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How citizen scientists contribute to monitor protected areas thanks to automatic plant identification tools

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Abstract

1. Successful monitoring and management of plant resources worldwide needs the involvement of civil society to support natural reserve managers. Because it is difficult to correctly and quickly identify plant species for non-specialists, the development of recent techniques based on automatic visual identification should facilitate and increase public engagement in citizen science initiatives.

2. Automatic identification platforms are new to most citizen scientists and land managers. Pl@ntNet is such a platform, available since 2013 on web and mobile environments, and now included in several workflows such as invasive alien species management, endemic species monitoring, educational activities and eco-tourism practices. The successful development of such platforms needs to identify their strengths and weaknesses in order to improve and facilitate their use in all aspects of ecosystem management.

3. Here we present two Pl@ntNet citizen science initiatives used by conservation practitioners in Europe (France) and Africa (Kenya). We discuss various perspectives, including benefits and limitations. Based on the experiences of field managers, we formulate several recommendations for future initiatives. The recommendations are aimed at a diverse group of conservation managers and citizen science practitioners.

KEYWORDS
artificial intelligence, automatic plant identification, citizen science, deep learning technologies, opportunistic data, plant biodiversity monitoring, public engagement, volunteers

1 | INTRODUCTION

The emergence of citizen science in biodiversity monitoring over the past decade has transformed the methods by which biodiversity surveys can be conducted (Chandler et al., 2017). Citizen science has a considerable potential for increasing contributions for both 'data quantity' and 'number of contributors' to global biodiversity monitoring, if a long -term partnership between scientists and citizens is established

(Pocock et al., 2018). Recent citizen science programmes have mostly been based on digital tools and platforms, which enable the management of a broad community of participants. These platforms offer a way to share protocols and objectives, structure participants' contributions and facilitate exchanges both of data and of points of views (Newman, Graham, Crall, & Laituri, 2011; Preece, 2016). Apart from providing new tools and ways to involve citizens into research programmes, the platforms have the potential to support the participation of citizens to conservation and management actions. Indeed, managers of endangered species and protected areas face the need to collect large amounts of data with limited means and workforce. In addition, the public is not often aware of the objectives and activities of managers. The new platforms and digital tools used for citizen sciences have the potential to support the activities of managers and to increase the awareness of visiting citizens.

Identifying plants is often challenging for practitioners, and even more often for citizens. Several hundreds to thousands of different plant species can coexist in restricted geographical areas, making it difficult for non-specialists to identify and monitor them. Inventories are still essential for characterizing natural habitats (e.g. Corine Biotope, or Natura 2000 for European countries), and consequently for the conservation of associated animal species. The identification problem has long hindered the development of citizen science programmes for monitoring a large number of plant taxa. Overcoming the issue requires (i) developing a computational framework for automatic identification, (ii) acquiring initial training data for efficient automated identification and (iii) building platforms and databases collecting large quantities of observations to meet the multiple needs in this respect. This explains recent investment in computer techniques (Christin, Hervet, & Lecomte, 2019; Wäldchen & Mäder, 2018) based on artificial intelligence and deep learning technologies, in particular.

