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RESEARCH ARTICLE

Priority indigenous fruit trees in the African rainforest zone: insights from Sierra Leone

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Abstract There is an increasing interest in indigenous fruit trees (IFTs) and their potential role for agroforestry, food security and poverty alleviation. Despite the growing numbers of studies on IFTs in Africa, little research has focused on the rainforest zone outside Cameroun and Nigeria. This study investigated if the important IFTs of Sierra Leone are among those previously identified as 'priority' species for this zone and, as they are not, a new approach combining focus-group data, field observations, a market survey and a ranking exercise was used to determine which IFTs have highest potential for agroforestry in a given area. Results indicated that the most important IFTs in Sierra Leone as established by local farmers are *Parinari excelsa* Sabine, *Cola lateritia* K. Schum., *Pentaclethra macrophylla* Benth., *Heritiera utilis* (Sprague) Sprague and *Bussea occidentalis* Hutch. However, following the ranking exercise, the species *H. utilis*, *Garcinia kola* Heckel and *Beilschmiedia mannii* (Meisn.) Benth. et Hook. f. ex B. D. Jacks., highly appreciated by locals, already managed by some farmers and reported 'difficult to find in the wild', were found to have the highest potential for agroforestry in the country. The findings highlighted that previous IFTs prioritization in Cameroun and Nigeria were not representative of the whole African rainforest zone. A new approach was successfully used to identify the IFTs with greatest potential for agroforestry in Sierra Leone. This simple cost-effective approach, which straightforwardly identifies opportunities and challenges for each species, could be used elsewhere in the tropics to establish a baseline for future domestication programs.

Keywords Agroforestry · Farmers' preferences · Fruit trees · Rainforest zone · West Africa

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Introduction

In rural communities in Africa, food security can be improved and poverty alleviated by diversifying the farming systems through the introduction of indigenous fruit trees (Ofori et al. 2014). Most indigenous fruit trees (IFTs), considered neglected or underutilized, are fruit bearing trees that are locally available, not highly researched and which are generally ignored by the formal commercial sector. IFTs provide an alternative source of nutrition, especially in times of famine, can be an important source of cash income and often, are also used as medicine (Akinnifesi et al. 2008). The value to rural communities of non-timber products harvested from wild trees in the tropics,

including IFTs, has recently been reviewed and highlighted by Dawson et al. (2014). IFTs improve site conditions by nitrogen fixing, by avoiding soil erosion or by increasing soil moisture. Despite these ecological benefits, most IFTs are not cultivated and therefore are mainly collected from the wild. There are however some exceptions as some IFTs have been subject to domestication. For instance, bush mango (*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill.), which has been subject to participatory domestication by International Center for Research in Agroforestry (ICRAF) scientists, is nowadays well integrated into the rural faming systems of Cameroon. Its sale generates over 8 million US dollars annually in Cameroon only (Tchoundjeu et al. 2013). The African pear (*Dacryodes edulis* (G. Don) H. J. Lam), another IFT of the Central African rainforest, is also cultivated and traded in the regional markets (Tchoundjeu et al. 2002).

Domestication can be defined as a human-induced change in the genetics of a plant to bring it into wider cultivation through a farmer-driven or marked-led process (Harlan 1975), although domestication first targets changes in phenotypes. There are several 'degrees' of domestication, from being only unconsciously managed and selected to being dependent on humans for its continued existence (Harlan 1975). In the past few years, several programs have been focused on IFTs domestication, especially in the African drylands (see Ræbild et al. 2011). A few species, identified as 'priority' trees, have been subjected to great research. In the African savannah and drylands these comprise *Adansonia digitata* L., *Sclerocarya birrea* (A. Rich.) Hoscht., *Ziziphus mauritiana* Lam., *Balanites aegyptiaca* (L.) Delile, *Tamarindus indica* L. and *Uapaca kirkiana* Müll. Arg. (Ofori et al. 2014). In dry West Africa, *Parkia biglobosa* (Jacq.) R. Br. ex G. Don. and *Vitellaria paradoxa* C. F. Gaertn. are also included (Ræbild et al. 2011) while in the miombo woodlands of southern Africa *Parinari curatellifolia* Planch. ex Benth. and *Strychnos cocculoides* Baker are also considered priority species (Akinnifesi et al. 2008).

Interestingly, the number of 'priority' trees for the African rainforest zone seems lower than in savannah and drylands. While the World Agroforestry Center (WAC) focus its research on *I. gabonensis, I. wombolu*, *D. edulis*, *Ricinodendron heudelotii* (Baill.) Heckel and *Chrysophyllum albidum* G. Don (Ofori et al. 2014), Akinnifesi et al. (2008) reports that the priority species for the African rainforest zone are well the four above-mentioned species together with *Vitex doniana* Sweet and *Syzygium guineense* (Willd.) DC. Considering higher levels of biodiversity in the rainforest zone compared with the drylands, this is surprising. The fact that most research on IFT and their domestication in the rainforest zone has been carried out in Cameroon and Nigeria (see Tchoundjeu et al. 2013) might explain this situation. Local preferences in useful plant species and even plant parts of the same species are known to differ geographically and in relation to ethnic group (Assogbadjo et al. 2012; Sop et al. 2012). Local preferences are also related to local abundance of certain plant species and other useful plant species being present in an area (Wickens and Lowe 2008). Economical purposes are other leading preferences nowadays.

A recent exhaustive review on agroforestry in the tropics suggested that the main objective and challenge for the next decade (2012–2021) in Africa is the scaling up of successful agroforestry tree domestication programs (Leakey et al. 2012). However, these successful programs cannot be scaled up if local and regional preferences are not in agreement with current selected 'priority species'. Thus, there is a need to assess in a cost-effective way which IFTs could be promoted in a specific area. Species priority setting by farmers is considered to be the first step in the participatory approach to successfully domesticate high value agroforestry species (Akinnifesi et al. 2008).

