Lack of Coherence Between Commercial and Scientific Names for Timber Species: Implications for the Sustainable Exploitation of Andoung in Gabon

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Abstract

The lack of coherence between the trade names applied to commercially sold wood and the scientific names of the species involved may be contributing to the degradation and loss of biodiversity. To test this, a study was conducted in nine forestry concessions in Gabon to evaluate how well tree spotters were able to recognize and identify the group of nine species referred to by the commercial name *andoung*. Only 65% of the 308 trees recognized by the spotters as *andoungs* belonged to this group; this includes species in two genera, *Aphanocalyx* and *Bikinia*, both of which are often confused with members of other, more distantly related genera of Fabaceae. Trees assigned a commercial name with a qualifying epithet, corresponding to a particular species of *andoung*, were correctly identified only 11% of the cases. The inability to distinguish among species means that those that are rare and/or have restricted distribution, and may therefore be threatened, are almost certainly being harvested and sold. To improve this situation, we propose several steps designed to favor more accurate in-field identification of *andoung* species and to promote greater awareness of which species are suitable for sustainable harvested and which ones require legal protection to ensure their survival.

Introduction

Central Africa contains the world's second largest area of dense humid forest after the Amazon basin, and all signs point to the fact that this globally important ecosystem is under increasing anthropogenic and climatic pressures, and rapidly approaching a crucial turning point (de Wasseige et al. 2013 and 2015). While the region's forests constitute a key source of revenue in both the formal sector (including large and small industrial timber exploitation as well as small-scale harvesting of precious woods) and the informal sector (such as non-timber forest products and exploitation of wood for energy and shelter), they are also being subjected to rapidly increasing impacts from agriculture, mining and energy production (Tchoumba et al. 2021). Not only is the forestry sector the second most important source of revenue derived from natural resource exploitation, it is also the second most important source of employment after the civil service, with the total number of jobs increasing from 9,567 in 2014 to 12,606 in 2016 (MEPDD 2016). Moreover, with the inevitable decrease in gas and petroleum extraction in Gabon, hopes and aspirations are increasingly being placed on the forestry sector in an effort to diversify the country's economy (World Bank 2020).

The Gabonese government has been encouraging the development of a sustainable timber industry since the 1990s, with the implementation of forest concession management plans and increasing certification (MEFEDD 2010). After a first ban on harvesting some species that had become increasingly rare, a log export ban started in February 2010 (Manciaux 2011). More recently, the administration has further focused on favoring local transformation and the certification of timber concessions (Karsenty 2021). At the same time, it has also favored an expansion of the number of exploited species: in 2005, 17 new timber species from Gabonese forests appeared on the market (Demarquez 2006). Reconciling biodiversity conservation and economic development in the context of efforts to promote sustainable forest exploitation requires an understanding of forest dynamics and acceptable levels of harvest, the development of a control and monitoring system and knowledge of the species referred to by names used in the commercial timber trade (Doumenge et al., 2016). A lack of consistency between the trade names applied to timber trees and the corresponding scientific names – and species – could compromise sustainable exploitation and exacerbate the loss of biodiversity in countries such as Gabon, where forestry increasingly represents a pillar of economic development. When two or more

species resemble one another (i.e., they are morphologically similar and thus difficult to tell apart) they can easily be confused (Gérard et al. 2016; Bouka et al. 2019). This situation is common in Africa among various groups of timber trees such as members of the family Sapotaceae (Détienne 1979). Similar confusions have been reported among members of Fabaceae in Gabon (Détienne 1998), reflecting a widespread difficulty to distinguish among members of this family.

This situation likewise applies to the Fabaceae species identified and sold under the trade name of *andoung*, a vernacular name used by the Fang, Gabon's largest ethnic group. Wood from several species is sold under the name *andoung*, including *Aphanocalyx heitzii* and members of the genus *Bikinia* (Christy et al. 2003). Moreover, as this name applies to a somewhat heterogeneous assemblage of taxa belonging to subfamily Caesalpinoideae, it is often accompanied by a qualifying epithet (for example, *andoung* de Durand; see Table 1).

All these species were previously assembled within the genus *Monopetalanthus* (Wieringa 1999; Kite and Wieringa 2003).

The total number of species regarded as to *andoung*, whether as a vernacular or commercial name, has varied among authors: Saint Aubin (1963) recognized 12 species in five genera, whereas Aubréville (1968a and b) indicated 10 species in six genera. More recently, according to the new listing published by International Technical Association for Tropical Woods (ATIBT) in 2016, the commercial name *andoung* corresponds to wood obtained from more than six taxa, viz., *Aphanocalyx hedinii, A. heitzii, Bikinia coriacea, B. durandii, B. le-testui* and *B. Pellegrinii* as well as other *Bikinia* species, still maintaining some confusions. Adding to the confusion, the Gabonese forestry ministry has specified in the official list of exploitable timber trees (decision n° 000119 of March 1, 2004) that the commercial name *andoung* designates not only seven named species [viz., *A. heitzii, A. microphyllus, B. coriacea, B. durandii, B. le-testui, B. pellegrinii* and *Tetraberlinia polyphylla*, but also *Bikinia spp*. and *Aphanocalyx spp*. (i.e., all members of these two genera that cannot be assigned to a species).

On the other side, based on the taxonomic work of Wieringa (1999), botanists now recognize nine taxa in Gabon to which the name *andoung* can be applied: *Aphanocalyx heitzii, Bikinia aciculifera, B. coriacea, B. durandii, B. evrardii, B. grisea, B. le-testui* subsp. *le-testui, B. media* and *B. pellegrinii*, each of which has a corresponding commercial name with a qualifying epithet (Table 1). In the remainder of the present paper, these nine species will be referred to as "true *andoungs*" or *andoung sensu stricto*, whereas all other species that have at one time or another been assigned this name will be called "false *andoungs*". Together these two groups will be referred to as *andoung sensu lato*.

