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Empirical Trials of Plant Field Guides

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Abstract: *We designed 3 image-based field guides to tropical forest plant species in Ghana, Grenada, and Cameroon and tested them with 1095 local residents and 20 botanists in the United Kingdom. We compared users' identification accuracy with different image formats, including drawings, specimen photos, living plant photos, and paintings. We compared users' accuracy with the guides to their accuracy with only their prior knowledge of the flora. We asked respondents to score each format for usability, beauty, and how much they would pay for it. Prior knowledge of plant names was generally low (<22%). With a few exceptions, identification accuracy did not differ significantly among image formats. In Cameroon, users identifying sterile Cola species achieved 46–56% accuracy across formats; identification was most accurate with living plant photos. Botanists in the United Kingdom accurately identified 82–93% of the same Cameroonian species; identification was most accurate with specimens. In Grenada, users accurately identified 74–82% of plants; drawings yielded significantly less accurate identifications than paintings and photos of living plants. In Ghana, users accurately identified 85% of plants. Digital color photos of living plants ranked high for beauty, usability, and what users would pay. Black and white drawings ranked low. Our results show the potential and limitations of the use of field guides and nonspecialists to identify plants, for example, in conservation applications. We recommend authors of plant field guides use the cheapest or easiest illustration format because image type had limited bearing on accuracy; match the type of illustration to the most likely use of the guide for slight improvements in accuracy; avoid black and white formats unless the audience is experienced at interpreting illustrations or keeping costs low is imperative; discourage false-positive identifications, which were common; and encourage users to ask an expert or use a herbarium for groups that are difficult to identify.*

Keywords: Africa, Caribbean, community-based conservation, ecosystem management, ecotourism, forest, traditional ecological knowledge, vascular plants

Pruebas Empíricas de Guías de Campo de Plantas Hawthorne, Cable & Marshall

Resumen: *Diseñamos tres guías de campo basadas en imágenes para especies de plantas del bosque tropical en Ghana, Granada y Camerún y las probamos con 1095 residentes locales y 20 botánicos en el Reino Unido. Comparamos la certeza en la identificación de los usuarios con formatos diferentes de imágenes, incluyendo dibujos, fotos de especímenes, fotos de plantas vivas y pinturas. Comparamos la certeza del usuario una vez que usó las guías con la certeza basada solamente en sus conocimientos previos de la flora. Le preguntamos a los encuestados que calificaran cada formato en las categorías de utilidad, belleza y cuánto estarían dispuestos a pagar por ella. El conocimiento previo del nombre de las plantas en general fue bajo (<22%). Con pocas excepciones, la certeza de identificación no difirió significativamente entre el formato de las imágenes. En Camerún, los usuarios que identificaban especies estériles de Cola consiguieron una certeza de entre 46-56% en todos los formatos; la identificación fue más certera con las fotos de las plantas vivas. Los botánicos en el Reino Unido identificaron correctamente entre el 82-93% de las mismas especies camerunesas; la identificación fue más certera con los especímenes. En Granada, los usuarios identificaron correctamente entre el 74-82% de las plantas; los dibujos arrojaron identificaciones significativamente menos certeras que las pinturas y las fotos de las plantas vivas. En Ghana, los usuarios identificaron correctamente el 85% de las plantas. Las fotos digitales a color se ubicaron en las posiciones más altas en las categorías de belleza, utilidad y cuanto pagarían los usuarios. Los dibujos a blanco y negro se ubicaron en las posiciones más bajas. Nuestros*

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resultados muestran el potencial y las limitaciones del uso de guías de campo y personas no especializadas para la identificación de plantas, por ejemplo, en aplicaciones de conservación. Recomendamos a los autores de guías de campo de plantas usar el formato de ilustraciones más barato o más fácil, ya que el tipo de imagen tuvo consecuencias limitadas sobre la certeza; igualar el tipo de ilustración con el uso más probable de la guía para tener pequeñas mejoras en la certeza; evitar formatos en blanco y negro a menos que los usuarios tengan experiencia en la interpretación de ilustraciones o mantener bajos los costos es necesario; desalentar identificaciones falso-positivas, que fueron comunes; y alentar a los usuarios que le pregunten a expertos o que recurran a un herbario para grupos difíciles de identificar.

