, 2016). Similarly, in Central Africa, the IFL concept and Motion 65 are shaking up forest conservationists and managers (COMIFAC, 2016; FSC, 2016).

With a rainforest covering approximately 1,700,000 km^2, the Central African region is the second largest tropical ecosystem in terms of size and biodiversity after the Amazon Basin (Marquant et al., 2015). One third of Congo Basin forests are allocated as logging concessions, and 10% of the area encompassed by these concessions are FSC certified (Marquant et al., 2015). The main cause of deforestation in Central Africa is the conversion of forest to agricultural land for subsistence and industrial production (Gillet et al., 2016). Timber production is not a direct cause of deforestation in Central Africa, due to low extraction rates and the implementation of management plans (Gillet et al., 2016; Marquant et al., 2015; but see Brandt et al., 2016; Kleinschroth et al., 2017). Assuring effective and sustainable forest management is a considerable challenge for Central African countries given the importance of timber and NTFPs for economic and social development and the trade-offs with the numerous ecosystem services and the ecological functions held by tropical forests (Gibson et al., 2011; Marquant et al., 2015; Putz et al., 2012).

This study aims to evaluate the IFL concept and suggest additional or complementary paths for its implementation in the Central African region. Based on an extensive scientific literature review on IFLs and Central African forest management, this paper addresses the three following questions: (1) How did different concepts proposed for identifying wild/intact areas evolve over time? (2) What are the advantages and the drawbacks of the IFL method for identifying priority areas for conservation in Central Africa? (3) Are there specific constraints regarding the implementation of the IFL concept (as currently defined and identified) in Central Africa and how could they be overcome?

2. Research method

To describe the history, characteristics and relevance of the Intact Forest Landscape (IFL) concept in the Central African context, we conducted a literature search. We compiled studies that define the former concepts that are compared with IFL by its authors ("world's wilderness areas", "frontier forests", "human footprint map" and "last of the wild") and those that assess the advantages and drawbacks of all these concepts. Given that FSC certification reflects the criteria required for IFLs with High Conservation Value Type 2 (HCV2) forests (Fällman et al., 2014; Rodrigues et al., 2014), we also searched for studies addressing this concept. We included only those studies that comprise a critical evaluation of a concept, and excluded papers those referring to case-studies undertaken in sites identified as World's Wilderness Areas, Frontier Forests, Last of the Wild or Intact Forest Landscapes. Studies that address the exploitation and conservation of Central African forest ecosystems were consulted to review recommendations regarding their sustainable management. Searches were realized in Google Scholar, Scopus, AGRIS, CABAbstract, Environment Complete and ULg Discovery. The relevant references of included articles were also searched. A total of 105 documents were finally included in our review after consideration of those recommended by anonymous reviewers. This literature review is not exhaustive, but we are confident that it is representative and covers the important aspects of the topic.

3. Intact Forest Landscapes and comparison to former concepts

In their paper presenting the IFL method, Potapov et al. (2008) compare it to other methods previously used to identify areas less impacted by human activities (Figs. 1 and 2 A–D). All four concepts are based on the definition of "wilderness" or "intactness" as the absence of human disturbance (mainly associated with settlements and transport infrastructure) (Bryant et al., 1997; McCloskey & Spalding, 1989; Potapov et al., 2008; Sanderson et al., 2002). Contrary to the other three concepts, the Human Footprint Map is initially focused on assessing the levels of human activity and not on the identifi cation of preserved areas, and is built on a gradient of human influence instead of a binary classification (wild/intact *vs.* disturbed) (Sanderson et al., 2002). However, the Human Footprint Map led to the identification of the least-disturbed zones for each biome, namely the Last of the Wild (Fig. 2 C), which is a concept similar to the Wilderness Areas, the Frontier Forests and the Intact Forest Landscapes.

While the Last of the Wild and the World's Wilderness Areas were defined for all biomes, the Frontier Forests and the IFLs are focused on

[1] The High Conservation Value 2 is defined as «*Intact forest landscapes and large landscape-level ecosystems and ecosystem mosaics that are significant at global, regional or national levels, and that contain viable populations of the great majority of the naturally occurring species in natural patterns of distribution and abundance*» (FSC, 2015).