For Gabon's forestry industry, Fabaceae represents about one third of the salable species (Demarquez 2006), and those identified as *andoungs* have, in some years, been among the country's ten most exported timber, contributing on average 3% of the total volume sold as "various woods" between 1995 and 1999 (Christy et al. 2003). The actual volume of *andoung* sold varies from year to year, depending on demand, and could increase significantly in the future as more heavily exploited species whose wood has similar characteristics become increasingly rare. The various steps taken during the last several years to support the development of Gabon's timber industry have not only sought to sustain and protect the country's forest resources, but also to place it at the center of economic development in the coming decades. However, unless problems such as those resulting

from a lack of clarity and consistency in the names applied to important timber trees, including *andoungs*, are rectified, these issues could compromise efforts to implement sustainable economic development in the forestry sector. While some species of *andoung sensu stricto* are relatively widespread and abundant, and should therefore be suitable candidates for sustainable exploitation, others are rare and/or have restricted ranges, and should therefore be protected (Wieringa 1999; Mboma 2012). In order to manage, protect and conserve the full array of Gabon's timber species, it will be critical that each of them be well understood and that they can consistently and unambiguously be recognized to species.

In order to begin addressing this need, we conducted a study in nine forestry concessions in Gabon in order to test the level of knowledge of tree spotters regarding *andoung sensu stricto*. In particular, we focused on the following aspects: 1) the level of effort made during field reconnaissance (i.e., general identification using the generic term *andoung* vs. detailed identification using an epithet); 2) the level of accuracy achieved by the spotters (i.e., the correspondence between an assigned name using an epithet and the true botanical species); and 3) their mastery of the nuances between strictly vernacular names in Fang (*andoungs sensu lato*) and commercial names used in the forestry industry (*andoungs sensu stricto*).

Material And Methods

Choice of species and sites

Field work was performed entirely in Gabon, a country of Central Africa bordering the Atlantic coast, between 2008 and 2010. The results of two preliminary inventories of all exploited Fabaceae in two concessions (indicated by A and E in Fig. 1) led to the decision to focus on species of *andoung*, which stood out for their complexity and the difficulty encountered by tree spotters in identifying individual trees correctly. These species are also particularly tall (often exceeding 30 m) and occur in areas that are difficult to access, which explains why a limited number of herbarium collections are available (Wieringa 1999). Moreover, the strong resemblance of species of *andoung* (all of which have pinnately compound leaves with small leaflets) and the lack of fertile reference material add to the difficulties involved in identifying specimens.

Ultimately, nine timber concessions were inventoried (Fig. 1 and Table 4), selected to comprise a representative sample of the diversity found in Gabon's forests (Saint Aubin 1963, Caballé 1978, Caballé & Fontes 1978, Doumenge et al. 2001) and chosen based on the commitment of the forestry company operating in each concession to the principles of sustainable development as well as the documented presence of species of true *andoungs* (Saint Aubin 1963, Aubréville 1968a and b, Wieringa 1999, Sosef et al. 2006). Data were also gathered from specimens deposited in the National Herbarium of Gabon (LBV), the Paris Museum (P) and the University of Wageningen (WAG; acronyms according to Index Herbarium 2019).

Tree spotters

Field data were gathered at each site by the first author, accompanied by a botanical technician from the national herbarium in Libreville and a tree spotter employed by the concession (Table 5). Tree spotters are using trade names when inventorying the wood resources of the forests, and each of them was asked to recognize and identify *andoung* trees with whatever trade name they find adapted.

Inventory and specimen collection

The field work was structured to evaluate the likely impact on efforts to achieve sustainable management of true *andoungs* that may result from possible inconsistencies between the commercial names applied to trees in forestry concessions and the actual botanical species to which they belong. All trees recognized as an *andoung* by the tree spotter were given a unique collection number corresponding to a voucher specimen prepared in the field, and the commercial name given by the spotter was recorded. When possible, three duplicate specimens were prepared and deposited at LBV, P and WAG.

A brief description of the habitat (forest type, substrate, characteristics of the understory) and the tree itself (presence/absence of flutes on the bole, texture of the bark and slash, and shape of the bole) was recorded to facilitate identification and enable a description of the ecology of each species. The height and diameter of each tree were also recorded to estimate its maturity (young or adult), photos were taken of the bark slash and of the herbarium specimen (leaves, plus flowers and/or fruits when available) before it was pressed, and the geographic coordinates were noted using a GPS unit. All these data were collected in order to ensure the determination of the species.

Specimen identification

The trees recorded during the inventory were identified in a three-step process. A preliminary identification was made in the field using available reference works, in particular Aubréville (1968a and b), Vivien & Faure (1985), and Wilks & Issembe (2000). These were then verified and refined by comparing voucher specimens with reference material deposited at LBV, P and WAG identified personally by J. Wieringa, the taxonomic specialist on the group, again using key reference works (Aubréville 1968b, Wieringa 1999, Wilks & Issembe 2000). Finally, the voucher specimens were examined with J. Wieringa to ensure accurate identification.

Data analysis

Using the data collected during the field inventory, a series of indices were calculated to assess the following parameters.

Effort made by tree spotters to recognize andoung trees

- **Generic Identification Index** (GII) for *andoung sensu lato*

This index was calculated as the percent of total number of trees inventoried (NT; Fig. 2) that were identified as an *andoung* at the generic level, i.e. without a qualifying epithet (NG), using the following formula: $GII = (NG/NT) \times 100$. This index provides an indication of the lack of differentiation of specific entities within the name a*ndoung*, i.e. the lack of efforts by tree spotters in identifying various entities within the *andoung* group.

- **Global Recognition Index** (GRI) of true *andoungs*

This index was calculated as the percent of total trees inventories (NT) that were identified correctly as an *andoung* tree (NA), with or without a qualifying epithet: $GRI = (NA/NT) \times 100$. This index provides an indication of how well each tree spotter was able to identify correctly true *andoungs*, whether at the generic level or with a qualifying epithet.

Reliability of identification using a qualifying epithet

- **Global Recognition Reliability Index** (*GRRI*) of true *andoungs*

This is the percent of total trees inventoried (NT) that were correctly identified as a true *andoung* using a trade name with a qualifying epithet (NC): $G_RRRI = (NC/NT) \times 100$.

- **Specific Recognition Reliability Index** (SRRI) of true *andoungs*

This is the percent of trees identified using a trade name with a qualifying epithet (NE) for which the name was correctly applied (NC): SRRI = (NC/NE) ×100. This and the previous index provide an indication of the reliability of identifications of individual trees to which a specific trade name was applied by the spotters, in reference to all *andoungs* (GRRI) or to trees named with a qualifying epithet (SRRI).

Each of the four indices presented above was then calculated for all tree spotters collectively. Other indices have also been calculated by each trade name:

- **Global Recognition Index by Commercial name**: GRIC = (CA/CE) x 100.
- **Specific Recognition Index by Commercial name**: SRIC = (CC/CE) x 100.