Palabras Clave: África, bosque, Caribe, conocimiento ecológico tradicional, conservación basada en la comunidad, ecoturismo, manejo de ecosistemas, plantas vasculares

Introduction

Plant field guides are books or electronic resources used to identify plants, primarily in the field. Regional floras and taxonomic monographs are principally aimed at experts and emphasize taxonomic completeness and the identification of fertile plant specimens in herbaria. In contrast, field guides are typically tailored to a less specialized readership and have more limited taxonomic coverage. They can help users learn names for unrecognized plants or communicate about species across language barriers. They are key tools for conservation because they facilitate biological diversity assessment, increase public awareness, and broaden participation in conservation.

To guide a user toward identification, authors employ either a browsing and recognition method, where users compare images of similar species to their specimen with limited guidance, or they supply analytical tools such as diagnostic keys and full morphological descriptions, usually supported by illustrations (Lawrence & Hawthorne 2006). The first botanic identification guides were sparsely illustrated, due to technological constraints; thus, diagnostic dichotomous keys were used widely (Scharf 2009). Keys are still presented as the primary identification method for plants in specialist texts, and when well written and correctly used they are highly beneficial because they guide users efficiently through diagnostic characters to reach a conclusive identification.

Keys and technical descriptions have been hard for nonspecialists to use, and they have been largely shunned by the public in favor of image-based browsable field guides (Stevenson et al. 2003). Keys are relatively laborious even for taxonomists, especially when the taxon is unfamiliar to them. Nonspecialists are increasingly encouraged to become involved in biological diversity or ecosystem services assessment and monitoring (e.g., Sheil 2001; Luzar et al. 2011; Larrazábal et al. 2012). Although not all community conservation efforts require accurate identification of plants, accuracy in communication about species across language and training barriers is beneficial in many cases. There is recognition that inexperienced botanists or nonspecialists perform less well than specialists using traditional taxonomic resources (Scott & Hallam 2003; Ahrends et al. 2011).

Identification by browsing and recognition of pictures within broad groupings is an approach commonly used in zoological field guides (e.g., Peterson 1998) and is increasingly common for plants (e.g., Foster et al.'s [2013] Rapid Color Guides, New England Wild Flower Society's *Go Botany* [2013] and guides by Hawthorne & Gyakari 2006; Harris et al. 2011; and Marshall & Hawthorne 2013). With the call for and success of digital and online field guides (Stevenson et al. 2003; Agarwal et al. 2006) illustration is increasingly at the forefront. A number of on-line tools have helped advance the science of producing guides, including Lucid (a software platform for producing keys) and Free DELTA (an open source software system for processing taxonomic descriptions and producing keys and interactive identification tools). Yet there have been few published studies which have assessed how accurate the image-browsing format of field guides can be for the identification of plants by either specialists or nonspecialists. In a taxonomically limited study (although of commercial relevance), Johnson et al. (2007) found a low rate of misidentification (3.5%) of cocoa cultivars with their field guides to 69 cultivars in which they used digital images of the cocoa pod along with morphological descriptions. Bad taxonomy in ecological and conservation science is probably rife and underestimated—62.5% of ecological papers published 2005–2007 made no reference to how species identifications were verified (Bortolus 2008).

We investigated the accuracy with which nonspecialist and specialists could identify tropical forest plants through the use of recognition-based guides. We compared users' accuracy with the guides with their accuracy based on only their prior knowledge. We tested the fitness of various types of illustration, including specimen scans, living plant photos, drawings, and paintings to determine which type of image yielded the greatest accuracy because illustration is one of the most time-consuming and expensive of the ingredients in a guide (Hawthorne & Wise 2006). We also determined how users rate types of illustration for other purposes—ease of use, beauty, and how much they would pay for them. We evaluated field guide formats in field trials in forest areas of West Africa (Cameroon and Ghana), the Caribbean (Grenada), and the United Kingdom (Daubeny Herbarium, FHO, at the Department of Plant Sciences, University of Oxford). The results have important implications when designing efficient approaches for promoting identification of plants in the field.

Methods

We prepared browsable, image-based guides in different formats for different purposes for species in Ghana, Grenada, and Cameroon. We also tested Cameroonian material in the United Kingdom. We chose 20–130 focal species for each study site and prepared photographs, specimens, and other image types and incorporated them into a series of trial guides (Table 1). These guides were laminated cards with illustrations, produced without text or professional binding, so that illustration formats alone could be compared.