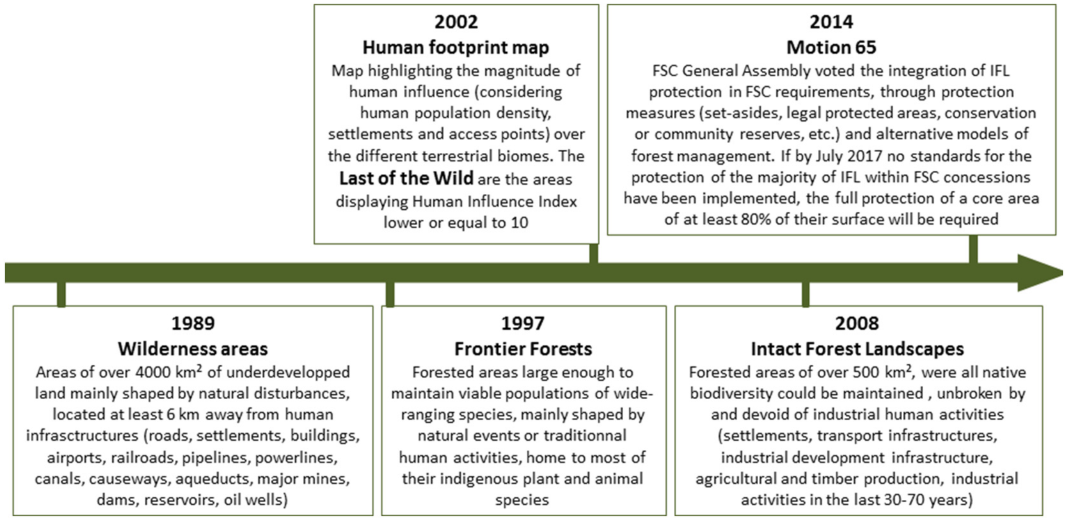

Fig. 1. Definitions and chronology of the concepts relevant to the Intact Forest Landscapes concept.

forest vegetation (Bryant et al., 1997; McCloskey & Spalding, 1989; Potapov et al., 2008; Sanderson et al., 2002). Consequently, non-forest habitats with high conservation value might be disregarded by these concepts.

Although the size criterion was not specified for the Frontier Forests and the Last of the Wild, it seems to have decreased over the years (from 4000 km^2 for World's Wilderness Areas to 500 km^2 for IFLs) (McCloskey & Spalding, 1989; Potapov et al., 2008). Similarly, the buffer applied around human infrastructure has decreased from 6 km (World's Wilderness Areas) to 1 km (IFLs) (Fig. 1). In Central Africa, these modifications have led to a larger total amount of forest identified as being preserved from human activities, consisting in practice of more but smaller patches that are more connected (Fig. 2). The evolution of technical tools used to analyze the intactness of landscapes, from paper maps and visual analysis to satellite imagery and automated algorithm, is well highlighted by the important increase in the precision level of the maps.

Besides the methodological aspects linked to the definition and identification of IFLs, the most striking difference between this concept and the former ones is its practical implication in forest ecosystem management policy, through its integration into FSC standards (Fällman et al., 2014; Rodrigues et al., 2014). However, the suitability of the theoretically-defined IFL concept as a practical policy tool for forest management needs to be considered.