With CE: total number of trees inventoried given a commercial name with a specific qualifying epithet (within *andoungs sensu lato*) such as *Andoung de Durand*; CA: number of trees given a specific commercial name which are true *andoungs* (i.e. number of trees named *Andoung de Durand* which are true *andoungs*); CC: number of trees correctly identified, with the epithet corresponding to the correct scientific name (i.e. number of trees named *Andoung de Durand* which correspond to the botanic species *Bikinia durandii*).

Use of commercial names by individual tree spotters

The way in which commercial names were applied according to tree spotter was assessed using correspondence analysis based on a contingency table of commercial name vs. spotter, in an effort to evaluate the type of identification made by each spotter, i.e., generic (all individuals simply named as *andoung*), specific (trees identified as *andoung* with a qualifying epithet), or mixed (only some individuals assigned a qualifying epithet).

Results

Effort to recognize andoung trees, reliability of identification

A total of 308 trees were inventoried corresponding to 18 species in eight genera, all members of Fabaceae subfam. Caesalpinioideae except for *Piptadeniastrum africanum*, which belongs to subfam. Mimosoideae (Appendix 3). Only 65% of the trees were true *andoungs* (GRI index, Table 2), i.e., they belonged to one of the nine species of *Aphanocalyx* and *Bikinia* to which this name is now correctly applied, based on the work of Wieringa (1999; Table 1). The other species to which the name *andoung* was applied by tree spotters in the field (i.e., false *andoungs*) belong to genera that are not closely related, such as *Didelotia* and *Piptadeniastrum*.

The generic commercial name *andoung* was applied to 63% of the trees inventoried (GII index, 194 out of 308 trees), while the remainder (37%) were assigned one of the nine commercial names with a qualifying epithet used by the spotters, seven of which correspond to true *andoungs* and two others (*andoung noir* and *andoung touwé*) apply to species of false *andoungs*, viz. *Tetraberlinia bifoliolata* and *Didelotia brevipaniculata*. In all,

only 11% of the individuals identified by the tree spotters who participated in this study were assigned a correct name using a qualifying epithet (Table 2, GRRI index). However, the portion was higher (29%) when considering only *andoungs* named with an epithet (SRRI index).

The name *andoung rouge*, which correctly refers only to *Aphanocalyx heitzii* (Table 1), was the commercial name that generated the highest level of confusion, having been applied to six different species by the tree spotters (Fig. 3). They collectively assigned correctly to *A. heitzii* only 6% of all trees referred to by this trade name, but 74% of these trees correspond to a species of true *andoung* (respectively SRIC and GRIC indexes in Table 3). The only species that was correctly identified each time it was encountered by the tree spotters was *Aphanocalyx heitzii*, named under the alternative names *andoung de Heitz* (Table 6, and Table 3, SRIC index) and *andoung rouge* (although the latter of these is sometimes misapplied).

Trees of all other species were either identified simply by the generic name *andoung* or under one to three names with a qualifying epithet (Fig. 3 and Appendix 3). Four out of nine of true *andoungs* were only recognized in a fifth of cases or even less (SRIC index in Table 3). *Andoung* 66, which stands for two botanical species (*Bikinia grisea* and *B. media*) has only been used for the later, always correctly. The trade name *andoung de Morel*, corresponding also to two species (*B. aciculifera* and *B. coriacea*), has only been applied correctly once to the first species and usually misapplied the rest of the time (Table 6, and Table 3, SRIC index). *Andoung touwé* and *andoung noir*, whose trade names do not correspond to true *andoungs*, have been used by tree spotters to name true as well as false *andoungs*, creating even more confusions.

Structure of commercial names according to tree spotter

A correspondence analysis was performed to examine the relationship between commercial names and tree spotters. The first two axes of the analyses (Fig. 4) explain almost 70% of the total variation, which indicates a strong relationship between the name used and the individual spotter. The commercial names cluster around the spotters who used them for trees inventoried in their respective concessions.

Axis F1 of the correspondence analysis separates those spotters who used the generic name *andoung* (TS_2 through TS_6) from those who used names with qualifying epithets. The latter were completely unaware of the entities (species) recognized by botanists as comprising *andoung sensu stricto*. The two spotters located near the center of this axis, TS_7 and TS_9, used a mixture of names, with spotter TS_7 tending to use more specific names and TS_9 using the generic name *andoung* more often. These two spotters both used the common commercial name *andoung rouge*, while only TS_7 used the name *andoung noir*.

Among the spotters who used qualifying epithets, axis F2 separates one spotter who identified *andoungs* with a high level of accuracy (TS_8) from another one (TS_1) who did not. Spotter S8 was 100% accurate in his use of commercial names for *andoung sensu stricto*; all six names he used were correctly assigned to the 31 trees inventoried, which belonged to as many species. By contrast, spotter (TS1) failed to use commercial names correctly, and was unique among the spotters surveyed in using a name (*andoung touwé*) that in fact applies to a false andoung (*Didelotia brevipaniculata*). TS_1, TS_7 and TS_9 knew that these nine species exist but were unable to distinguish them from one another.

Discussion

Clearly recognizing and naming species that are exploited and commercialized is a long standing and widely shared question. It is not solely a problem in the timber industry but also in food, medicine and cosmetic (Andrianoelisoa et al. 2012, Oketch-Rabah et al. 2018). In these sectors, apart from the problem of traceability of the product and its economic value, confusions in trade names may result in sometimes serious health problems (Small 1996, Carson and Riley 2001, Bussmann et al. 2015). As for timber species, confusions may arise 1) from new taxonomic separation of previously combined species which has not been transferred from scientists to producers or traders (Iglésias et al. 2010, Rivera et al. 2013) or 2) lack of interest from producers or traders in separating species which may present close properties such as taste, medicinal or wood properties (Lamb 1963, Mariaux 1963).