Different approaches have been used for IFT priority setting (e.g. Akinnifesi et al. 2008). A common approach is a survey of farmer preferences, and sometimes, a valuation survey is also conducted, which makes the process more costly. It has already been identified that this approach has an important weakness as it does not explicitly assess the market potential of different species and products (Akinnifesi et al. 2008). Therefore, apart from assessing farmers' preferences, a market survey is also needed. Moreover, as more than 90 % of the marketed IFTs products still come from the wild (Akinnifesi et al. 2008), field observations on harvesting techniques and abundance in the wild are also of key importance as IFTs products' harvesting often alters the rate of survival, growth, and reproduction of harvested individuals (Gaoue and Ticktin 2007). Finally, as there is often a

gap between current management and farmers' adoption of domesticated trees, it is also relevant to discuss with local farmers both current management techniques and reasons behind them. In this study a compound ranking system to score these different criteria was used.

In the field of species priority setting for efficient conservation and use, several authors have used a similar approach. For example Brehm et al. (2010) assessed priority crop wild relatives (CWR) and Wild Harvested Plants species for conservation in Portugal, using four methods (point scoring procedure, point scoring procedure with weighting, compound ranking system and binomial ranking system) to score different criteria, among which were: native status, economic value, ethnobotanical value, global distribution, national distribution, conservation status, legislation and threat assessment of each species. A similar approach was used by Idohou et al. (2013) to prioritize crop wild relatives in Benin.

This study focuses on Sierra Leone, a country located at the westernmost part of the Upper Guinean Forests, which are known to be one of the most important biodiversity hotspots and centers of endemism (Myers et al. 2000). Two related questions are addressed. First, considering differences in species, ecoregions and cultures, are the most important IFTs of Sierra Leone (as determined by local farmers) in agreement with those previously identified as 'priority' species for the African rainforest zone? Second, if they are not, how can it be determined which IFT have the highest potential for agroforestry in the country and the region a simple cost-effective way? A new approach, which combines focus-group data, a market survey, field observations on harvesting techniques and species' abundance and a ranking exercise, is presented. Through this case study in Sierra Leone, gaps in current IFT research are highlighted and a new method to address them is presented.

Materials and methods

Study area

Sierra Leone is a small West African country. It has a tropical humid climate with a wet season (May–October) and a dry season (November–April). Annual rainfall is 2500–3000 mm, but it is higher in the coastal areas. The average temperature is 26 °C, with little annual variation, and the relative humidity exceeds 80 % for most of the year. The interior plains or lowlands, which make up most of the country, used to be covered with lowland moist evergreen high forest. Nowadays they are mainly covered of fallows of different ages and most old-growth forest left is confined to protected areas such as national parks (NP) and forest reserves (FR). However, because of financial and human constraints, most FR are not actually protected on the ground (Cuni-Sanchez 2012, pers. obs.). The only protected areas where law is reinforced are those receiving support from external donors: e.g. Gola Forest National Park (GRNP) in the eastern region. This study focused on the eastern region of Sierra Leone, where more FR and the largest remaining forest (GRNP) are located.

Sierra Leone has six million inhabitants, 70 % of which lives below the poverty line. In 2014, this country ranked 182 out of 187 countries in the UN Human Development Index List. Sierra Leone is home to sixteen sociolinguistic groups. The major two are Temne in the capital and northern region and Mende in the eastern region. Most of the participants in this study were Mende as this group dominates in the eastern region.

In the eastern region, communities are subsistence farmers, with few investing in cash crops such as cocoa and coffee. The traditional farming activities include inland valley swamp farming (mainly for rice) and upland farming (intercropping of rice, beans, maize, etc.), the latter being based on slash-and burn agricultural practices. Cleared fields are only cultivated for 1–2 years, due to low yields if longer cultivation is attempted. In this country farmers do not manage/invest on their agricultural space as much as farmers do in other parts of Africa, where they create agroforestry systems (e.g. in the parklands of the Sudanian zone, where beneficial trees are protected/planted, see Boffa 1999) because of their continuous shifting of land being cultivated (Cuni-Sanchez 2012, pers. obs.).

Focus groups in villages

Focus-group (FG) discussions were organized in 25 villages in eastern Sierra Leone (total number FG = 25, Fig. 1). Villages were randomly selected around five protected forests. These were: Kambui

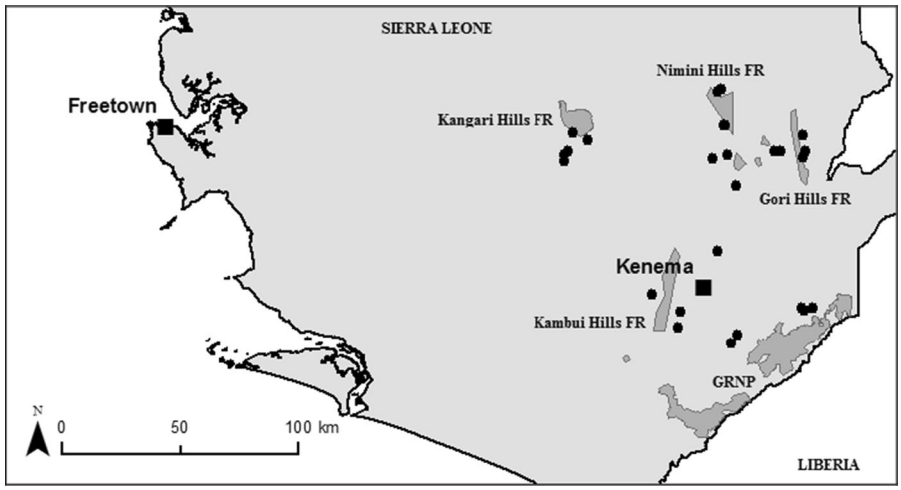

Fig. 1 Geographical location of the villages selected for focus-group discussions, nearby forest reserves (FR), Kenema (major city in the eastern region) and Freetown (capital). GRNP refers to Gola Rainforest National Park

Hills forest reserve (FR), Kangari Hills FR, Nimini Hills FR, Gori Hills FR and Gola Rainforest National Park. Each FG included 6–10 participants (mainly men) selected on a voluntary basis among which 1–2 village elders. Participants were farmers who usually harvest IFTs' products for personal use or for sale. IFTs products' collection in protected areas is legal and not regulated.