In Cameroon, we designed field guide material for the small to medium-sized *Cola* trees (Malvaceae, previously Sterculiaceae) growing around Mt. Cameroon, where the genus includes several similar species of commercial and conservation importance. Examples of this material are in Supporting Information, and specimens are housed at FHO. In Grenada, the material covered a wide spectrum of local plant life relevant to tour guides who could generate income for local communities and raise conservation awareness and skills. This material was ultimately incorporated into a full guide for Caribbean plants (Hawthorne et al. 2004). In Ghana, we designed a nontechnical field guide to trees for rural communities, who are promoted as participants in forest conservation by the United Kingdom's Department of International Development. This material was incorporated into a field guide to Ghanaian trees (Hawthorne & Gyakari 2006). Examples of all the field guide materials can be found in Lawrence and Hawthorne (2006).

We had 1115 respondents take part in trials. In Cameroon, the 277 respondents were mostly volunteers with agricultural backgrounds, recruited from villages on Mt. Cameroon. Trials were conducted in rainforest around Mt. Cameroon in Limbe Botanic Garden. In Oxford, 20 botanists working in the Department of Plant Sciences, University of Oxford, with no previous experience with Cameroonian *Cola*, were recruited. Trials were conducted using specimen material brought from Cameroon. In Grenada, the 434 respondents were from a variety of backgrounds, including some advanced students and forestry workers. Trials were held in forests of various types (Table 1). In Ghana, the 384 respondents were recruited from nearby villages and had mostly agricultural backgrounds. Trials were conducted in 5 moist evergreen forest sites (Table 1). Prior informed consent was given by all participants. Before trials began, the layout of all guides was explained and demonstrated. During the field trials, facilitators recorded the respondents' identifications with indifference to their correctness. In Oxford, respondents recorded their own answers. Respondents were not allowed to alter their initial answers following later experience in a trial.

To test for prior knowledge of the species, respondents were asked to provide a specific name (common or scientific) for each numbered plant before using any guide. Generic names, names covering several unrelated species, uncorroborated names, and unverified names were not considered to constitute prior knowledge.

To test identification accuracy, respondents were asked to identify 20 tagged plants to species. In Cameroon and Ghana, each respondent identified 10 plants using one guide format and another 10 plants with a different format. In Grenada, each respondent was given 20–22 species cards proportionally allocated to the 3 formats. Formats were randomly allocated to species. Each species was represented in only one format during the tests, which were random for each combination of respondent and species. The actual scientific names of the species were provided by W.D.H. and S.C. and were based on all available taxonomic information for the field sites and extensive experience with the vegetation. Scientific names followed Cable and Cheek (1998) for Cameroon, Hawthorne et al. (2004) for Grenada, and Hawthorne and Gyakari (2006) for Ghana.

In all trials, a few species not in the guides were included to check how well respondents could detect absences from the guide. Respondents were warned that such "trick" plants might be included. Respondents' guides also always included some species which were not numbered plants. Correct, incorrect, and false-positive identifications were recorded and attributed to the format of the guide being used. Identification accuracy was the mean number of accurate identifications for each format converted to a percentage. We used t tests to test for differences between means in our data sets.

Following identification trials, and having revealed the correct answers, we recorded subjective valuations of each format for all respondents through questionnaires. We recorded scores for usability (how easy users found each format to handle and interpret) from 0 (unusable) to 4 (very easy). A less usable guide requires more effort, concentration, or time to achieve the same level of accuracy. Beauty was determined on the basis of how pleasant respondents thought the guide contents looked (score range 0–4). Respondents were asked to ignore the lamination and binding. Price was how much respondents would pay, in their own currency, for a finished 100-page guide of the format in question.

Table 1. Summary of field guides prepared for field trials.

Study site	*Target species group*	*Image formats tested*
Cameroon—Limbe Botanic Garden	21 *Cola* species found around Mt. Cameroon	photographs of dried leaf specimen; photographs of dried leaf specimen with pointers to key features; line drawings; line drawings with x-ray details of venation; photographs of fresh plants (6 small images per species); photographs of fresh plants (4 larger images per species); life-size photocopies (black & white) of dried specimens; real, dried leaf specimens in a polythene bag
United Kingdom—Oxford University herbarium (FHO)	21 *Cola* species found around Mt. Cameroon	photographs of dried leaf specimen; line drawings; photographs of fresh plants—6 small images per species; life size photocopies (black & white) of dried specimens; real, dried leaf specimens in a polythene bag.
Ghana—5 sites in moist evergreen forest	140 of circa 250 species of the largest canopy and emergent forest trees of Moist Evergreen forest	photographs of fresh plants, laminated on A5 (210 × 148 mm) cards; photographs of fresh plants, laminated on A6 (148 × 105 mm) cards
Grenada—4 sites covering coastal dry forest, mangrove swamp, moist forest at 200-m altitude, and submontane Myrtaceae–Melastomataceae forest	100 of circa 1000 perennial, vascular plant species on the island	photographs of fresh plants; line drawings (black & white); paintings (color); all presented on cards of the same size