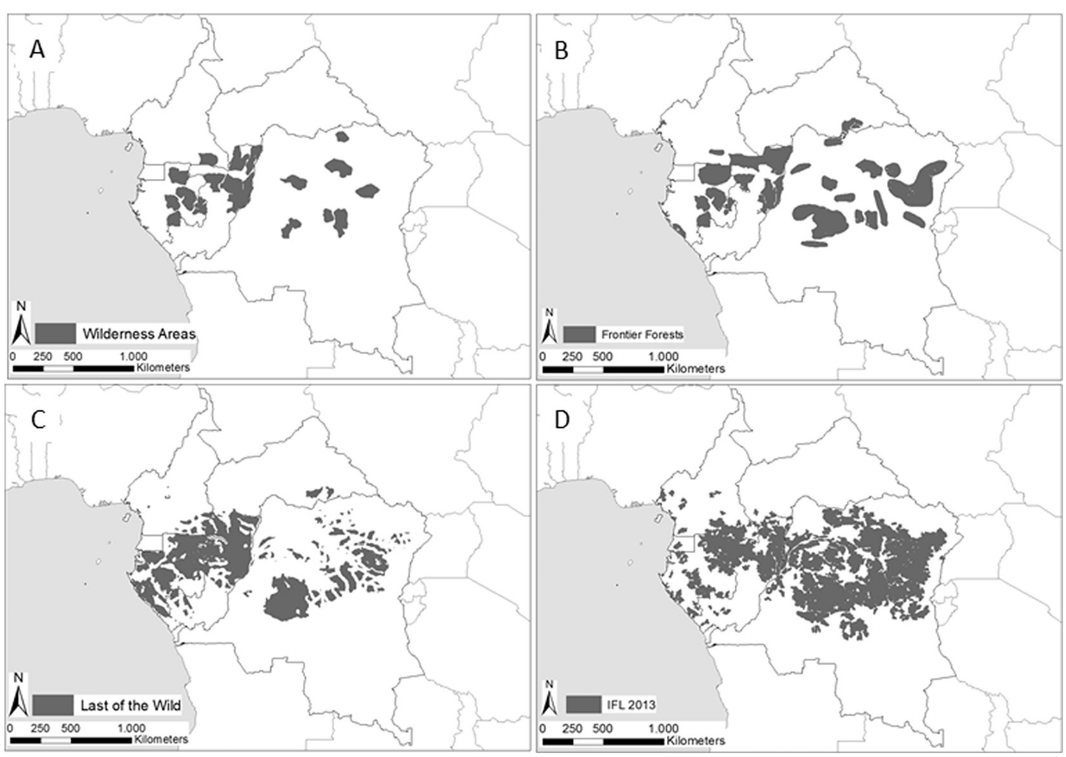

Fig. 2. Comparison of the geographic delimitation of concepts in the Central Africa (A) Wilderness Areas (McCloskey & Spalding, 1989; UNEP, 2016), (B) Frontier Forests (Bryant et al., 1997), (C) Last of the Wild based on the Human Footprint Map (Sanderson et al., 2002) and (D) Intact Forest Landscapes (Potapov et al., 2008). NB: For the maps of the Wilderness Areas and the Last of the Wild, only the items located in dense forest are displayed to allow for comparisons with Frontier Forests and IFLs.

4. Pros and cons of Intact Forest Landscapes as a tool to identify and implement conservation priority areas in Central Africa

4.1. Global remote sensing is a powerful tool but it does not depict the local context

Compared to previous approaches, the method to identify IFLs presents many advantages, particularly for landscape scale management: (i) satellite data are available anywhere at low cost, even for inaccessible areas, and can be rapidly compiled; (ii) remote-sensing data are collected according to rigorously defined methods and thus can be statistically analyzed and are comparable in space and time; and (iii) the remote-sensing analysis is easy to apply and suitable for all continents (Laestadius et al., 2011; Potapov et al., 2009). The global pattern of the IFL analysis is helpful for a general consideration of the management and preservation of valuable forests.

However, previous studies have highlighted the fact that satellite imagery can be erroneously analyzed, leading to misinterpretation and biased results (Karsenty et al., 2016). Additionally, considering the highly-contrasted socio-ecological contexts of the targeted regions, it is important to avoid drawing conclusions for localized areas (Hájek, 2002; Heino et al., 2015; Innes and Kenneth, 2002; Laestadius et al., 2011; Lee, 2009; Potapov et al., 2009; Sanderson et al., 2002). Notably, resilience to human activities may vary with forest type (Hájek, 2002; Heino et al., 2015; Innes and Kenneth, 2002; Laestadius et al., 2011; Lee, 2009), as was shown for Central African forests (Fayolle et al., 2014). Therefore, the local context needs to be taken into account to set a management design to protect IFLs. Indeed, even if there is a correlation between global and regional analysis, the implementation of a management plan is always made at the national (or even local) scale (Woolmer et al., 2008).