Participants were first informed that the aim of the study was to establish a baseline for future IFT domestication programs. Then, discussions centered on four topics. Firstly, they were asked to identify the five most important IFTs for their village and state the reasons behind. Secondly, they were requested to state which IFTs' products were being commercialized in their village and to whom. Thirdly, they were requested to explain which IFTs were being cultivated in their village (or preserved in the fields when clearing the land for cultivation) and why. Finally, the useful plant parts of each IFTs mentioned and their purpose was discussed.

All comments made in a single FG were considered to be a general opinion in the village if no clear disagreement between individuals was observed during the discussion. If there was a disagreement, the discussion continued until consensus was reached. Data were pooled per FG and therefore 'village' was the main unit of analysis. However, cultivation and transplanting of IFT seedlings when mentioned in a FG, was only carried out by 1 or 2 participants in that FG. Despite of this, cultivation and transplanting of IFT seedlings were considered as 'observed' in that village and these differences between participants in the same FG for these two questions are further addressed in the discussion. Results are reported as percentage of villages which answered positively to a given question (e.g. are IFTs being commercialized in this village?). With regard to the reasons preventing farmers from cultivating IFTs in a certain village, as more than one reason might have been mentioned in a village, the sum of percentages when considering 'all' reasons mentioned in all villages is >100 %.

Observations on current management, uses and trade

In order to establish IFT species' relative abundance and current harvesting techniques, observations were made (1) in several cultivated fields and abandoned fallows of each village where a FG took place and (2) in the five abovementioned protected forests. In the cultivated fields and abandoned fallows, 100 temporary circular plots (radius 19.95 m = 0.125 ha) were randomly established across the 25 villages. While all trees >30 cm diameter at breast height (dbh) were identified in the 19.95 m radius plot, all trees 10–30 cm dbh were surveyed in a sub-plot of radius 6.31 m (0.0125 ha) (see Pearson et al. 2007, Cuni-Sanchez et al. accepted). In GRNP, 100 plots of the same size randomly selected from a network of 600

permanent plots established in 2006 (by Lindsell and Klop 2013) were also measured following the same procedure. Due to time constraints, no temporary plots were established in the other FR, but visual observations were made while walking through these FRs. Species' relative abundance was computed as number of individuals per hectare.

The urban market of Kenema (the largest city in eastern Sierra Leone) was visited every two weeks and during 12 months to identify which products were being commercialized and during which time of the year and at which prices (similar to Jusu and Cuni-Sanchez 2013). When a product was found to be available, at least five vendors were consulted to determine its average price. As most remaining forest in this country is located in the eastern region, it was considered that Kenema urban market would give a good overview of the diversity of IFT species being traded. Two major towns visited for a medicinal plant survey were found not to have any IFTs in their market (Jusu and Cuni-Sanchez 2013). A literature review was also conducted within and outside our region of interest on the more commonly discussed IFTs in the FG.

Potential of IFT for agroforestry

A categorical scaling exercise, similar to the point scoring procedure described in Brehm et al. (2010), was used to assess IFT potential for agroforestry in Sierra Leone. Several characteristics considered important for IFT prioritization were assessed. First of all, the main use and other uses of IFT, in Sierra Leone and elsewhere in the literature, was considered. Some uses, especially timber and fuelwood, might compete with the fruit use. For example, in Uganda, local populations cut for firewood *Vitellaria paradoxa*, an important IFT formally used and appreciated for its fruits (Okiror et al. 2012). Secondly, the information available in the literature on morphological variation, seed germination and other propagation techniques was investigated. These two areas of research are the next two basic steps towards tree domestication after the identification of 'important' species by farmers (Akinnifesi et al. 2008). With regard to morphological variation, it should be noted that genetic variation within wild and semi-wild populations of several African IFTs is often high (Jamnadass et al. 2011), with >fivefold variation common in nutrient content, yield and economic value, and lower but still important variation in other important traits (Atangana et al. 2011). This great variation allows for the identification of certain 'ideotypes' with preferred characteristics, which can then be vegetatively propagated. Therefore, if more information is available on morphological variation and/or propagation techniques, it is likely to be easier to promote a species for agroforestry in this country.

Thirdly, it was taken into account if the species was considered threatened. ICRAF's domestication program includes two over-exploited endangered medicinal trees (*Prunus africana* (Hook. f.) Kalkman and *Pausinystalia johimbe* (K. Schum.) Pierre ex Beille), and it is considered that their domestication will help these species' conservation (Tchoundjeu et al. 2013). After these three areas, the information gathered in the FG discussions in Sierra Leone was also ranked.