In particular, confusion in the use of commercial names for timber species, discussed for the first time with regard to Gabon nearly half a century ago by Détienne (1979), persists today. If reference documents in the nomenclature of tropical woods (ATIBT 2016, Gérard et al. 2016) have made some progresses in clarifying confusions of species within commercial wood names, these progresses are still insufficient. Despite the adoption of new legislation emphasizing the sustainable use of forest resources and the development of management plans for forestry concessions based on the concept of sustainability, species of *Bikinia* and *Aphanocalyx* corresponding to *andoung sensu stricto* are still regularly confused with one another and with taxa that belong to other genera. Just over 10% of the trees referred to as *andoung* by the professional spotters surveyed in our study were correctly identified to one of these nine species. The basic training in botany that some spotters had received does not appear to provide any guarantee of their being able to make accurate identifications; on-the-job training and experience in the field appear to be more effective. While the overall level of accurate species identification of *andoung sensu stricto* is very low, it is worth noting that the only tree spotters who made correct identifications work for forestry companies that have a commitment to engage in sustainable management.

The low rate of accurate identification of *andoung* using a commercial name with a qualifying epithet may be linked to a lack of attention on the part of the Ministry responsible for Gabon's forests, which does not require that timber companies distinguish among the various types of *andoung*. Moreover, poorly known or unknown species (*Bikinia* spp) are also exploited as *andoung* (ATIBT 2016). This has added to the confusion and reinforced the tendency of many spotters to take advantage of the lack of administrative clarity and simply identify trees as *andoung* rather than making the additional effort to assign each tree to a species using a name with a qualifying epithet. Moreover, the various species of true *andoung* (i.e., *andoung sensu stricto*) are all of the same commercial value and are therefore sold under the same name. It is thus not surprising that most forestry companies have no particular interest in the accurate identification of trees using qualifying epithets that correspond to species and have not required their tree spotters to apply these names.

Nearly 63% of the trees inventoried were identified simply as *andoung* (without a qualifying epithet), indicating that the tree spotters studied were, as a group, either not aware that true *andoungs* are including several taxa, or they were unable to differentiate among the taxa or saw no use in doing so. The fact that other species (false *andoungs*) were recorded in the inventories underscores the spotters' lack of knowledge and the need to improve their skills. Nearly two decades after the publication of the field identification manual of forest trees by Wilks and Issembe (2000), the spotters included in our study continued for the most part to base their work on a considerably older work in which the name *andoung* was applied in the vernacular sense of the Fang people

(Saint Aubin 1963), and was used to refer to taxa placed in the genera *Didelotia*, *Julbernardia* and *Tetraberlinia* according to taxonomic concepts that are no longer accepted. It is thus not surprising that some spotters did not distinguish between strictly vernacular names (in Fang) and commercial names. Some vernacular names have been adopted as commercial names, and several species of true *andoungs* (such as *Bikinia coriacea*, *B. durandii* and *B. le-testui*) share the Fang vernacular name *andoung*. The fact that the Gabonese forestry administration and the timber industry have failed to integrate the taxonomic revision of Wieringa (1999) into regulation and practice has contributed significantly to maintaining the level of confusion revealed by our study.

Among the commercial names with a qualifying epithet, *andoung rouge* was the most often confused. Two different types or confusion plague this name, intra-generic (between the two species of *Aphanocalyx* and among the eight species of *Bikinia*) and inter-generic (between the members of these two genera). This situation reflects the fact that members of all species of true *andoungs* can have red trunks, depending on where they grow, although as indicated above, only *A. heitzii* has an evident dark red bark slash. As mentioned above, these errors reflect either the lack of training of the tree spotters or a lack of interest in separating various species.

Three species of *andoung sensu stricto* (*Bikinia aciculifera*, *B. coriacea* and *B. durandii*) are endemic to Gabon and three others (*Aphanocalyx heitzii*, *B. grisea* and *B. media*) are nearly endemic (Wieringa 1999, Sosef *et al*. 2006,). Among the species of false *andoung* present in Gabon, four are likewise subendemic [*Hymenostegia pellegrinii*, *Julbernardia brieyi*, *Tetraberlinia longiracemosa* and *T. moreliana*]. However, all species of *andoung*, whether endemic, subendemic or more widely distributed, are harvested, without regard to their geographic range or rarity. As a result, forestry companies and the tree spotters they employ likely contribute to the over-exploitation of rare and/or range-restricted species and thereby unknowingly or unintentionally exacerbate their risk of extinction.

The accurate field identification of species of *andoung* remains a significant challenge for forestry companies in Gabon and the tree spotters working for them. Wieringa's (1999) revision and description of new taxa greatly improved our understanding of species limits but let to further confusion within the forestry industry. The broadly defined commercial names currently being used, many of which refer to several taxa, are insufficient to distinguish species from one another, a situation that is likely to compromise Gabon's efforts to reconcile economic development with sustainable use of natural resources and biodiversity conservation. The fact, for example, that *Bikinia aciculifera* and *B. coriacea* both have highly restricted distributions yet are being harvested under the same commercial name casts doubt on whether they are indeed being managed sustainably and diminishes the prospects for their long-term conservation.

The current application of commercial names with qualifying epithets to distinguish among the nine species of *andoung sensu stricto* is problematical, with the exception of the easily recognized species *Aphanocalyx heitzii*. All of the remaining species of *andoung* were incorrectly named by the tree spotters surveyed in our study, which points to the inadequacy of the spotters' current knowledge and training. For a country such as Gabon, which has chosen to make sustainable forestry a cornerstone of the national economy, the ability of field staff to identify accurately all species that are marketed or potentially marketable should be a *sine qua non* for exploitation in forest concessions. The application of a governmental decision to prohibit the export of raw

logs, starting on May 15, 2010 (Manciaux 2011), has forced the industry to strengthen capacity to transform products locally, as required since 2001 by the forestry code. However, to develop this new dimension properly, the ability to identify felled trees with a high degree of accuracy is essential in order to guarantee that wood sold under a particular commercial name is uniform in quality and corresponds to a single species.

Some species of true *andoungs* are rare or have a restricted distribution (Wieringa 1999, Mboma 2012) and are likely threatened according to the IUCN Red List risk of extinction criteria (IUCN 2012). Other species that are more common and widespread are probably not threatened by timber harvesting, at least not today, although the example of *moabi* should serve as a reminder of what can happen as a result of abusive over-exploitation. The same could be predicted for Okan, *Cylicodiscus gabunensis* Harms, a species of Fabaceae subfam. Mimosoideae whose export volume quadrupled in just four years (Fig. 5). In the absence of both adequate capacity to distinguish reliably among the taxa of true *andoungs* and a regulatory system that requires doing so, these species are being exploited without any consideration of the consequences to their conservation status or their long term survival.