Another drawback associated with remote sensing and its global analysis is that some human activities and their associated impacts are hard, or impossible, to detect (Laurance et al., 2012; Yaroshenko et al., 2001), in particular when using one-date image data (Hájek, 2002). IFL analysis is biased towards overestimation because whenever a disturbance cannot be detected, landscapes are still considered intact (Laestadius et al., 2011). In fact, the concept of IFL is focused on the intactness of the canopy cover, but many human impacts, such as defaunation or carbon loss, cannot be detected from above (Abernethy et al., 2016; Barlow et al., 2012; Laestadius et al., 2011; Potapov et al., 2009; Putz & Redford, 2010; Wilkie et al., 2011; Zhuravleva et al., 2013). Despite being classified as IFL, Minkebe National Park in Gabon was home to an illegal gold mining camp until 2011 and suffers high poaching pressure that lead to the decimation of its elephant population (Poulsen et al., 2017). Other IFLs located in Gabon, Congo and Democratic Republic of Congo are predicted to display medium or high hunting pressure by Ziegler et al. (2016); and IFL with a low predicted hunting pressure were observed to be subjected to high level of hunting activities (see Fig. 6 in Abernethy et al., 2016). Considering the severe impacts of hunting and the bushmeat trade on Central African forest ecosystems (Abernethy et al., 2013; Wilkie et al., 2000), the intactness of the animal community should also be considered in IFL identification. The “empty forests syndrome”, whereby large and medium wildlife populations have been extirpated from structurally intact forests, has been long recognized (Redford, 1992; Terborgh et al., 2008; Wilkie et al., 2011). As wildlife fulfills important ecological functions in forest ecosystems, defaunated forests will probably evolve differently to forests displaying preserved animal communities (Abernethy et al., 2013, 2016; Kurten, 2013; Redford, 1992; Terborgh et al., 2008; Wilkie et al., 2011). For example, in Nigeria, hunting lead to the depletion of primates and an increase in seed-predating rodents which led to seed dispersal failures for primate-dispersed tree species (Effiom et al., 2013). Similar results have been highlighted in Cameroon (Wang et al., 2007). Over the long term, such competitive release may result in alteration of the vegetation composition as small-sized and wind-dispersed tree species are favored, as it was shown in Peru (Terborgh et al., 2008).

Moreover, the intactness of forest structure does not inform on botanical or animal diversity in the forest (Laurance et al., 2012), and the conservation and/or biological value of intact areas will vary across target species and communities (Woolmer et al., 2008). The most intact areas might be the least biodiverse, considering the positive correlation between human density and biodiversity observed in sub-Saharan Africa (Balmford et al., 2001) and the location bias of protected areas away from the most species-rich ecosystems (Joppa & Pfaff, 2009).

4.2. Roads are not a single feature class

“Intactness”, as proposed by Potapov et al. (2008), is defined as the absence of human infrastructures and management for intensive exploitation of natural resources. These criteria are mainly focused on vegetation cover and structure. Therefore, intact forests are associated with non-fragmented, road-free forests. The first road encroaching into a remote area is often the most detrimental to natural ecosystems (Andrew et al., 2012; Laurance et al., 2015), as this allows a sudden access to previously inaccessible areas, and additional activities subsequently develop (Selva et al., 2015). Human disturbance is ‘contagious’ (Andrew et al., 2012; Laurance et al., 2015): for example agricultural expansion, the major driver of forest loss, and other forms of forest clearing, are concentrated around roads and other such infrastructures (Joshi et al., 2015; Zhuravleva et al., 2013). As wildlife movements are often influenced by roads, a low road density can be considered an indicator of high conservation value (Kleinschroth et al., 2017; Selva et al., 2015). For example, in the Central African region, elephants have been observed to avoid crossing active laterite roads because of their associated high levels of human activity (Blake et al., 2008).

However, it is likely to be the wider political, economic and social context surrounding roads - whether paved or unpaved - that determines the degree of the resulting degradation or deforestation (Neira et al., 2002). Roads are highly variable in the way they affect ecosystems, and should not be considered as a single feature class (Woolmer et al., 2008). In Central Africa, the impacts of logging roads, notably, are generally restricted in space and time (Kleinschroth et al., 2015; Kleinschroth et al., 2016). For example, in this region, on unpaved secondary logging roads can no longer be detected after an average of 20 years by remote sensing (Kleinschroth et al., 2015); they could therefore be considered transient elements, whose influence on the intactness of a forest ecosystem is not persistent (Kleinschroth et al., 2016). While the expansion of the road network must be limited to avoid further fragmentation of continuous forest tracts (Laurance et al., 2015; Kleinschroth et al., 2017), the main point is to ensure an effective road management (control of access, anti-poaching strategies, *etc.*) as it is implemented in FSC-certified concessions, to reduce the resulting negative effects on natural habitats.