All these characteristics considered important for IFT prioritization were assessed in a scale with 3 categories, where: -1 = it hampers the species potential for agroforestry, 0 = it does not have a positive or negative effect, and 1 = it benefits the species' potential for agroforestry. The categories were as follows: morphological variation: categories -1 = not observed, 0 = observed but not assessed, 1 = observed + assessed; seed germination categories: -1 = slow and low, 1 = easy; other propagation categories: 0 = not assessed, 1 = possible; cultivation assessed by foresters categories: 0 = no, 1 = yes; used in agroforestry elsewhere categories: 0 = not assessed, 1 = yes; nitrogen fixing categories: 0 = no, 1 = yes; threatened status categories: 0 = no, 1 = yes. With regard to FG data gathered in Sierra Leone: among the five most important in FG categories: 0 = no, 1 = yes; managed by some farmers categories: -1 = no, 0 = cultivated or transplanted, 1 = cultivated and transplanted; marketed in the villages categories; 0 = no, 1 = yes; marketed in Kenema categories: -1 = no, 1 = yes; expensive in Kenema categories: 0 = no, 1 = yes; availability in the wild categories: 0 = abundant, 1 = not abundant; other uses categories: 0 = no, 1 = yes.

The total score for a given species was computed as the sum of scores for each characteristic. This might seem a very 'rough' rating system, as (1) other characteristics could also have been included in the assessment, (2) the scale used only had three categories, and (3) the fact that some characteristics might

Table 1 Most important IFTs as reported in focus groups, commercialisation and tree management at the village level with regard to percentage of villages surveyed (25 villages) and relative abundance of trees in fallows and Gola Rainforest National Park (GRNP)

Most important IFT	Considered important (%)	Traded (%)	Left when land clearing (%)	Cultivated from seed (%)	Transplanted seedling* (%)	Fallows (trees/ha)	GRNP (trees/ha)
Parinari excelsa	92	12				0.16	2.42
Heritiera utilis	80	4	12	8		0	9.45[a]
Pentaclethra macrophylla	76					0.32	1.77
Cola lateritia	72	16				0	0.35
Bussea occidentalis	44					0.08	1.50
Garcina kola	40	16	12		4	0	0.11
Dacryodes klaineana	36					0	1.37
Beilschmiedia mannii	20	12	20	12	8	0	0.01
Uapaca guineensis	20					0	1.71
Parkia bicolor	8					0.4	1.35
Irvingia gabonensis	4			4		0	0.05
Dialium guineense	4					0	1.55
Myrianthus arboreus	4					0.8	0.12

* Refers to transplanting a naturally germinated seedling

[a] Refers to a very abundant tree in GRNP but which could not be observed in any other FR

be more important than others was not taken into account. However, the total score of each tree is just considered as an indication of its potential compared with the other species assessed. After the total score was computed, the species were assembled into four groups with decreasing potential for agroforestry in Sierra Leone, and the region (discussed separately).

Results

Focus groups data

Four species were mentioned as the most important IFT by >70 % of the villages sampled: *Parinari excelsa* Sabine, *Heritiera utilis* (Sprague) Sprague, *Cola lateritia* K. Schum. and *Pentaclethra macrophylla* Benth. (Table 1). *Bussea occidentalis* Hutch. was mentioned by 44 % of the villages sampled (Table 1). Most villages listed the same species, in total 13 species were mentioned (Table 1).

Only five IFT were found to be commercialized in some of the villages sampled, and even for these species the percentage of villages commercializing them was low (<20 %, Table 1). In general, IFTs' fruits or seeds were sold to people passing by the village, and trade was not organized any further. Only in the case of *Garcinia kola* Heckel seeds a salesman came to two villages to buy all seeds available. Note that a species is considered as being commercialized in a village only when some people in that village are selling plant parts of that species to someone. Being aware that people in the urban areas buy e.g. *G. kola* seeds, does not mean the species is being commercialized in that village if inhabitants have no salesman or other way to sale their *G. kola* seeds.

In most villages it was mentioned that farmers generally fell IFTs when clearing land prior to cultivation. Only in a few villages (<20 %) farmers avoid felling three species of IFTs (*H. utilis, G. kola* and *Beilschmiedia mannii* (Meisn.) Benth. et Hook. f. ex B. D. Jacks.) when clearing the land (Table 1).

Similarly, in most villages, farmers do not cultivate IFTs. Only in a few villages (<15 %) farmers mentioned cultivating *H. utilis, B. mannii* and *I. gabonensis* from seeds (Table 1). Transplanting of naturally germinated seedlings from the forest or fields was reported for only two species (*B. mannii* and *G. kola*) in <10 % of the villages (Table 1). Farmers keeping some IFT species in their fields when clearing the land mentioned that they did so because these species are not abundant in the wild. Farmers who cultivated certain IFTs from seeds or transplanted naturally germinated seedlings mentioned doing so to have better access to these species' fruits.

The main reason preventing farmers from IFT cultivation was their high abundance in the wild (65 % of the villages). Other reasons mentioned included: lack of need as these species germinate naturally in the forest (30 % of the villages), lack of commercial potential (30 % of the villages including statements such as 'we are not interested because there is no market for them', 'we only sow timber species'), lack of knowledge on how to sow IFTs (5 % of the villages) and lack of tradition to do so (5 % of the villages, referring to the fact that their ethnic group does not plant IFTs even if other ethnic groups elsewhere might do so).

Observations on current management, uses and trade

Fields observations were found to be in agreement with farmers' comments on IFTs kept when clearing the land. In the 100 fields/fallows visited, only four had some IFT which had been left when clearing the land. The species left were *P. excelsa, P. macrophylla* and *B. occidentalis* and not those mentioned in FG (Table 1). Five fields had *Myrianthus arboreus* P. Beauv., a species typically found in abandoned fallows.

Similarly, field observations in GRNP were found to agree with farmers' perceptions of abundant or 'not abundant' IFTs in the wild. As mentioned by farmers in FG, *B. mannii* and *G. kola* where not abundant (<0.5 trees/ha Table 1). In GRNP, *C. lateritia*, *I. gabonensis* and *M. arboreus* were also not abundant, the latter one being related to its main habitat being fallows (<0.5 trees/ha, Table 1). Although *H. utilis* was found to be very abundant in GRNP (>9 ind./ha, Table 1), no individual of this species was observed in the other FR. For the other species, observations in other FR followed the same pattern as those in GRNP, with *B. mannii* and *G. kola* being particularly less abundant than other IFT species.