The search for high-performance methods to identify species by image, in order to support citizen science actions, is a recent field of research pursued by computer research teams (Ceccaroni et al., 2019), particularly within the framework of the LifeCLEF international scientific forum (Joly et al., 2019). The plant identification task of this forum involves dozens of teams around the world, which use datasets made available every year since 2011. Annual overviews of this task are available in the following publications: Goëau et al. (2011), (2012), (2013b), (2014), (2015), (2016), (2017), (2018) and (2019b). Developing operational platforms relying on these methods still represents a real challenge due to the large expectations to which they are subject, for their identification performances in particular. In order to increase the involvement of managers of natural areas in these platforms, to enable citizen scientists to benefit more widely from them and to increase their contribution to the activities of these managers, we present and discuss here two case studies using one of the most widely used citizen science platforms worldwide (i.e. the Pl@ntNet platform[1] (Affouard, Lombardo, Goeau, Bonnet, & Joly, 2017), in different environmental and socio-cultural contexts. The first case study addresses the use of Pl@ntNet for monitoring plant biodiversity in a nature reserve in Western, temperate Europe, where access to mobile technologies is widespread. In this nature reserve, the volume of animal occurrences recorded by the managers is more than ten times higher than that of plants, that is 64,000 animal records and 6,000 plant records. The second concerns the monitoring of flora in a nature reserve in tropical East Africa, with more limited access to web and mobile technologies. This nature reserve is mainly known for the richness and diversity of its fauna. These case studies illustrate the diversity of interactions between natural land managers and citizens (as presented in Figure 1), as well as part of the expectations of the actors involved. Since we anticipate the increasing use of mobile apps like Pl@ntNet for biodiversity monitoring, such as for early invasive alien species detection as described by Johnson, Mader, Dasgupta, and Kumar (2020), we underline the need to clearly identify obstacles and ways forward for beneficial interactions between practitioners and citizen scientists. This article aims to share the perception of automated identification tools by nature reserve managers, the modes of appropriation they have and the recommendations they would like to share to increase their capacity to involve citizens in conservation initiatives. We believe that sharing these experiences will improve the discussions between managers of natural areas on the benefits and limits of these tools.

2 | CONTEXTS

2.1 | The Pl@ntNet platform

Pl@ntNet[2] is a participatory research and educational platform for producing, aggregating and disseminating botanical observations. Initiated in 2009, it is based on a web and mobile computational infrastructure, allowing the identification of plants by means of automatic visual recognition. The public version of this platform covers plants from all continents (America, Europe, Africa, Asia, Oceania). Identification performance depends on the volume and quality of visual data used for training the deep learning model of the identification service. Identification performance of Pl@ntNet is not a central topic of this article, but it is important to note that it is a major concern in the development of the platform. In particular, several performance indicators are computed each time the deep learning model is updated. Therefore, three validation image datasets have been created, one related to the French Alpine flora, one related to the English flora, and a third one related to Mediterranean herbs. At the time of writing the accuracy measured for the first five species proposed for each image of these test sets ranges from 89% for the English flora to 63% for the most difficult dataset (i.e. the Mediterranean herbs). The identification service is updated monthly based on new data produced, shared and validated by the network of participants (i.e. users who have created an account and become members of the community). Pl@ntNet mainly concerns wild plants (i.e. propagating spontaneously in the natural environment)

[1] The Pl@ntNet platform has been used every month by 1 to 4.5 million people since the beginning of 2020, on all continents except Antarctica.

[2] https://plantnet.org/.