4.3. The size threshold of IFL does not ensure conservation value in Central Africa

A size threshold of 500 km^2 has been applied in IFL identification. In ecology, the size of a natural area is recognized as an important criterion for the preservation of biological diversity because the number of species present and preserved is often positively related to the size of the focal zone (Yaroshenko et al., 2001). Large continuous forest areas provide refuges for wildlife, especially wide-ranging species (Hájek, 2002; Innes and Kenneth, 2002; Zhuravleva et al., 2013 but see Section 4.1). Restricted accessibility through infrastructure limits hunting, fire and other types of disturbances (Andrew et al., 2012; Naughton-Treves, 2004; Zhuravleva et al., 2013). In contrast, forest fragments lack connectivity and are subject to edge effects and microclimatic gradients (Barlow et al., 2012; Powers et al., 2013; Thies et al., 2011; Yaroshenko et al., 2001). They are more accessible to humans (Thies et al., 2011; Yaroshenko et al., 2001) and consequently more prone to human pressure.

However, the correlation between the size of a natural area and its biodiversity could vary with biome and forest type (Hájek, 2002; Innes and Kenneth, 2002; Laestadius et al., 2011). Notably, as hunting was not assessed in IFLs identification, the presence of wildlife, especially large and/or wide-ranging species, within IFLs should be verified (see Poulsen et al., 2017). Additionally, as the Motion 65 only concerns the preservation of IFLs within FSC-certified FMUs (ie. about 13,000 km^2 of IFLs, totaling only 1.5% of their extent in Central Africa), the global-scale conservation of IFLs is far from ensured.

Moreover, the IFL size threshold was initially set up to match the home range of animal species indigenous to Russian forests (Potapov et al., 2008; Yaroshenko et al., 2001). Therefore, this threshold may not be appropriate for large Central African mammals, such as elephants, buffalos or great apes. As an example, the estimated home range size for the African forest elephant (*Loxodonta cyclotis* Matshie) is 25–2000 km^2 and is notably influenced by active roads (Blake et al., 2008).

4.4. "Intactness" should be defined by anthropogenic impacts instead of anthropic pressure

The identification of IFLs is based upon a dichotomy between forested and non-forested lands. However, there is a whole set of natural ecosystems which might present particular ecological values (Laestadius et al., 2011; Putz & Redford, 2010). Similarly, there is no binary classification between wild/intact and not-wild/disturbed forests; rather the two extremes represent either ends of a gradient (Aksenov et al., 2002; Andrew et al., 2012; Barlow et al., 2012; Hájek, 2002; Joshi et al., 2015; Potapov et al., 2009; Yaroshenko et al., 2001). The assessment of intactness implies the setting of a reference, which corresponds to the "intact level". But it is difficult to establish a universal benchmark, considering the diversity of natural forest ecosystems around the globe (Aksenov et al., 2002; Barlow et al., 2012; Hájek, 2002; Morales-Barquero et al., 2014; Yaroshenko et al., 2001). Moreover, forests are dynamic systems that constantly change under natural and/or human disturbance (Innes and Kenneth, 2002; Morales et al., 2014). Degraded forests might evolve towards increasing degradation but also towards recovery (Joshi et al., 2015; Morales-Barquero et al., 2014; Willis et al., 2004). For example, with time, Central African logged tropical forests naturally recover in terms of structure and composition (Gourlet-Fleury et al., 2013a; Gourlet-Fleury et al., 2013b), as well as in wildlife abundance if hunting is prevented or controlled (Lewis et al., 2015). A recovery of logged forest vegetation may be enhanced through enrichment planting and other silvicultural practices (Doucet et al., 2016; Fayolle et al., 2015; Ouédraogo et al., 2014). The above-ground biomass recovery rate was shown to be twice as fast when thinning was applied to logged forests in Central African Republic (Gourlet-Fleury et al., 2013a).

The definition of "degradation", and the extent of it, depends on the aims, stakeholders, methods and other specificities of a project (Di Marco et al., 2013; Laestadius et al., 2011; Morales-Barquero et al., 2014; Zhuravleva et al., 2013). Indeed, some disturbed forests may still be of high conservation value (Gibson et al., 2011; Putz et al., 2008; Putz et al., 2012; Stokes et al., 2010). In Central Africa, forests under reduced-impact logging management have been observed to host important populations of great apes, elephants and golden cats, sometimes at densities that are similar to those observed in protected areas (Bahaa-el-din et al., 2016; Clark et al., 2009; Haurez et al., 2014; Haurez et al., 2016; Maisels et al., 2013). Until now, the definition of wild or intact areas has been focused on the identification of human pressures but the realized impact of these pressures on natural ecosystems has not been assessed (Venter et al., 2016). The identification of conservation priority areas should not be focused on a binary classification of "intactness", but on the value of the ecosystem in terms of biological diversity, ecological function and ecosystem services (Hájek, 2002; Innes and Kenneth, 2002; Neira et al., 2002). It is important to not only target forests devoid of human activities, but to identify forests that function as "intact" (Aksenov et al., 2002; Hájek, 2002; Innes and Kenneth, 2002; Noss, 1990).