With regard to harvesting techniques, during field observations no trees fallen to collect 'all fruits at once' were found. In general, farmers collected fruits or seeds from the forest floor, with exception of *M. arboreus*, *Dacryodes klaineana* (Pierre) H. J. Lam and *Dialium guineense* Willd., as these trees are often smaller and might be easily climbed by farmers.

In this study, the main use of most IFTs considered was food use, except for *G. kola* which is used for medicinal purposes. Another important type of use for several IFTs was fuelwood (Table 2). Timber use was also highlighted for *H. utilis* and *B. mannii*. In general, fewer uses than those reported in the literature were recorded (Table 2). Two uses mentioned in this study were not found in the literature review (Table 2). Outside Sierra Leone timber use for export or for local furniture is common for some of the species studied (see Table 4).

Ten of the 13 most important IFTs were found to be traded in Kenema market (Table 3). While most products were sold fresh and were only available on a seasonal basis, *P. macrophylla, B. mannii, I. gabonensis* and *G. kola* seeds were traded fresh or dried and were available during the whole year (Table 3). *B. mannii* and *B. occidentalis* seeds were found to be much more expensive than other products (Table 3). It should be noted that prices fluctuated depending on availability (higher at the period when availability is lower).

In general, vendors selling IFTs were young females which collected the products themselves in a nearby forest reserve (Kambui Hills FR) (Table 3). These young female vendors were not specialized on IFTs products; they only sold one species as an occasional activity. The more expensive products (*B. mannii* and *B. occidentalis* seeds) together with *G. kola* and *H. utilis*, which were 'difficult to find' in Kambui FR (as stated by vendors) mainly came from Gola Rainforest National Park and surroundings (Table 3).

IFTs' potential for agroforestry

In Sierra Leone, four main groups of important IFTs, with decreasing ranking values in their potential for agroforestry were observed (Table 4):

- *Group 1* This group includes *H. utilis*, *G. kola* and *B. mannii*, species that ranked high in terms of local preference, they are traded in some villages, they are

Table 2 Main uses of the five most important IFTs in Sierra Leone (SL) and the literature (Lit)

Categories of use	*Parinari excelsa*		*Heritiera utilis*		*Pentaclethra macrophylla*		*Cola latericia*		*Bussea occidentalis*	
	SL	Lit	SL	Lit	SL	Lit	SL	Lit	SL	Lit
Fruit pulp is eaten raw	x	xx					x	x		
Fruit pulp is eaten cooked										
Fruit pulp is fermented for alcoholic drink		x								
Fruit pulp used as dye		x								
Seed is eaten raw			x	x						
Seed is chewed as stimulant								xx		
Seed is eaten boiled, roasted or fried		x	x	x	x	x			x	xx
Seeds are used to make sauce			x*			x			x	x
Edible oil is extracted from seeds				x	x	xx				
Oil from seeds can be used to make soap						x				
Pods are used to make sauce					x*					
Pods are used as fuelwood					x	x				
Leaves are eaten as vegetable								x		
Leaves are used as fodder		x								
Bark added for flavouring in palm wine		x								
Bark is used to make ropes								x		
Bark is used as poison										x
Bark is used as dye				x						
Wood is used for timber		x	x	xx						
Timber is traded internationally		Before		x						
Wood is used for furniture and others		x	x	x		x		xx		xx
Wood is used as fuelwood/charcoal	x	x			x	xx				
Wood used to make paper										
Wood is used for railway slippers	Before									
Medicine		x		x		x		x		x
Used to improve soil conditions		x				x				
Used to shade coffee		x								

'Before' refers to use no longer existing, 'xx' refers to main use in the literature and x* refers to use only reported from Sierra Leone

Information from the literature was gathered from Prota database (Adam 2005; Brink 2007; Oboh 2007; Djagbletey and Bosch 2011; Oyen 2012) and references therein (see http://www.prota4u.info/)

expensive in Kenema, they are not abundant and some farmers have started managing them, but there is limited information/use in agroforestry elsewhere.

- *Group 2* This group includes *P. macrophylla* and *I. gabonensis*, which ranked high because there is quite an amount of information and use in agroforestry elsewhere. In Sierra Leone they are relatively abundant.
- *Group 3* It includes *P. excelsa*, *C. lateritia* and *B. occidentalis* with medium ranking as locals appreciate them, but they are abundant and there is limited information/use in agroforestry elsewhere.
- *Group 4* It encompassed species like *Myrianthus arboreus*, *Dialium guineense*, *Dacryodes klaineana*, *Uapaca guineensis* Müll. Arg. and *Parkia bicolor* A. Chev., with low ranks mainly because they are only appreciated by some farmers and they are abundant.

P. excelsa, C. lateritia and *B. occidentalis*, all among the most important IFT as classified in FG, were not found to have as much potential in agroforestry in Sierra Leone as other species assessed (Table 4).