Results

Prior Knowledge

In Cameroon, prior knowledge of most *Cola* species was negligible. Less than 10% of the 5540 tree x respondent encounters involved trees previously known to the 277 respondents. Many people knew one of the trick plants (*Wokeku* = *Myrianthus arboreus*). Some common names, like Monkey Cola, were allocated to several *Cola* species so were not counted as prior (species-level) knowledge.

In Grenada, prior knowledge of wild and nonuseful species was low across the sites, although a few people knew several of the commoner or commercial species such as tamarind (*Tamarindus indica*). Overall, names were given for 1565 of 7100 respondent x species encounters (22%). The range was from 4.2% for the difficult-to-identify montane vegetation at Grand Etang to 36% for easier-to-identify lowland vegetation.

In Ghana, prior knowledge among the 384 respondents overall was similarly low; less than 10% of species were identified even with a generic local name. This is surprising because most respondents were at least rural dwellers and were often hunters or farmers. However, several common, distinctive species were known by 25–55% of respondents. Standard deviation in our prior knowledge data set for Ghana was relatively large; 15 respondents named more than 15 of 20 species, but 107 respondents named none (Fig. 3).

In Oxford, respondents with no prior knowledge of Cameroonian *Cola* species were selected explicitly.

Identification Accuracy

In Cameroon, identification accuracy varied greatly by species. Averaged across all guide formats, *Cola lateritia* was correctly identified in 93% of encounters. Other *Cola* species were named with 47–79% accuracy. The trick non-*Cola* trees in the trials were the greatest cause of error. They were correctly identified as a non-*Cola* in only 26% of encounters. Respondents were clearly inclined to match missing species to the best fit in a guide.

Across all the species tested, there was remarkably little difference in identification accuracy (46–56%) between the formats tested (Fig. 1), although the least accurate format (specimen photos) and the most accurate format (sets of 6, smaller living plant photos) were significantly different from each other ($P = 0.0029$). The addition of a simple diagrammatic key to species groups increased the overall accuracy of all formats somewhat (49–63%) and significantly improved accuracy for the photocopies. There was no significant difference by gender of respondent or according to self-assessed botanical or other plant experience (e.g., herbalism, forest tree spotting). More experienced respondents suggested more local names for the plants prior to using the guides.

In Oxford tests with specialists produced a significantly higher level of accuracy (82–93%), averaged across all respondents (Fig. 1). The guides were tested on dried leaf material from Cameroon, so results were not directly comparable because in Cameroon living plants were identified. Two participants who were not experienced herbarium identifiers scored <40% and were dropped from the analysis. As in Cameroon, the main source