The existence of "pristine" forests has long been debated. Many studies argue that primary forests not shaped by human activities, including within Central African, no longer exist or are very rare (Brncic et al., 2007; Lewis et al., 2015; Morales-Barquero et al., 2014; Morin-Rivat et al., 2014, 2017; Van Gemerden et al., 2003; Willis et al., 2004; Zhuravleva et al., 2013). Indeed, some light-demanding tree species may suffer from a lack of forest disturbance in ageing forests of Central Africa, thus causing regeneration shortages (Biwolé et al., 2015; Morin-Rivat et al., 2017), and potentially leading to an alteration in forest structure and composition. The aim of the IFL method is not only to identify "pristine" forests; rather the initial definition of IFLs does allow for the existence of "*traditional human influence*" on forests (Potapov et al., 2008). However, those activities considered traditional are not clearly defined (Yaroshenko et al., 2001). For example, on the one hand, "*low-intensity selective logging and hunting*" is considered a background influence while on the other hand "*industrial logging during the last 30–70 years*" is not permitted (Potapov et al., 2008). The IFL definition suffers from a lack of a defined threshold associated with the rate of logging that is considered acceptable (Laestadius et al., 2011). Long-term experiments in Central Africa have highlighted that above-ground biomass is recovered within one felling cycle (25–30 years) provided that the harvesting rate does not exceed 4 trees ha^{-1} (Gourlet-Fleury et al., 2013a). Although studies in Central African forests are lacking, such a harvesting rate seems to maintain most of the initial biodiversity (Putz et al., 2012). In Central Africa, while the logging rate is low (generally lower than 4 trees ha^{-1}; Ruiz Perez et al., 2005), hunting is one of the main threats to forest ecosystems and should not be disregarded (Abernethy et al., 2013; Wilkie et al., 2000).

4.5. IFLs are a theoretical concept integrated in forest management policy without consultation of stakeholders

Sustainable development demands a difficult compromise between social, environmental and economic benefits (Kareiva et al., 2007; Scullion et al., 2015). Economic sustainability is essential to the long term success of a conservation strategy (Bevilacqua and Ochoa, 2001). Indeed, Potapov et al. (2008) recognize that the integral protection of IFLs is unrealistic in cases where these forests are important for food and timber provisioning. In Central African FSC-certified FMUs, conservation zones already cover at least 10% of the concession area (FSC, 2012). Motion 65 in its current formulation could, and probably will, discourage logging companies from seeking FSC certification (COMIFAC, 2016; Rotherham, 2016), leading to logging practices that no longer necessarily conform with the high FSC standards, or to the transition towards a less-demanding alternative certification scheme. Considering the presumed environmental benefits associated with certification for timber-managed tropical forests (Burivalova et al., 2016), the former could result in deleterious impacts on the preservation of forest ecosystems.

Finally, the inclusion of the IFL concept in FSC standards suffers from a lack of integration of governments, local communities and the private sector, although the Free Prior and Informed Consent (FPIC) is an important principle in the FSC standards (FSC, 2015). For example, the Republic of Congo, Gabon and the *Commission pour les Forêts d'Afrique Centrale* (COMIFAC) have taken a position against the implementation of FSC Motion 65 (COMIFAC, 2016). Some concerns have also been raised regarding the potential violation of the FSC first principle which addresses compliance with the law (FSC, 2015). Indeed, the adapted management of IFL core and non-core areas was not initially included in the management plans validated by Central African governments. Modifying these approved management plans should be carried out following strict national criteria, a very expensive and time-consuming process.