Table 3 IFTs trade in Kenema urban market, part traded, period of availability, mean market price, type of vendor and source of product

Most important IFT	Traded in Kenema	Part traded	Period of availability	Mean price (SLL)	Vendors	Source
Parinari excelsa	Yes	Fresh fruit	Nov–Dec	500 large cup	F young	Kambui FR and around
Heritiera utilis	Yes	Fresh seed	Oct–Dec	1000 large cup		Mainly GRNP
Pentaclethra macrophylla	Yes	Fresh/dry seed	All year	500 large cup	F young	Kambui FR and around
Cola lateritia	Yes	Fresh fruit	Sept–Dec	200–500 one fruit	F young	Kambui FR and around
Bussea occidentalis	Yes	Fresh seed	Oct–Dec	2000 large cup	mainly F, all ages	Mainly GRNP
Garcina kola	Yes	Fresh seed	All year	200–500 one seed	M/F, all ages	Mainly GRNP
Dacryodes klaineana	Yes	Fresh fruit	March–April	1000 large cup	F young	Kambui FR and around
Beilschmiedia mannii	Yes	Fresh/dry seed	All year	2000 large cup	Mainly F, all ages	Mainly GRNP
Uapaca guineensis	No	Fresh fruit	–	–	–	–
Parkia bicolor	No	Fresh fruit	–	–	–	–
Irvingia gabonensis	Yes	Fresh/dry kernel	All year	1000 large cup	F young	Kambui FR mainly
Dialium guineense	Yes	Fresh fruit	March–April	200–500 one branch	F young	Kambui FR and around
Myrianthus arboreus	No	Fresh fruit	–	–	–	–

1USD=4400 SLL (local currency in Sierra Leone)

F female, *M* male, *FR* forest reserve, *GRNP* Gola Rainforest National Park

If the whole region (African rainforest zone) is being considered, group 2 would rank higher as there is more information available (Table 4). However, to be able to make a fair conclusion, more data should be gathered on marketing opportunities and abundance in the wild in other countries, information which could not be found for all species considered. As previously mentioned, little research has focused on IFT in the rainforest zone outside Cameroun and Nigeria.

Discussion

Important IFTs for farmers in Sierra Leone

Results indicate that the most important IFTs in Sierra Leone (as reported by local farmers) are *P. excelsa, C. lateritia, P. macrophylla, H. utilis* and *B. occidentalis*; none of which are among the species selected as 'priority' trees for the African rainforest zone (e.g. Akinnifesi et al. 2008, Ofori et al. 2014). This is quite a unique finding. In southern Ghana at least three of the four most important IFT species were among those selected by WAC: *I. gabonensis*, *C. albidum*, *V. doniana*, but not *D. klaineana* (Boateng et al. 2007). Similarly, in southern Benin three of the four most important IFT species were among those selected by WAC: *I. gabonensis*, *V. doniana*, and *P. biglobosa* but not *Blighia sapida* K. D. Koenig (Assogbadjo et al. 2012). This interesting result suggests that previous work on species priority setting, which was mainly focused in Cameroun and Nigeria is not representative of the existing variation in local preferences in the African rainforest zone, because of the differences in specific cultures and interactions with specific ecoregions. Therefore, IFTs prioritization should be assessed at a country, or regional level (e.g. following the methodology presented in this study). Another factor which should be considered with regard to IFTs prioritization is the limited knowledge on species

Table 4 IFT potential for agroforestry in Sierra Leone

	P. excelsa	*C. lateritia*	*P. macrophylla*	*H. utilis*	*B. occidentalis*	*G. kola*	*B. mannii*	*I. gabonensis*	*D. klaineana*	*U. guineensis*	*P. bicolor*	*D. guineense*	*M. arboreus*
Literature review													
Main use	Timber, fruits	Timber	Seeds	Timber	Timber	Medicinal	Timber, seeds	Vegetable oil	Timber	Medicinal/timber	Timber	Fruit, timber	Leafy vegetable, medicine
Trade (L = local, I = International)	L	L	L	I	I	I	I (timber), L(seeds)	L	L	L	I	L	L (leaves), I(medicine)
wood quality (low, medium, high)	Medium	Medium	Medium	High	Medium	Medium	Medium	Medium	Medium	Medium	High	Medium	Low
General information													
Morphological variation[a]	0	0	1	−1	−1	0	−1	1	0	0	−1	−1	−1
Seed germination[b]	−1	1	1	1	1	−1	1	1	1	1	1	1	1
Other propagation[c]	1	0	1	0	0	1	0	1	0	1	0	0	1
Cultivation assessed by foresters[d]	0	0	0	1	0	0	0	0	0	0	1	0	0
Used in agroforestry elsewhere[e]	1	0	1	0	0	1	1	1	0	0	0	0	1
Nitrogen fixing[f]	0	0	1	0	0	0	0	0	0	0	0	0	1
Threatened[g]	0	0	0	1	0	1	0	0	0	0	0	0	0
In Sierra Leone													
Five most important in FG[h]	1	1	1	1	1	0	0	0	0	0	0	0	0
Managed by some farmers[i]	0	0	0	1	0	1	1	1	0	0	0	0	0
Marketed in the villages[j]	1	1	0	1	0	1	1	0	0	0	0	0	0
Marketed in Kenema[k]	1	1	1	1	1	1	1	1	1	0	0	1	0
Expensive in Kenema[l]	0	0	0	0	1	1	1	0	0	0	0	0	0
Availability in the wild[m]	0	0	0	1	0	1	1	0	0	0	0	0	0
Other uses[n]	1	0	1	1	1	0	1	1	1	1	1	1	0
Total score (Sierra Leone)	5	4	8	8	4	7	7	7	3	3	2	2	3

Table 4 continued

	P. excelsa	*C. lateritia*	*P. macrophylla*	*H. utilis*	*B. occidentalis*	*G. kola*	*B. mannii*	*I. gabonensis*	*D. klaineana*	*U. guineensis*	*P. bicolor*	*D. guineense*	*M. arboreus*
Total score (region with available information)	1	1	5	2	0	2	1	4	1	2	1	0	3

Total score in Sierra Leone includes everything while *total score for region* only includes the section *General Information*

[a] Morphological variation: categories −1 = not observed, 0 = observed but not assessed, 1 = observed + assessed