To address the twin problems of confusion in the commercial names applied to species of *andoung* and the inability of professional tree spotters to recognize them reliably, the following measure are suggested:

- Identify easily observable morphological characters that can be used, even on sterile trees, to enable spotters and others involved in forestry inventories make accurate field identifications of species of *andoung sensu stricto*.

- Produce and distribute to tree spotters and other potential users a practical field guide (including distribution maps) of *andoung* species occurring in Gabon in order to facilitate identification.

- Update Gabon's list of marketable tree species produced by the Ministry responsible for forestry so as to bring it in line with the current taxonomic framework. Some current trade names are still standing for two botanic species and should be changed. A solution could be to add to the generic name *andoung* an epithet highlighting a morphological characteristic of each species. Another solution could be to add as epithet the specific botanical name; for example, *andoung de Morel* could be changed in *andoung aciculifera* (for *Bikinia aciculifera*) and *andoung coriacea* (for *B. coriacea*). This could have the advantage of linking more closely trade and botanical names.

- Organize a training program and refresher courses on the identification of commercial tree species, with a emphasis on *andoung sensu stricto*. This could be coupled with an effort to increase the level of professionalism for those involved in tree spotting, which would benefit the spotters themselves, the forestry companies for which they work, and Gabon's regulatory agencies.

- Pursue and expand botanical inventory work to improved our knowledge of the geographic distribution and ecology of the species of *andoung*, especially those that are rare and/or have a restricted range, in order to inform the evaluation of their conservation status and risk of extinction.

- Initiate a research program on *andoung* species, focusing on phenology, reproductive biology, regeneration, population characteristics, growth rates, diameter and its relationship to minimum flowering size, etc., in order to inform and improve management policies so that they fully consider the unique aspects of each species.

In order to evaluate and verify the reliability and accuracy of identifications made by tree spotters and others professionals in the forestry industry, forest inventory of timber trees should be monitored before, during and after harvesting. This could be facilitated, including for species of *andoung*, by using DNA barcoding, which has proven to be effective for commercial timber species elsewhere in the world (Gonzalez 2009, Gonzalez et al. 2009). A unique genetic fingerprint would be established for each of the nine taxa of *andoung*, making it possible to identify living trees before harvest as well as logs once they have been cut. This could also help strengthen the conservation and rational exploitation of *andoungs* by ensuring that threatened species are not harvested, while enabling accurate identification of those that can be cut as part of a sustainable forest management program. Toward this end, Gabon should develop the expertise and technical capacity needed to establish a DNA barcoding program for its entire forestry industry, with an ultimate goal of ensuring that all timber trees can be identified reliably and that only authorized species are harvested.

Finally, as mentioned earlier, our work on the confusion of timber species is undoubtedly of a wider importance within and outside the timber sector itself. Most of the above recommendations might also be valid in other contexts.

Declarations

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

The first draft of the manuscript was written by MBOMA Raymonde and all authors commented on previous versions of the manuscript.

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Tables

Table 1

Correspondence between trade names and botanic species, and range of true *andoungs* in Gabon

Species	Herbarium specimens	Commercial name	Endemicity in Gabon
Aphanocalyx heitzii	Raymonde MBOMA_1039	*Andoung de Heitz / Andoung rouge*	Subendemic
Bikinia aciculifera	Raymonde MBOMA_995	*Andoung de Morel*	Endemic
Bikinia coriaceae	Raymonde MBOMA_1073	*Andoung de Morel*	Endemic
Bikinia durandii	Raymonde MBOMA_1033	*Andoung de Durand*	Endemic
Bikinia evrardii	Raymonde MBOMA_745	*Andoung de Dibata*	Widely distributed
Bikinia evrardii	Raymonde MBOMA_745	*Andoung de Dibata*	Widely distributed
Bikinia grisea	Raymonde MBOMA_537	*Andoung 66 (or andoung 1966)*	Subendemic
Bikinia le-testui	Raymonde MBOMA_833	*Andoung de Le-Testu*	Widely distributed
Bikinia media	Raymonde MBOMA_741	*Andoung 66 (or andoung 1966)*	Subendemic
Bikinia pellegrinii	Raymonde MBOMA_541	*Andoung de Pellegrin*	Widely distributed

Table 2

Andoung recognition indexes for all prospectors from nine forestry concessions in Gabon

Index	*GII*	*GRI*	*GRRI*	*SRRI*
Value (%)	63	65	11	29

Note - GII: Generic Identification Index; GRI: Global Recognition Index; GRRI: Global Recognition Reliability Index; SRRI: Species Recognition Reliability Index (see text for explanation).

Table 3
Recognition rate of commercial names for *andoungs* and accuracy of identification to species by forestry prospector

Commercial name	Total number of trees to which commercial name was assigned	Percent of named trees correctly assigned to true *andoungs* (GRIC)	Percent of named trees correctly assigned to the corresponding species (SRIC)
Andoung de Heitz	9	100	100
Andoung rouge	31	74	6
Andoung de Morel	6	17	17
Andoung de Durand	34	21	21
Andoung de Dibata	0	-	-
Andoung 66 or 1966	4	100	100
Andoung de Le Testu	10	100	20
Andoung de Pellegrin	9	89	89
Andoung touwé	7	100	0
Andoung noir	4	75	0
Note - GRIC: Global Recognition Index by Commercial name; SRIC: Specific Recognition Index by Commercial name (see text for explanation).			

Table 4 Characterization of the forestry concessions studied

| Commitment of the concession to sustainable development practices	Forest type	Total area (ha) of forestry concession	Forestry concession
Forestry concessions being managed for sustainability	Atlantic coastal forest	264,680	A
	Atlantic hill forest and semi-deciduous forest	139,810	B
	Atlantic hill forest	237,878	C
	Atlantic hill forest	267,232	D
Forestry concessions under provisional agreements for preparation, exploitation or transformation	Atlantic coastal forest	131,297	E
	Western Congolean forest	135,000	F
	Atlantic hill forest and Western Congolian forest	8,451	G
	Atlantic hill forest and Western Congolian forest	134,945	H
Forestry concessions not committed to a sustainable management approach	Atlantic hill forest	Data not available	I

Source: General Directorate of Water and Forests, Gabon (2008)