5. Proposition of an alternative method adapted to fit the Central African context

Historical deforestation rates in Central Africa are low because of low population density, poor road networks, political instability and a low conversion rate to agricultural lands (Gillet et al., 2016; Phalan et al., 2013). Nowadays, Central African forests are under growing pressure from increasing human population density, resource exploitation (timber, minerals and oil), and conversion to crop production (Gillet et al., 2016; Maisels et al., 2013; Phalan et al., 2013; Venter et al., 2016). Although the loss of IFLs from 2000 to 2013 in Central Africa countries ranges from 4.2% (Democratic Republic of Congo) to 34.4% (Central African Republic) (Potapov et al., 2017), the proportion of forest loss in total forest extent and in IFL were much lower, ranging respectively from 0.86% (Central African Republic) to 2.72% (Democratic Republic of Congo) and from 0.12% (Cameroon) to 0.37% (Democratic Republic of Congo) from 2000 to 2012 (Heino et al., 2015) (Table 1). Therefore, opportunities to protect large forest ecosystems of the region still exist. However, by now, the implementation of IFL protection through Motion 65 does not fully meet the criteria stated by Lusiana et al. (2014): "*Quality criteria for the application of science in natural resource management involve salience (actionable conclusions), credibility (evidence-based and empirically tested theoretical frameworks, explicitness of assumptions, and analysis of confidence intervals) and legitimacy (matching multiple stakeholder perceptions of representing their perspectives)*".

5.1. Ecosystem integrity should be taken into account

The IFL method is a useful tool for obtaining a first overview of forest ecosystem status at a global scale; but an additional local-scale assessment is required to integrate this concept into decision making. For example, a high diversity of organisms within a forest is thought to ensure the preservation of ecological functions and interactions that sustain forest ecosystems and preserve their integrity (Brandon, 2014; Linder et al., 2012).

Considering the weaknesses of the IFL method, we advocate the need to integrate an assessment of faunal community integrity to spatially determine explicit IFLs on a regional scale (see Wilkie et al., 2011). This is particularly important for Central Africa, where hunting is a significant threat. As the focus of the IFL method is to identify the less human-disturbed forests, an assessment of forest maturity should be undertaken at the local level to define IFL core areas. Old growth forests can be identified from their botanical structure and composition (Fayolle et al., 2014; van Gemerden et al., 2003). This vegetation maturity assessment should be combined with the wildlife community characterization, involving the verification of the presence of human-sensitive species. As botanical and wildlife data are available at the concession scale in Central Africa and have been demonstrated to be valuable (Fayolle et al., 2014; Réjou-Méchain et al., 2011), these could be a starting point for a local-scale characterization of IFLs.

5.2. Central African forests should be managed through a multiple-use landscape management plan

Designating protected areas (PAs) is an important strategy in the conservation of natural landscapes (Gibson et al., 2011; Heino et al., 2015; Lele et al., 2010; Mackey et al., 2015). However the designation of a PA is often restricted to areas with no economic interest or lacking accessibility for exploitation (Heino et al., 2015; Joppa & Pfaff, 2009; Neira et al., 2002). Due to a shortage of financial resources only 50% of PAs have positively affect the protection of biodiversity (Laurance et al., 2012; Maisels et al., 2013; Wilkie et al., 2011). Therefore, a conservation strategy that relies only on PAs would be inefficient (Laurance et al., 2012).

Based on the concept of an ecological matrix, the implementation of integrated landscape management is increasingly seen as the best approach for forest conservation (Kareiva et al., 2007; Laurance et al., 2012; Lewis et al., 2015; Mace, 2014; Naughton-Treves, 2004). Strictly protected areas are important, but, beyond their boundaries conservation needs to be reconciled with economic and social development to ensure long-term forest sustainability (Bevilacqua and Ochoa, 2001; Naughton-Treves, 2004). To design an effective multiple-use landscape management plan for Central African forests, we advocate the need for a thorough assessment of the impacts of human activities (such as mining, selective logging, hunting, harvesting of non-timber forest products, *etc.*) on the various forest types, and of the effectiveness of measures to reduce such impacts (*e.g.* in the context of forest certification) (Jobidon et al., 2015).

5.3. Stakeholders should be consulted to design conservation policies

When compared to other large areas of intact landscapes, Central African forests display the highest human population density (Mittermeier et al., 2003). This underlines the importance of taking local people into account when planning for conservation of these forest ecosystems. All stakeholders, including local resource users and indigenous people, should be involved in the establishment of a long-term forest management plan (Miranda et al., 1998; Thies et al., 2011; Wilkie et al., 2011). Working with local stakeholders is considered one of the most cost-effective and durable approaches towards sustainable management, as communities that are implicated in decision-making processes tend to better accept regulations regarding their uses of natural resources (Scullion et al., 2015). For example, the consultation of local communities

Table 1
Forest extent, forest loss and IFL loss in Central African countries from 2000 to 2013.