[b] Seed germination categories: −1 = slow and low, 1 = easy

[c] Other propagation categories: 0 = not assessed, 1 = possible

[d] Cultivation assessed by foresters categories: 0 = no, 1 = yes

[e] Used in agroforestry elsewhere categories: 0 = not assessed, 1 = yes

[f] Nitrogen fixing categories: 0 = no, 1 = yes

[g] Threatened categories: 0 = no, 1 = yes

[h] Five most important in FG categories: 0 = no, 1 = yes

[i] Managed by some farmers categories: −1 = no, 0 = cultivated or transplanted, 1 = both

[j] Marketed in the villages categories; 0 = no, 1 = yes

[k] Marketed in Kenema categories: −1 = no, 1 = yes

[l] Expensive in Kenema categories: 0 = no, 1 = yes

[m] Availability in the wild categories: 0 = abundant, 1 = not abundant

[n] Other uses categories: 0 = no, 1 = yes

diversity and taxonomic confusion. For example, *Irvingia wombolu* is abundant in the Volta forest of Ghana and people do assimilate it to *I. gabonensis* although they are different species (Lowe et al. 2000).

Preferences in useful plant species are related to ethnic group, abundance of certain plant species and other useful plant species being present in an area (Wickens and Lowe 2008; Assogbadjo et al. 2012; Sop et al. 2012). *H. utilis* could be an example of preference related to local abundance of a species. *H. utilis* is only found from Sierra Leone to Ghana (Adam 2005). It is locally abundant in some parts of eastern Sierra Leone (it is the most abundant tree in GRNP, Lindsell and Klop 2013). However, in some parts of its distribution it has been overexploited due to its timber use (e.g. in Ghana, Hawthorne and Gyakari 2006) and even in several FR in Sierra Leone (FG participants' comment). The fact that other species of the same genus with larger/tastier fruits are present in some countries might explain why some species are not amongst the most appreciated IFTs outside Sierra Leone. For example, as the fruit of *P. excelsa* is edible but not as tasty as that of *P. curatellifolia*, in regions where both species exists locals prefer the latter (White 1978). This is the same for *Cola nitida* (Vent.) Schott et Endl. seeds, preferred over *C. lateritia* seeds for chewing (Brink 2007).

Local taste/texture preferences are also important. As it has been reported by several participants in FG, *I. gabonensis* is a relatively abundant tree in Sierra Leone forests and its seeds are used to make a source to be eaten with rice. However, Mende people of Sierra Leone prefer the sauce made from *B. mannii* or *H. utilis* seeds; both considered 'very delicious sauce' (FG participants' and vendors' comment). This might explain why *I. gabonensis* was only mentioned as an important IFT in one village.

A new approach to prioritize IFTs for agroforestry

The most important IFTs in Sierra Leone are not among the species selected as 'priority' trees for the African rainforest zone. So, how can it be assessed in a cost-effective way which of these IFTs could be promoted? Apart from being considered 'important' by local farmers, other aspects affect the potential of a tree species for agroforestry. The new approach is presented starts with a survey of farmer preferences of species, like many previously described in the literature (e.g. Akinnifesi et al. 2008), but it goes one step further by including other relevant information on farmers' current management and uses of these IFTs, a market survey, field observations on species' abundance and harvesting techniques, a literature review and a ranking exercise.

The ranking exercise is carried out by the scientists and it includes several characteristics rated into three categorical groups, to keep it simple and fast to calculate. This is different from other surveys on species' ranking such as Franzel et al. (1996), who found it to be expensive and very similar to an assessment of farmer preferences of species. The characteristics considered in the ranking exercise presented here relate to six themes: uses (main/competing), morphological variation and propagation (existing information available), conservation status (extra reason to manage/cultivate), current management (what happens and reasons behind), current commercialization (what happens and reasons behind) and current abundance/harvesting techniques (to avoid overharvesting/to cultivate what is 'difficult to find').

These six themes selected comprise topics considered important when promoting plant species. For example, it has been highlighted that the market potential of different species and products should be assessed as markets and market access have the potential to stimulate cultivation of plants by smallholder farmers (Assogbadjo et al. 2012; Muriuki et al. 2012). If cultivation is considered, current management and existing information available on morphological variation and propagation is also necessary in order to determine what can be done in the future. Indeed, as previously mentioned, these two areas of research are the next basic steps towards tree domestication after the identification of 'important' species by farmers (Akinnifesi et al. 2008). Plant abundance and harvesting techniques are other important factors to take into account as IFTs products' harvesting often alters the rate of survival, growth, and reproduction of harvested individuals (Gaoue and Ticktin 2007). Moreover, because some uses, especially timber and fuelwood, might compete with the fruit use (e.g. Okiror et al. 2012), uses also need to be considered. Similarly, as domestication can help species' conservation (Tchoundjeu et al. 2013), it also seems important to take into account the conservation status of a given species.

Although it might seem that the amount of work needed for implementing this new approach is considerable, it should be noted that: (a) while doing the FG to establish farmers' preferences, current management and uses were also discussed, and observations on abundance/harvesting techniques were carried out in fields/forest reserves around these villages; and (b) the market survey was a rapid assessment of a few vendors. The method presented here has an extra advantage: by gathering information on different topics from the very beginning of the 'domestication process', it is easy to identify the opportunities and challenges for each species, and, therefore, one can straightforwardly determine which steps should be followed to promote a particular species.

The new approach applied in Sierra Leone

First the findings in relation to the six themes considered in the ranking exercise are discussed, and then the final selection of priority species is addressed. With regard to uses, the fuelwood use of most IFTs is not as extended and important as food use as '*there are many other trees around to be cut down*' (participant comment); and only *H. utilis* was reported to have an important timber use. When considering morphological variation and propagation, in general, little research has been carried out on all these aspects for most IFTs considered 'important' by in the FG. Only two important IFTs are considered threatened in IUCN Red list: *H. utilis* and *G. kola* (Hawthorne 1998; Cheek 2004) and all IFTs considered were found to be sustainably harvested.