Table 5 Characterization of tree spotter

Tree spotters (TS)	Educational level	Type of professional training	Previous professional experience	Age group (years)	Forest concession where based
TS1	Middle school	On the job	No	<25	A
TS2	High school	On the job	No	25-40	B
TS3	Middle school	Formal	Yes	>40	C
TS4	High school	Formal	Yes	>40	D
TS5	High school	On the job	Yes	25-40	E
TS6	Middle school	On the job	No	25-40	F
TS7	Middle school	On the job	Yes	>40	G
TS_8	Middle school	Formal	Yes	>40	H
TS_9	High school	Formal	Yes	>40	I

Table 6 Details of commercial names assigned to trees of each botanical species

| Species	Andoung	Andoung de Durand	Andoung rouge	Andoung de Heitz	Andoung de Le-Testui	Andoung de Pellegrin	Andoung Towé	Andoung de Morel	Andoung 66	Andoung noir	Number of Trees
True andoungs											
Aphanocalyx heitzii			2	9							**11**
Bikinia aciculifera	11		4								**15**
B. coriacea	3							1			**4**
B. durandii	19	7	14							3	**43**
B. evrardii	9										**9**
B. grisea	17								4		**21**
B. le-testui	33		3		2		7				**45**
B. media	21										**21**
B. pellegrinii	14				8	8					**30**
False andoungs											
A. microphyllus	24		1								**25**
Didelotia brevipaniculata	2		7			1					**10**
Hymenostegia pellegrinii	20										**20**
Julbernardia brieyi	6										**6**
Piptadeniastrum africanum								1			**1**
Plagiosiphon emarginatus	12										**12**
Tetraberlinia bifoliolata										1	**1**
Tetraberlinia longiracemosa								4			**4**
Tetraberlinia moreliana	3	27									**30**
Number of trees	**194**	**34**	**31**	**9**	**10**	**9**	**7**	**6**	**4**	**4**	**308**