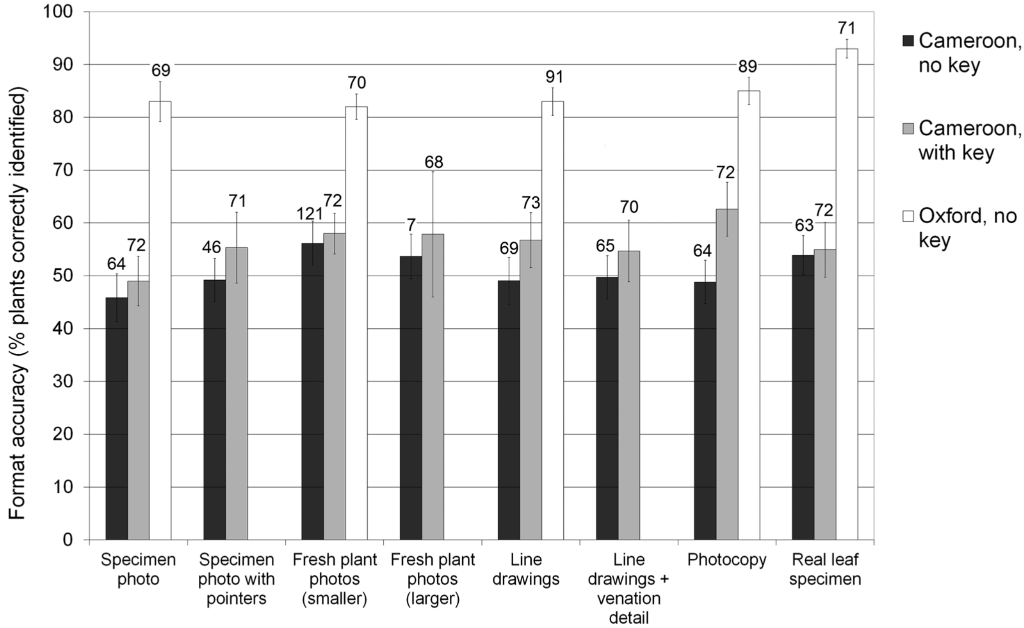

Figure 1. Species identification accuracy with the 8 illustration formats tested in Cameroon with local respondents in Cameroon and with specialists in Oxford with no previous experience with Cameroonian Cola species (error bars, 95% CI; number above bars, number of respondents).

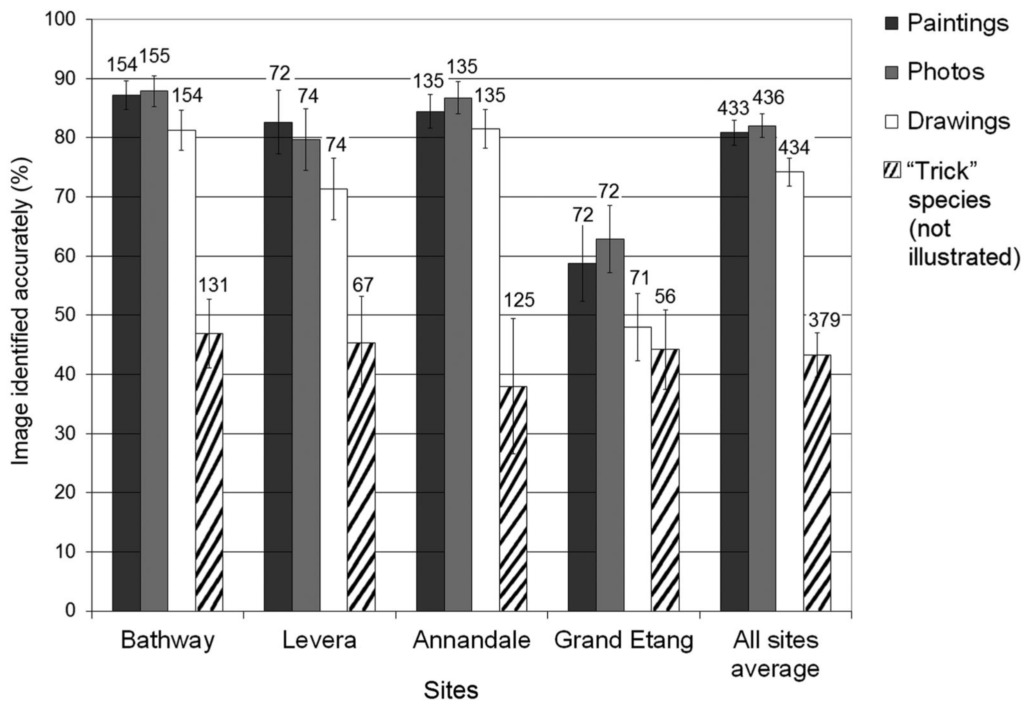

Figure 2. Species identification accuracy of the 3 illustration formats tested at 4 sites in Grenada (error bars, 95% CI; numbers above bars, number of respondents).

of error was an inability to identify a non-*Cola* specimen that looked like *C. nitida* (juvenile *Diogoa zenkeri*, Olacaceae). The format that gave the highest identification accuracy was the actual specimen (i.e., comparing laminated dried leaf material with other dried leaf material) and provided for significantly more accurate identification (93%) than any illustrated format.