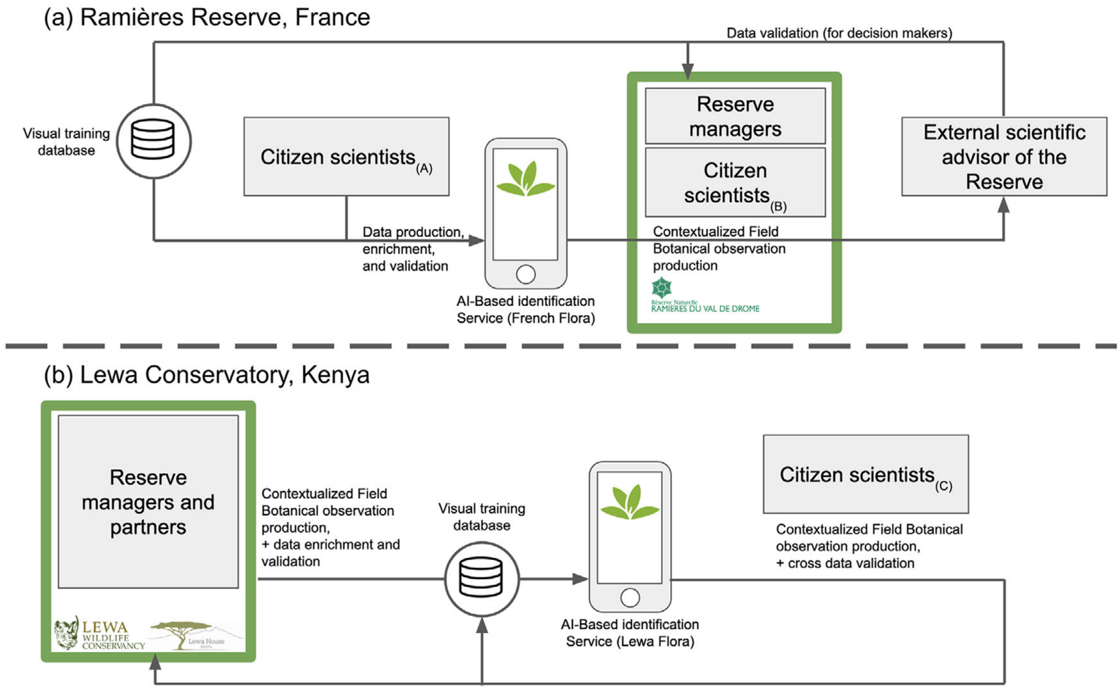

FIGURE 1 Data acquisition and management workflow implemented in the two analysed case studies. (a) In the Ramières Reserve, pioneer citizen scientists (i.e. Citizen scientist$_{(A)}$) have provided a large volume of visual data to allow accurate automatic identification by reserve managers and local citizen scientists (i.e. Citizen scientist$_{(B)}$), which yields reliable observation data. In this case, pioneer citizen scientists did not use Pl@ntNet restricted to a reference local plant list, but designed for all French flora. The data provided have, however, made it possible to improve the identification of the species present in the reserve. The observations produced in the Ramières Reserve are shared with the external scientific advisor for validation. (b) For the Lewa Conservatory, the Lewa House and the Lewa Conservancy have contextualized a Pl@ntNet platform restricted to a reference species list and have produced a large amount of observations (more than 3,500 observations) to initiate the automatic identification service on Lewa flora. This context-specific platform is used by the Lewa managers, its partners and visitors (Citizen scientist$_{(C)}$) to improve the volume of data on, and knowledge of local flora

but also cultivated plants (of agronomic and horticultural interest). The visibility and use of this platform has accelerated since February 2013, after deployment on mobile devices (iOS in 2013 (Goëau et al., 2013a), and Android in 2014 (Goëau et al., 2014a)). Since 2013, the number of daily users has doubled every year, reaching more than 150,000 users per day at some peaks in 2019. In total, more than 16 million people (among which 1.7 million have created a user account) have used the application worldwide (available in 24 languages). Open access, stability over time, continuous improvement and accessibility without personal authentication have contributed to the popularity of the tool. Citizen scientists have contributed in many different ways (e.g. by producing and curating data, providing training) to adapt the platform to specific needs (such as monitoring endemic species of New Caledonia, weed species of Western Europe and invasive alien plant species worldwide; Botella, Joly, Bonnet, Monestiez, & Munoz, 2018).

2.2 | The Ramières Reserve, France

Pl@ntNet identification performances are currently best-suited for the flora in Western Europe, largely thanks to the numerous networks of amateur naturalists who have participated by producing, sharing and validating botanical observations. The involved citizen science networks, the largest being related to the Tela Botanica association,[3] have generated a great richness and diversity of visual data, providing a reliable tool for conservation professionals in the region. The Ramières Reserve[4] is a typical case presented here. The reserve, as illustrated in Figure 2, has chosen to use Pl@ntNet to increase inventory capacities. Not all managers of this natural reserve are plant specialists, and Pl@ntNet was used initially (i) to generate field observations with a preliminary automatic identification and (ii) secondly, to encourage the production and sharing of observations by visitors of the reserve. The reserve is freely accessible and received more than 50,000 visitors per year. As illustrated in Figure 1, the reserve managers benefited from the fully public Pl@ntNet platform (i.e. not a context-specific version), already enriched by contributions (i.e. illustrated botanical observations) of citizens who participated in building the initial identification service. Reserve employees have produced 1,390 observations, after initial contributions from citizens, for more than 460 species with the platform. Managers are thus downstream from the involvement of participants from civil society on this platform.