Figures
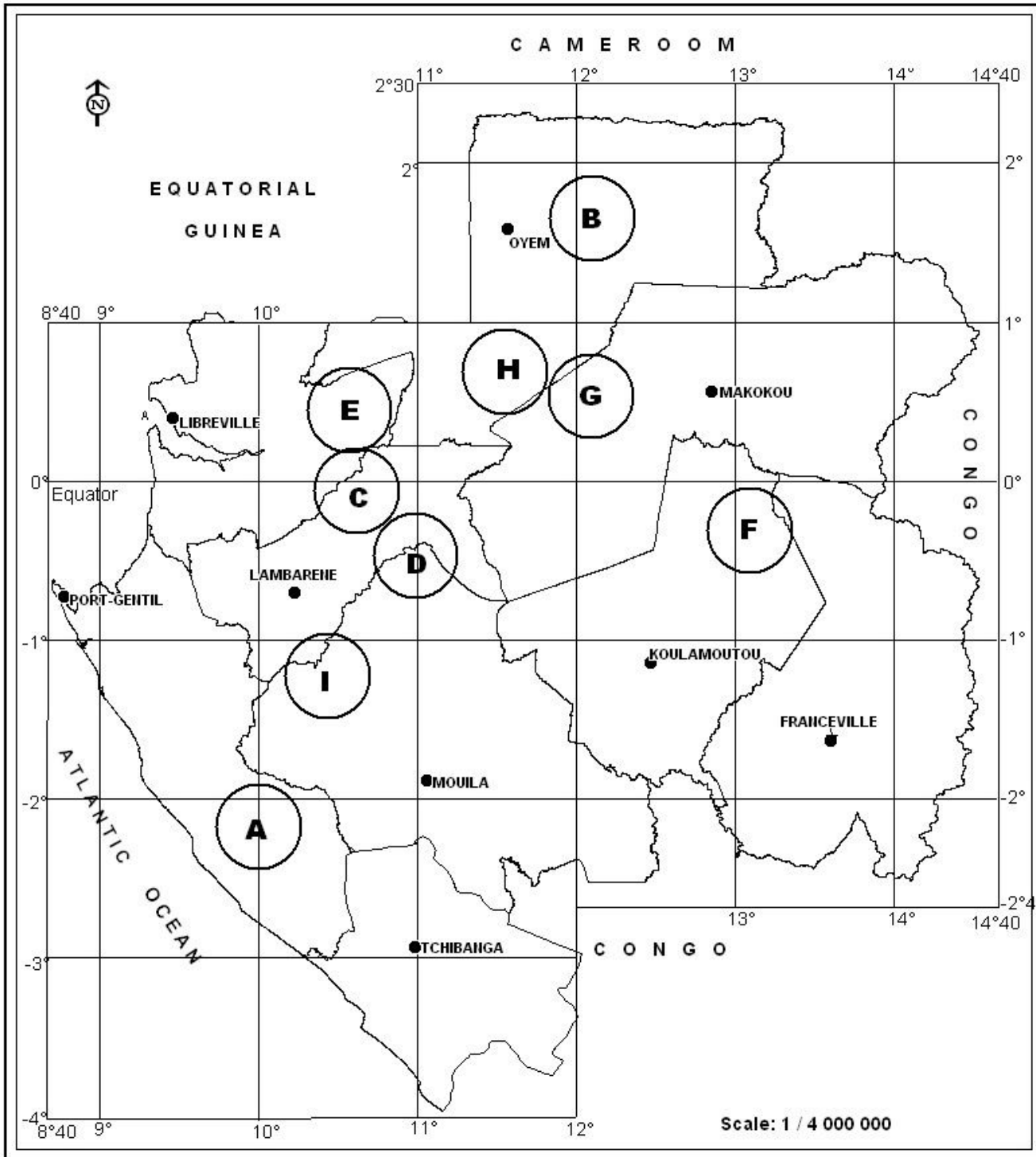
Figure 1

Location of the forestry concessions inventoried in Gabon (A-I)
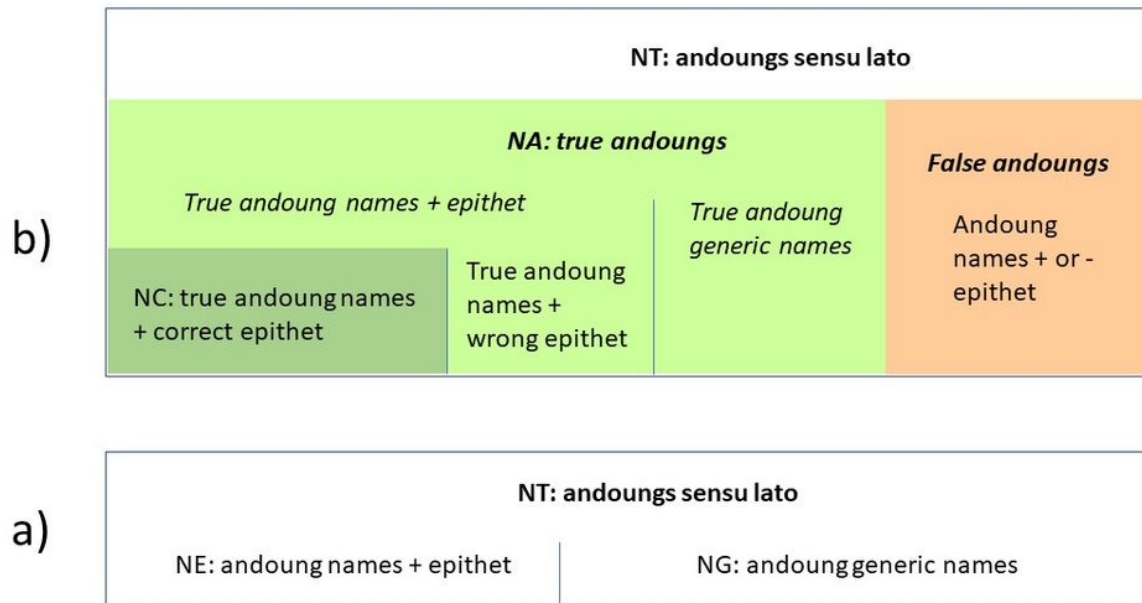
Figure 2

Categories of trees' identification when using the name *andoung*: a) generic vs specific names, b) true vs false *andoungs*

Note: GII: Generic Identification Index; GRI: Global Recognition Index; GRRI: Global Recognition Reliability Index; SRRI: Species Recognition Reliability Index (see text for explanation).
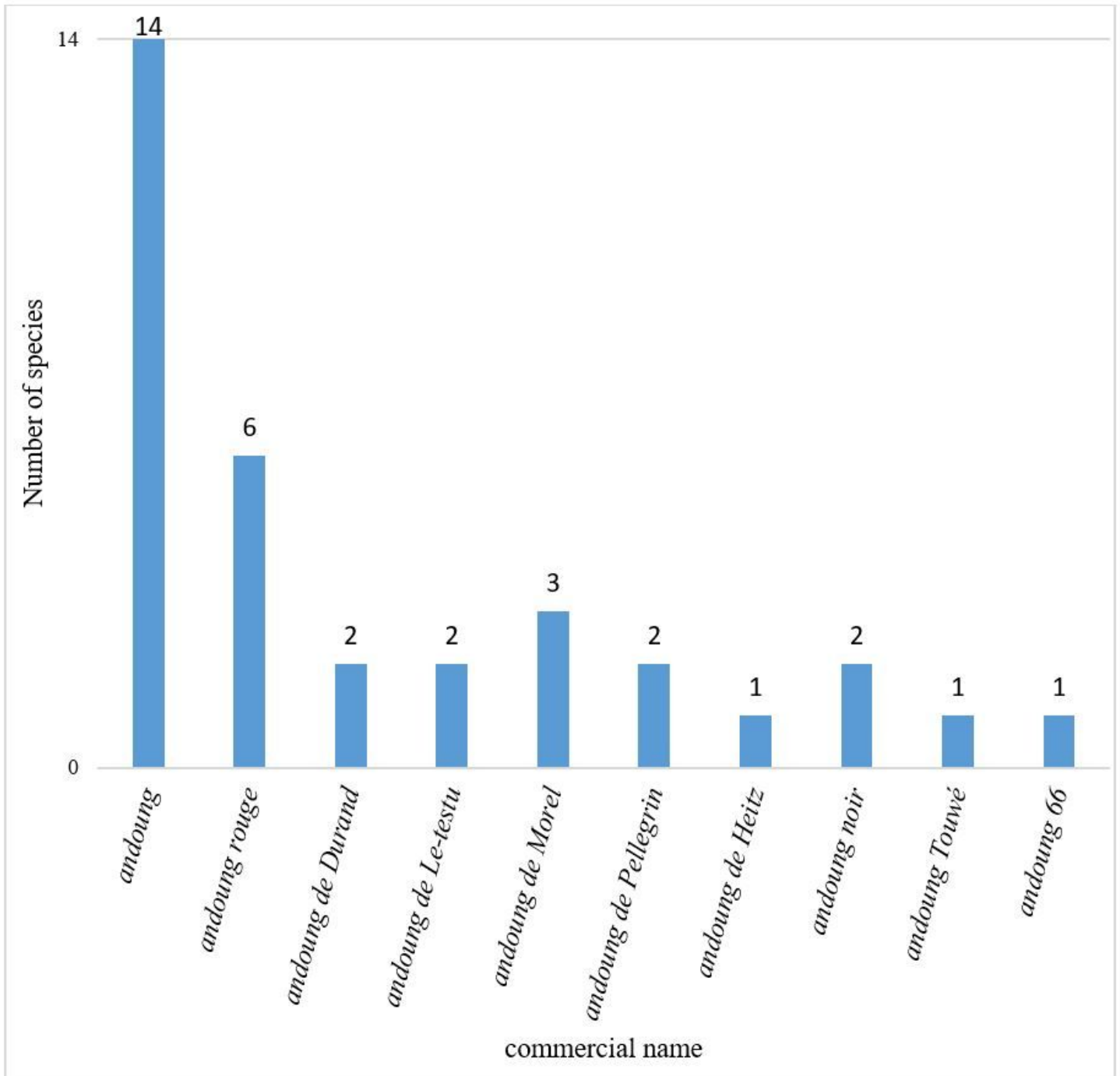
Figure 3

Number of botanic species referring to each of the trade names used to identify *andoungs*