In Grenada, accuracy was higher overall than in Cameroon. Differences in accuracy between sites were marked; montane forest species at Grand Etang were

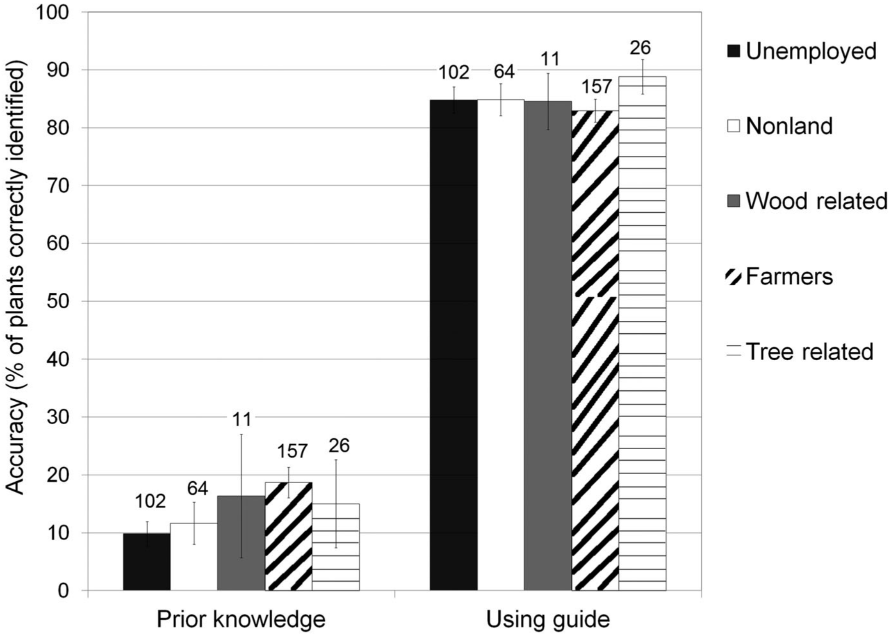

Figure 3. Accuracy of plant species identification using prior knowledge and the field guides at sites in Ghana with respondents from different professions (error bars, 95% CI; number above bars, number of respondents; nonland, those with employment not directly related to land or plants; wood related, those who work with wood including carvers and saw millers; tree related, those who work as tree spotters for timber companies).

significantly harder to identify accurately. The most remarkable feature, as in Cameroon, was the similarity in accuracy scores between formats, rather than their differences. Photographs and paintings performed similarly well at all sites, but averaged across all sites drawings performed significantly worse than photos (accuracy was 7.8% lower, $P < 0.0001$) or paintings (accuracy was 6.65% lower, $P < 0.0001$)—slight albeit significant differences (Fig. 2). As in the Cameroonian trials, the false-positive identification was a common pitfall. Plants missing from the guides were identified as such in 43% of encounters (averaged across all sites).

In identification trials in Ghana, the 2 different sizes of guides were not significantly different in accuracy overall. Due to the limited differences between them (both showed the same photos, but one on a page half the size of the other), we grouped them for analysis. Both performed well for such a difficult subject, providing 83–89% accuracy (Fig. 3). As in Cameroon, there were no significant differences in accuracy between male and female respondents or between younger (<23 years) and older (>23 years) respondents. Tree spotters for logging companies performed significantly better than farmers with the guides ($P = 0.0240$), and farmers named significantly more species beforehand than respondents who did not have land-related employment ($P = 0.0039$) or who were unemployed ($P < 0.0001$) (Fig. 3).

Subjective Valuations

In Cameroon, the 2 sizes of living plant photos were ranked first and second for usability and beauty (Table 2). Of all the formats, respondents said they would pay the most (price in Table 2) for the smaller living plant photos, which included more photos per page. In Oxford, this format was middling (third of 5) for all criteria. Oxford respondents thought the specimen photos were the most beautiful and the most usable, and they were willing to pay the most for this format, although their accuracy with them was middling (83%). The most accurate format (herbarium specimens) was ranked as least attractive. Drawings and black and white photocopies were ranked as the bottom 2 formats (summing across all criteria) in Cameroon; the same photocopies were also the least preferred format in Oxford across all criteria; drawings were ranked in the middle.

From best to worst, the order of preference in Grenada for both usability and attractiveness was photographs, paintings, and drawings. Drawings were also the least accurate format. Tourists were prepared to pay much more than the local secondary school students and more advanced local students and more than other Grenadians (data not presented).

In Ghana, the larger format photos were judged most beautiful but less useable than the smaller format. Respondents said they would be willing to pay more for the larger format photos.