[3] The Association of Francophone Botanists, https://www.tela-botanica.org/.
[4] A natural river space of 371 ha, hosting more than 700 plant species, located along the French river, Drôme, and protected since 1987.

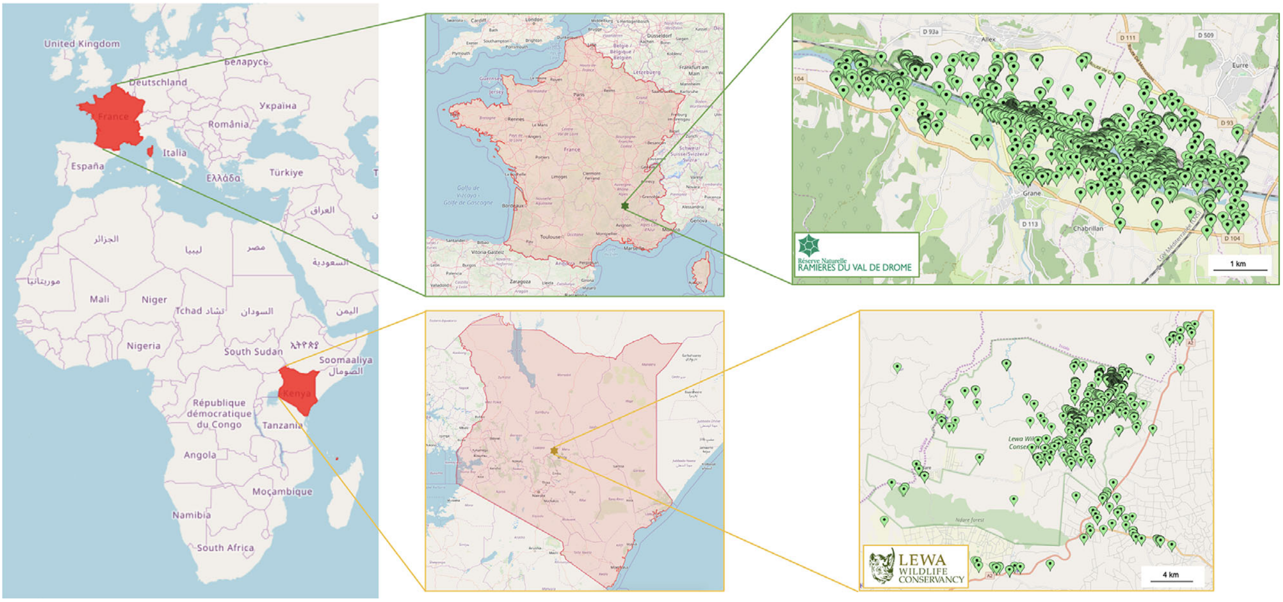

FIGURE 2 Location of (a) the Ramières Reserve and (b) the Lewa Conservatory. On the left, France and Kenya are highlighted in red on European and African continents. In the middle, a yellow star locates the Lewa Conservatory, and a red star the Ramières Reserve. On the right, we can see all geo-localized identification requests submitted to Pl@ntNet platform in the perimeter of each reserve (5,051 identification requests for the Ramières Reserve, and 5,107 identification requests for the Lewa Conservatory)