Notes: *andoung de Dibata* was not encountered during the study; *andoung* 66 has only been applied to one of the two species it refers to.
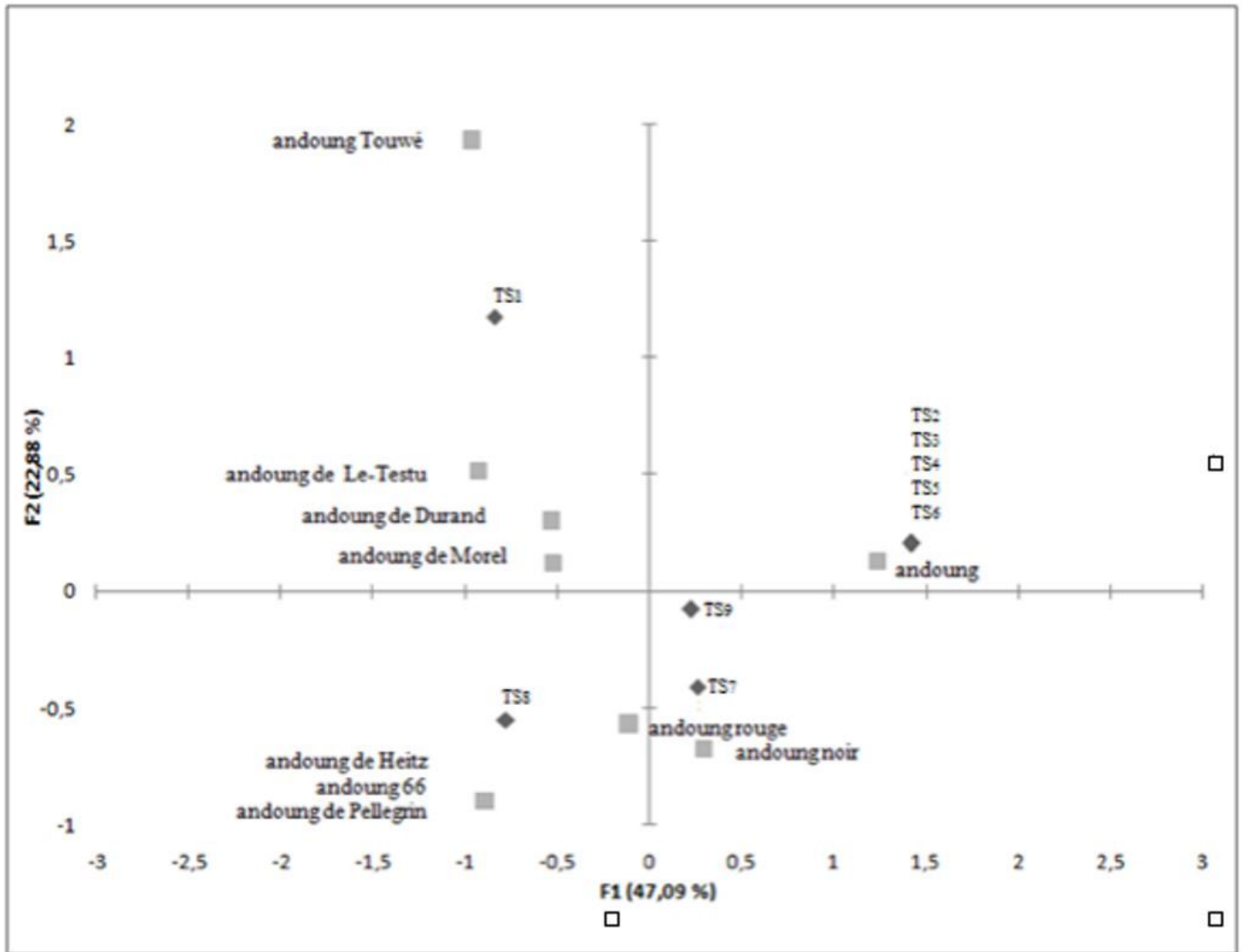
Figure 4

Distribution of commercial names by forest prospector for the nine concessions in Gabon (axis 1 and 2 of a Principal Components Analyses based on a contingency table of commercial names and tree spotters)

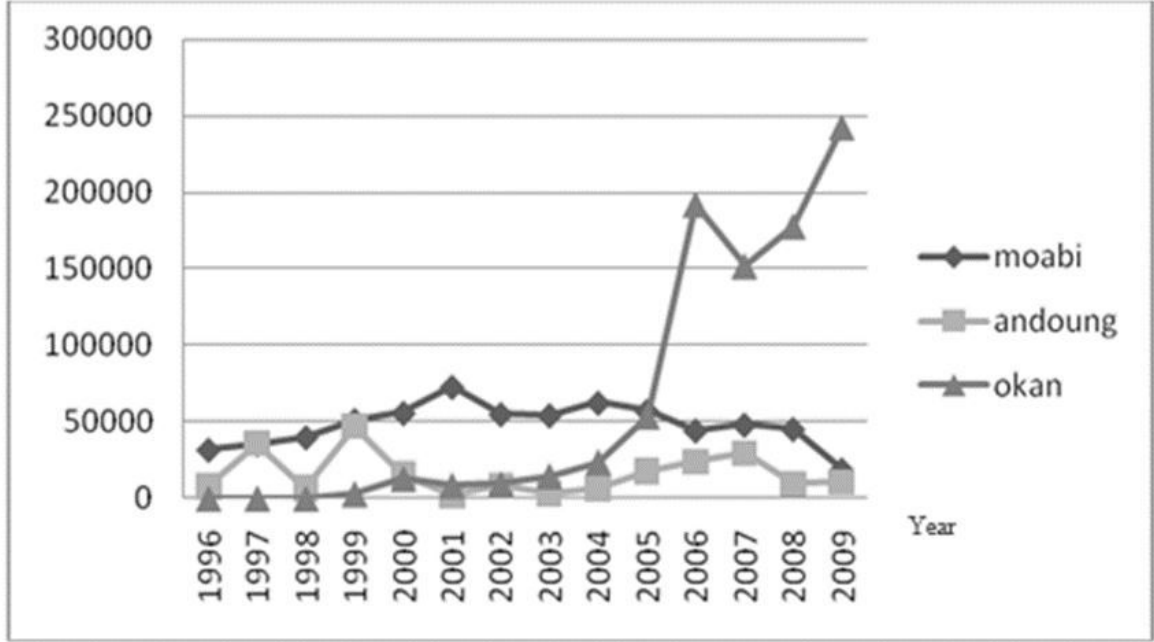Legend: commercial names (■), tree spotters ( )

Figure 5

Volume (m^3) of exported logs of moabi (*Baillonella toxisperma*), okan (*Cylicodiscus gabunensis*) and *andoungs*

Note - log exports has been banned since 2010.

Source: Société d'Exploitation des Parcs à Bois du Gabon (SEPBG), 2010