Discussion

We tested a cross-section of the species groups, vegetation types, and potential users of tropical forest plant guides, emphasizing nonspecialists in tropical forest. A large majority of the focal specimens were not fertile at the time.

Prior knowledge of the plant species in our trials was generally low. In most cases, our respondents thought

Table 2. Results of subjective valuations of field guide formats (ranking) at the 4 field trial sites.[a]

Country	Image type	Usability (0–4)[b]	Usability rank (highest rank-possible)[c]	Beauty (0–4)[b]	Beauty rank (highest rank-possible)[c]	Price (local-currencies)[d]	Price rank (highest rank-possible)[c]
Cameroon	actual specimen	2.96	3 (8)	2.99	4 (8)	2839.00	5 (8)
Cameroon	drawings	2.71	7 (8)	2.77	8 (8)	3037.00	4 (8)
Cameroon	drawings with venation	2.90	5 (8)	2.91	6 (8)	2754.00	6 (8)
Cameroon	living plant photos (large)	3.18	1 (8)	3.26	2 (8)	2131.00	8 (8)
Cameroon	living plant photos (small)	3.08	2 (8)	3.45	1 (8)	3511.00	1 (8)
Cameroon	photocopy	2.91	4 (8)	2.89	7 (8)	2679.00	7 (8)
Cameroon	specimen photo	2.59	8 (8)	2.96	5 (8)	3218.00	3 (8)
Cameroon	specimen photo, annotated	2.85	6 (8)	3.17	3 (8)	3332.00	2 (8)
United Kingdom	actual specimen	2.67	2 (5)	1.33	5 (5)	20.00	4 (5)
United Kingdom	drawings	2.44	4 (5)	3.00	2 (5)	24.44	2 (5)
United Kingdom	living plant photos (small)	2.50	3 (5)	2.88	3 (5)	21.25	3 (5)
United Kingdom	photocopy	2.43	5 (5)	1.57	4 (5)	14.30	5 (5)
United Kingdom	specimen photo	3.13	1 (5)	3.13	1 (5)	25.63	1 (5)
Grenada	drawings	2.81	3 (3)	2.21	3 (3)	29.26	3 (3)
Grenada	living plant photos	3.28	1 (3)	3.55	1 (3)	40.61	2 (3)
Grenada	paintings	3.00	2 (3)	3.39	2 (3)	43.58	1 (3)
Ghana	living plant photos (large)	3.29	2 (2)	3.40	1 (2)	66,727.00	1 (2)
Ghana	living plant photos (small)	3.35	1 (2)	3.17	2 (2)	51,928.00	2 (3)

[a] *Rankings for each result are given within the country of testing.*
[b] *Usability and beauty scores are from 0 (lowest) to 4 (highest).*
[c] *Usability, beauty, and price ranks are calculated within each site, where, for example, 1(8) is the top ranked format of the 8 formats tested in Cameroon.*
[d] *Prices are given in local currencies as they were at the time of the trials.*

they knew less than 22% of the plants in the test areas before they started. A very few people (e.g., 15 of 384 in Ghana), professional tree spotters or parataxonomists, gave a prior name for 75% or more of their species. Even if communities were to rely on such experts, and a reliable dictionary of local-scientific name equivalents was available, our evidence suggests these practitioners would still perform less well than a typical villager with a field guide and no prior experience. This emphasizes the need for more working field guides, if rural communities in our test areas are to participate fully in forest management and if accurate and replicable identifications are to be made.

With pictures and use of carefully selected key characters and formats for illustration, our results suggest that a typical user might attain 70–95% accuracy across all species in lowland, tropical forest vegetation. Some of our enthusiastic respondents reached this level from a foundation of no prior knowledge on the same day. Although a 5% error rate might still be unacceptable for some purposes, 95% is a reasonable accuracy for professional forest inventories of trees in the tropics. We expect this would be achieved by many users with field guides as their only taxonomic resource, patience, practice and especially with some feedback and correction from experts.

Others have compared identification accuracy with traditional identification materials. One study conducted in the United Kingdom estimates overall misidentification rates to be 5.9% at the species level, with much higher inaccuracy (25.6%) for less experienced botanists (Scott & Hallam 2003). Ahrends et al. (2011) found that less experienced botanists recorded fewer species overall and fewer rare species in the Eastern Arc mountains. They quote "certain" misidentification rates of <1%, which is very low, and nonidentification rates of 11%. Greater accuracy was associated with access to a herbarium. Our own experience of misidentification rates is closer to Scott and Hallam's (2003) estimate; our experienced botanists misidentified circa 7–17% of specimens. This is likely to be because identifications were made without a technical key.