2.3 | The Lewa Conservatory, Kenya

The Pl@ntNet platform can be customized to work on a specific list of species, for a particular region, a specific taxonomic group or a type of plant use. The selection of the specific flora can be done automatically according to the geo-location in cases where it is relevant. Contextualization greatly improves the performance of the identification service, since the species provided in the results should belong to a reference list defined by the land managers. The Kenyan nature reserves of Lewa[5] and Lewa House[6] have invested in such contextualization. Unlike the Ramières Reserve, a context-dependent version of Pl@ntNet was thus developed for the Lewa Conservatory in order (i) to increase visitor interest for the rich flora (more than 600 plant species) and (ii) to increase the volume of plant occurrence records available for analysis of species distributions within the park. The available visual data on this flora were much less numerous than for the flora of the Ramières Reserve, so that the Lewa organizations invested time to provide enough initial visual data for training identification by the Pl@ntNet platform. The production and validation of visual data contributed a lot to improve the identification performances of the application for the selected species. Apart from providing useful data, involving visitors in identifying plants fulfils an educational objective. Attention given to plants should draw attention to the diversity and role of flora for ecosystem health. As the performance of identification is improved with more and more data, a positive feedback is expected, as both practitioners and visitors should be happy to get accurate answers and will increasingly use the app. In addition, the tool should serve for the training of visiting students hosted by the nature reserve. Many of them are from countries far away from the Lewa Conservatory and focus often on 'target' mammal species, without local botanical knowledge. Therefore, it is anticipated that Pl@ntNet will contribute to improve the interest and quality of local education and research.

3 | METHODS

In order to encourage the involvement of a large number of citizen scientists, the Ramières Reserve and the Lewa Conservatory have developed distinct communication strategies, which are described below.

The Ramières Reserve used two complementary communication channels. The first one is the dissemination of a broad-audience article of a few pages, distributed through the magazine 'Nature Drômoise',[7] a seasonal magazine of a local environmentalist association. The objective was to present the implemented approach, the first results obtained, and the expectations of the managers of the reserve. The second communication channel was through oral communications within the framework of national conferences. One of them, during the 38th National Meeting of French Natural Reserves, aimed to raise awareness among managers of the benefit of new tools and methods in citizen science. In particular, a major aim was to facilitate the exchange of data between associative structures, such as those of Tela Botanica and Pl@ntNet, and public platforms, in the long-term.

[5] The Kenyan nature reserve is a UNESCO World Heritage natural site, located in the north of Mount Kenya, home to a wide variety of wildlife, including rare and endangered species of large mammals, such as the black rhino and Grevy's zebras. https://www.lewa.org/

[6] The Lewa House is an eco-lodge located in the heart of the Lewa Conservatory and working closely with it, designed to host visitors site. https://lewahouse.com/

[7] https://frapnadrome.org/notre-revue/

In order to create awareness, the Lewa Conservatory produced an eye-catching leaflet made available in lodges and various offices around the nature reserve, to communicate and encourage guests and people living and working within the Lewa Conservatory to take part in the citizen science project. Practical training sessions were organized to train field officers using the app. Meetings with partners of the nature reserve were also organized, such as the Northern Rangelands Trust[8] and the Ngare Ndare Forest Trust[9] (local community conservancy membership organizations), in order to foster exchanges on the limits and potential benefits of using a context-specific version of Pl@ntNet for local stakeholders involved in development and nature preservation. Already since initiating this project in 2019, this context-specific version of the app has focused attention on plants within the Lewa community and many of the species that have been recorded were not on the original reference list. Therefore, the list for the nature reserve will be updated with new species on an annual basis.

4 | DISCUSSION AND RECOMMENDATIONS

New citizen science platforms can greatly help environmental managers in their tasks of management and the protection of fauna and flora. However, the use of such new tools is inevitably hampered by difficulties and sometimes scepticism among the actors involved. Based on the results obtained in the Ramières Reserve and Lewa Conservatory, we present and discuss here the main benefits and obstacles encountered by the actors.