In relation to management, in eastern Sierra Leone, farmers fall IFTs when clearing the land, they do not plant IFTs nor do they protect naturally germinated seedlings. This situation is different elsewhere in West Africa, especially in the Sahel and Sudanian zone (Boffa 1999). Even in some parts of the rainforest zone, local farmers protect naturally germinated seedlings (e.g., *P. macrophylla* in Nigeria, *P. excelsa* in Guinea, *D. klaineana* in Ghana; see Boateng et al. 2007; Oboh 2007; Oyen 2012). Farmers' protection of adult trees or seedlings is often related to the perception of scarcity in the wild (Assogbadjo et al. 2012). Indeed, in this study most farmers reported that they do not protect or cultivate IFTs because of their high abundance in the wild. However, certain important IFTs (*B. mannii*, *H. utilis*) abundance is decreasing in the wild. This might be the beginning of the domestication process, as more farmers realize that these species are no longer abundant, they might be motivated to actively manage them (e.g., keep them on their fields when clearing land for cultivation or cultivate them) (Boffa 1999).

Other reasons preventing farmers from IFT cultivation were: lack of commercial potential, lack of knowledge and lack of tradition. Farmers know how to cultivate exotic trees such as mangoes and oranges (as mentioned in FG). However, they state that they do not know how to cultivate IFTs. This statement can be linked to low germination rates of certain IFT and the seed pre-treatment techniques needed for certain species' germination (e.g. *P. excelsa*). Lack of commercial potential is related to the poor infrastructure and the disconnection between villages and urban markets in the area, something already highlighted by Jusu and Cuni-Sanchez (2014), but which could be improved, though better links between collectors and vendors.

In Kenema city, IFT trade was found to be seasonal and 'opportunistic': young females collected the products themselves in a nearby FR and sold them on an occasional basis, which is less organized and 'specialized' than medicinal plant trade (see Jusu and Cuni-Sanchez 2013, 2014). It seems that low market prices and unreliable availability of fruits/seeds (partially due to seasonality), together with difficult storage and transportation (fruits/seeds are mainly consumed fresh and road infrastructure is limited in eastern Sierra Leone) makes IFTs an unattractive product for vendors in Kenema market. Several IFTs buyers mentioned that they would be keen to buy more IFTs products (mainly *B. mannii, B. occidentalis*, *H. utilis* seeds) but '*it is not easy to find them on the market*' (participant comment). Although further research is needed, the potential market for IFTs products is likely to be greater than its current one, at least for certain species.

With regard to the final selection of priority species, four main groups of important IFTs in Sierra Leone were identified, with decreasing ranking values of potential in agroforestry, and different opportunities and challenges. Group 1, found to have the highest potential, included *H. utilis*, *G. kola* and *B. mannii*: species which ranked high as locals appreciate them, they are traded in some villages, they are not abundant

and some farmers have started managing them, their price is high in Kenema market, but there is limited information/use in agroforestry elsewhere. The opportunities for this group are straight forward: farmers are likely to be interested in adopting these species. In fact, some farmers have already started to do so, as they have tried to cultivate these species from seeds following observations of decreasing abundance in the wild (see Table 1). The main challenge is the little information available on propagation techniques, which hampers these species' cultivation, and on existing morphological variation, which hinders the selection of preferred trees for cultivation (trees with e.g. larger fruits). Another interesting species is *B. occidentalis* (in group 3), which, despite being abundant in the wild, fetches high prices in Kenema market. If this species becomes scarce in the wild in the nearby future (e.g. following high exploitation), it is likely to become a priority IFTs for this country. In general, the next steps towards IFT promotion in Sierra Leone would include more research on morphological variation and propagation techniques for species in group 1. If intercropping with cocoa is being considered, studies on tree separation and light availability (e.g. Kan Koko et al. 2013) should also be carried out.

When considering priority IFTs for agroforestry in the region (African rainforest zone), if this new approach is to be implemented, more information is urgently needed, especially on marketing opportunities and relative abundance in the wild in other countries. Moreover, as this results highlight, local farmers' preferences, which might vary considerably between countries, should also be taken into account. Although at larger scales, it takes time and effort to assemble such information, the criteria selected and ranking exercise presented could be used in other countries, to start building a baseline for future IFT development programs, which do consider the existing variability in not only species presence and abundance in the wild, but also people's preferences. Even when a species has been identified as a priority tree for a number of years, its use and information available might vary considerably between different areas, e.g. *Adansonia digitata* (Gebauer et al. 2016). Leakey et al. (2012) suggest that the main objective for the next decade (2012–2021) in Africa is to scale up successful agroforestry tree domestication programs. Before that, it is necessary that the priority species identified do match the local and regional preferences and context.

Conclusions

This study shows that none of the most important IFTs of Sierra Leone were previously identified as 'priority' species for the African rainforest zone. This highlights the fact that previous work on IFT prioritization focused in Cameroun and Nigeria is not representative of the whole African rainforest zone. Therefore, more research is needed to identify IFT preference and potential for agroforestry in the highly diverse African rainforests, not only in terms of species, but also in ecoregions and cultures.

A new approach for species' priority setting which combines focus-group data, field observations, a market survey and ranking exercise is presented. This new approach, which uses a simple three category ranking exercise comprising six key themes for species' promotion (uses, morphological variation and propagation, conservation status, current management and commercialization, local abundance/harvesting techniques); is cost-effective and has the advantage that it straightforwardly identifies opportunities and challenges for each species from the very beginning. This approach could be used elsewhere in the tropics to establish a baseline for future domestication programs.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest. The authors were self-funded.

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