Country	Extent of total forest in 2000 (km^2)[a]	Extent of protected forest (km2)[a]	Extent of intact forest in 2000 (km^2)[a]	Protected forest of total forest in 2000[a]	Intact forest of total forest in 2000[a]	Protected intact forest of total intact forest in 2000[a]	Loss in forest from 2000 to 2012 (km^2)[a]	Loss in forest in intact forest from 2000 to 2012 (km^2)[a]	Loss in forest of total forest extent from 2000 to 2012[a]	Loss in intact forest of intact forest extent from 2000 to 2012[a]	Reduction of IFL area from 2000 to 2013[b]
Cameroon	351,740	44,647	52,839	12,69%	15,02%	37,16%	4320,8	61,158	1,23%	0,12%	25,20%
Central African Republic	528,550	78,574	8687,5	14,87%	1,64%	46,70%	4531,1	12,603	0,86%	0,15%	34,40%
Gabon	250,760	36,900	109,280	14,72%	43,58%	20,52%	1870,4	185,61	0,75%	0,17%	22,90%
Republic of Congo	292,920	30,455	139,180	10,40%	47,51%	16,23%	2908,4	266,31	0,99%	0,19%	17,70%
Democratic Republic of the Congo	2,143,700	229,590	643,310	10,71%	30,01%	17,34%	58,235	2377,6	2,72%	0,37%	4,20%

[a] Data from Heino et al. (2015).
[b] Data from Potapov et al. (2017).

in East Kalimantan (Borneo) permitted to better understand the traditional land management, and the importance of specific species and habitats (Sheil et al., 2006). This process highlighted priorities in terms of local people access to natural resources and outlined appropriate limits to management strategies. In South-Africa, integrating governments and local stakeholders in order to design natural resource management policies based on scientific research was also proved to be efficient at different spatial scales (Shackleton et al., 2009). The private sector, which has concessions over a wide proportion of Central African forests (Marquant et al., 2015), should also be included in the decision-making scheme (Neira et al., 2002).

We recommend to better integrate national governments, notably to take into account the development plans (*plans d'émergence*) of Central African countries, to define regional FSC standards to ensure the preservation of their forests. Strategic road development, the implementation of incentives for forest protection and regional land-use planning and management schemes are required to address the threats faced by Central African forests (Phalan et al., 2013). Moreover, a portion of the revenue generated by forest resource exploitation should be invested back into forest conservation, such as for research into impact mitigation or silviculture for the promotion of forest recovery (Doucet et al., 2016; Fayolle et al., 2015; Lewis et al., 2015; Ouédraogo et al., 2014; Miranda et al., 1998; Poulsen et al., 2009).

6. Conclusions

To overcome the constraints for IFL-related policy implementation in Central Africa our study highlights the need for (i) a local-scale assessment of the intactness of forest ecosystems, including the consideration of wildlife, (ii) a multiple-use management plan based on a rigorous evaluation of the impacts of human activities on forests, and (iii) the integration of local stakeholders and governments in the design of national or regional land management strategies that will cope with both environmental and socio-economic needs.

Timber societies should be held responsible for the move towards sustainable forestry that promotes biodiversity conservation and human livelihoods (Poulsen et al., 2009), but they will not do so without economic incentives. Indeed, certification in tropical forests has been shown to be financially unsustainable, and improved markets and price premiums are rarely sufficient certification incentives (Burivalova et al., 2016). Therefore, lower taxes and long-term concessions could help secure the involvement of timber companies in sustainable management and reduced-impact timber logging (notably forest management certification), and thus attract more companies towards the sustainable path (Amacher et al., 2009; Dauvergne, 2002).

Although we should not sacrifice the last "intact" or "natural" landscapes for a short-term economic gain (Sanderson et al., 2002), we are obliged to find a balance between conservation and economic development (Kleiner, 2003). Operational forest management schemes should involve scientifically-based assessments of the conservation value of forests to identify priority zones to be preserved and an evaluation of the socio-economic opportunity costs of their practical implementation.

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