4.1 | Communication

Communication is a key factor in the success of citizen science initiatives (Constant & Roberts, 2017). Involving citizens in participatory science approaches requires effective communication, adapted to the objectives of research and conservation programmes, developed within a particular territory. Communication must be targeted, in terms of format, channels of dissemination and information content.

Early sharing of the objectives of the citizen science programme is essential to facilitate the involvement of participants. In the case of the Ramières initiative, sharing and analysing data collected with an external scientific advisor from the *Conservatoire Botanique National Alpin* was the first objective. It required setting up an export mechanism to facilitate this process, without which the data produced by the reserve managers cannot be valued. In order to meet this need, a data export mechanism has been developed on the web version of Pl@ntNet, allowing each manager to extract and share their records with their partners. In the case of Lewa Conservatory, the multi-lingual and multi-platform of the Pl@ntNet app improved accessibility for a broad range of potential participants.

[8] https://www.nrt-kenya.org/
[9] http://www.ngarendare.org/

4.2 | Data quality and validation

Appropriate evaluation and validation methods must be designed to ensure the satisfactory quality of the data produced and used by managers (Kosmala, Wiggins, Swanson, & Simmons, 2016). To improve data quality in citizen science programmes, it is essential to make understanding of the evaluation and validation processes easier for citizens and to design an appropriate computational interface (Sharma, Colucci-Gray, Siddharthan, Comont, & Van der Wal, 2019). Indeed, one potentially important task for volunteers that is likely to generate errors is the identification of organisms to species level (Ratnieks et al., 2016). In the case of Pl@ntNet, validation covers both the visual quality of the images and the reliability of taxonomic determination. All images and public observations visible on the platform can thus be evaluated by any user with a user account. User votes are weighted with a score assigned to each user, and the daily score of a particular user is estimated on the basis of the number of species with validated observations of this user. The validation of an observation is effective when the score of an image of this observation exceeds a fixed threshold. This validation allows selecting the more reliable observations for training and improving deep learning models used for species identification, as well as to provide more definitive maps. Evaluation of data quality is a dynamic process, which allows quality to be reviewed on an ongoing basis, by all authenticated platform participants (experts as well as novices). A validated observation can thus be invalidated at a later date, if there is any doubt. It is important for all participants to understand how human resources and expertise are invested to validate the data produced. This facilitates trust in the methodology. The real-time operation of the platform, which instantly allows all users to view a shared observation, reduces data evaluation time and helps to ensure rapid feedback to participants. Furthermore, depending on the data use objectives, data can be processed in such a way as to guarantee its relevance according to a given objective (e.g. measure of observer expertise, computed on the average numbers of species recorded by observers in a specific area, can be used to improve the predictive performance of single-species occupancy models; Johnston, Fink, Hochachka, & Kelling, 2018). A clear and transparent validation process is thus an essential step to maintain the motivation of citizen participants and to maintain a good collaborative dynamism. This is even more critical in areas of rich biodiversity, where conservation issues are important but where the volume of visual data available is low.

4.3 | Acknowledging the motivation of participants

Identifying the expectations of citizen participants is essential to increase their engagement. The expectations can be characterized by comments on app stores (tens of thousands in the case of Pl@ntNet), email/messages received, questionnaires produced beforehand or individual or group interviews. In the framework of Pl@ntNet, sharing as much local data and knowledge as possible, such as common names, local plant uses and ecology helps boost the benefits to, and motivation of, the participants. The early identification of benefits for all participants (managers, citizens, researchers, decision-makers, etc.) avoids potential disappointment and decreasing participation. In this regard, it is important to provide appropriate communication tools to participants to support social learning, community building and sharing (Jennett et al., 2016). For instance, a 'WhatsApp' plant group was considered for the Lewa Conservatory, in order to increase knowledge exchanges between the most involved participants, and to confirm species identifications. The implementation of continuous improvement methods, illustrated in Pl@ntNet by a regular update of the identification system based on validated observations, makes it possible to stimulate participation, and thus ensure increasing overall performance of the citizen science programme. The observation process, which is based on opportunistic data collection by citizen scientists, leads to heterogeneous, non-random sampling and spatial correlations in the data. In order to allow the use of this data for species distribution modelling, specific statistical methods must be implemented to resolve the biases related to the data collection process (Botella, Joly, Monestiez, Bonnet, & Munoz, 2020).