Difficult-to-identify species remained difficult to identify regardless of format, whereas easy-to-identify species could be matched with almost any format. For difficult-to-identify vegetation, for instance, montane thickets dominated by sterile Myrtaceae and Melastomataceae, or for difficult-to-identify groups like sterile *Cola*, the accuracy obtained by browsing pictures alone fell below 50%. Difficult-to-identify groups often include species of conservation concern that look similar to more common species. It seems that for these, experience and dedication to longer term learning with a comprehensive technical guide, collection of specimens, and visits to the local herbarium remains necessary. This is true for field identification in general, which typically relies on sterile identification because few species may be fertile at any time. Most people consider fertile material considerably easier to identify, at least in the herbarium (Rejmánek & Brewer 2001). We recommend that field guide authors explicitly indicate where specialist identification, fertile material, or a visit to a herbarium is likely to be necessary for a species because our results showed that some species will always be hard to identify from illustrations alone, particularly when sterile.

Generally, different image formats made little difference to the accuracy of identification trials. There were some differences. For example, in Oxford accuracy was highest when laminated guide specimens were used to identify the trial specimens, and in Cameroon accuracy was highest when photos of living plants were used to identify living plants. This suggests that different formats are appropriate for different functions, even if accuracy alone is considered, although the ultimate difference in performance may be a matter of only a few percentage points. We therefore recommend that authors adopt the illustration format that is easiest or cheapest for them because the benefit of having a field guide illustrated in any format easily outstrips relying on prior knowledge; however, matching the guide format to the likely use of the guide could yield small improvements in accuracy.

Ease of production is an important factor when planning a field guide. Digital photography facilitates illustration, and one author can expect to produce 1 or 2 species pages per day with this technique (Hawthorne & Wise 2006). This is the format most appreciated by the general public in our test areas and did not yield remarkably less (or more) accuracy than other formats. Drawings were universally less successful than other formats. We think this is because they were not in color. Black and white photocopies were also unpopular, but (color) paintings produced by the same artist performed similarly to photos. In their favor, line drawings can be made from herbarium specimens without new field visits, and black and white reproduction will keep printing costs low. Also, more drawings can be packed on a page than photographs, especially if the artist designs the page. In Grenada, the greater price (about 40% more) that our respondents said they would pay for the colored formats would not normally cover the greater cost of printing full color (300% or more). We therefore recommend guides be illustrated in color, unless users are experienced at interpreting black and white images (our results showed that specialists in Oxford did not perform any worse with drawings and also ranked them as quite attractive) or if low production cost (e.g., in printed books) is obligatory.

The high levels of false-positive errors in all our trials revealed a strong inclination for people to match a plant to the most similar answer in a guide, even when they know some species are missing. We recommend producing field guides which include all or at least a high proportion of species likely to be found in an area to minimize false positives, even if this means defining a narrower, focal species group than would otherwise have been covered. If this is not possible, it is essential to indicate where confusable species are missing from a guide. Including many more descriptive details than may seem strictly necessary for species in a guide will help to introduce doubt and reduce false positives. It is also important to note when a microscope and a trip to a herbarium might be needed. Otherwise, by recognition of macroscopic characters alone, even the most experienced botanists will be misled.

Mention of essential plant details and basic keys improved accuracy a little (<5%) for the nonspecialists, but not significantly, except for photocopies in Cameroon. Details in keys and text can help experts or dedicated enthusiasts greatly when carefully written, but our results show that these improvements did not favour nonbotanists to the same degree. Botanists, on the other hand, could already interpret illustrations much more reliably than nonexperts.

We believe our results provide clearer information on the potential and limitations of the use of field guides and nonspecialists in the conservation of tropical forests. Field guides will never solve all field identification problems, but they can greatly facilitate field work and communication about species. Field guides should be planned in conjunction with training courses on how to use the guides to avoid common mistakes, selection and encouragement of the most enthusiastic learners, and follow up training in collection of specimens and herbarium identification.

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Supporting Information

Examples of the field guide material tested (Appendix S1) are available on-line. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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