4.4 | Open data policy

Quite surprisingly, the use of data from citizen scientists in research activities is sometimes very restricted (Groom, Weatherdon, & Geijzendorffer, 2017). This is why within the Pl@ntNet free platform, a Creative commons license (more precisely, cc-by-sa[10]) was chosen, facilitating the sharing and recognition of any contribution. Even if the cc-by-sa license is one of the most open, since it authorizes the sharing, modification and commercial use of this data, it imposes a strong constraint because derivative works can only be shared under a license identical to that of the original work. This may be a constraint for some scientific works requiring a change of license. However, partners can choose an alternative license in order to use data previously acquired by the partners under a different license. The use of this license is a strong motivating factor for the participation of many people. It is also a critical aspect for both managers (who make visual data available for improving the identification service) and the citizen participants (who produce observations in the framework of the programme). In addition, there should be a good balance between producing high-quality data, with precise localization for example, and ensuring that participants' personal data are well protected (Anhalt-Depies, Stenglein, Zuckerberg, Townsend, & Rissman, 2019).

4.5 | Technological constraints

It is important to be able to efficiently handle the application workload on the server side via a scalable and secure IT infrastructure. As this type of infrastructure has a high cost, it seems essential to federate its use, typically through the provision of an API (application programming interface), which allows other platforms / apps to use it in their own workflows. As an example, the Pl@ntNet identification service is accessible throughout such API,[11] which has been tested by more than 780 users. Taking into account all the technological constraints of the context in which a citizen science programme is implemented is also crucial. Most existing programmes come from relatively industrialized countries, and the use of computational tools such as Pl@ntNet can be hampered in countries with less economic and technological advantages (Loos et al., 2015). Citizen science is still very relevant and useful in African countries where funding for monitoring by public employees is limited (Steger, Butt, & Hooten, 2017). In the framework of Pl@ntNet, it is important (i) to ensure good functioning of mobile applications on devices adapted to field activities and to work with less powerful devices; (ii) to identify participation methodologies that are free of some constraints (such as, e.g., the lack of 3G or Wifi coverage in areas managed by the managers). As part of Pl@ntNet, Lewa participants in isolated (unconnected) areas can produce correctly geo-located and dated observations in the field, and then share them when they return to their offices or guest houses. A preliminary assessment of the technological expectations and constraints thus made it possible to ensure a good appropriation of this platform in the contexts in which it was deployed.

5 | CONCLUSION

Nature reserves and conservatories are located in exceptionally biodiverse and often vulnerable areas. Visitors can greatly contribute to the monitoring and management objectives and become aware of the conservation issues. Citizen science platforms providing automatic identification can help increase such contributions and raise awareness, provided that the methods and objectives are well understood, and that some mechanisms facilitate evaluation and participation. Conservation practitioners can benefit from these platforms: (i) if they are committed to make data available and allow access and use by contributors and (ii) if they support computational development by ensuring that the diversity of participants' expectations is taken into account.

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[10] Creative Commons - Attribution - ShareAlike.

[11] https://my.plantnet.org/

AUTHORS' CONTRIBUTIONS

FM, AJ, P.B, MS and BD conceived the initial ideas and led the writing of the manuscript. AA and J-CL contributed to the development and maintenance of the Pl@ntNet platform. J-MF, SB., DK, LM and CV have implemented the Ramières and Lewa cases studies. Authors contributed critically to the drafts and are involved in social, technical and scientific development of the Pl@ntNet initiative.

DATA AVAILABILITY STATEMENT

Data have not been archived because this article does not contain data.

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