Phytotaxa 609 (1): 065–068
https://www.mapress.com/pt/

Correspondence

ISSN 1179-3155 (print edition)
PHYTOTAXA
ISSN 1179-3163 (online edition)

https://doi.org/10.11646/phytotaxa.609.1.6

Mind your app: Could plant ID applications lead to an increase in extinction risk?

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Since the introduction of the first smartphones, which benefit from innovative touch screen technology, the use of mobile devices for purposes beyond simple vocal communications has become a global phenomenon (Gillenwater 2017). Few enthusiasts abstain from smartphones, tablets, and social media. Education, of course, is immersed in this revolutionary era. Alongside laptops, phones and tablets are increasingly present in classrooms, becoming indispensable tools in many educational programs.

The impact and widespread adoption of these tools are progressively overcoming many barriers, even within the realm of botanical science. It is now common for online repositories and data portals (e.g., GBIF, GenBank, and Dryad) to allow access to tools and resources that were unimaginable 20–30 years ago. Botanical knowledge (plants that are useful, heal, harm, or kill) is inherently intertwined with the evolution of human societies. The process of plant identification entails associating a known plant taxon with a specific specimen, based on the specimen's distinctive attributes (Bridson & Forman 1992). Traditionally, plants have been identified using dichotomous keys. This specialized and time-consuming task demands meticulous examination and expertise due to the intricate nature of botanical terminology and the challenges posed by certain taxonomic traits (Wäldchen & Mäder 2018). In most projects, accurate plant identification contributes to an increase in working hours and total expenses (Guo & Gao 2017). Hence, proficiency in taxonomic training stands as an essential competence within most university-level biological and environmental studies. Students are confronted with problems to be solved (i.e., plant specimens), and through the application of identification keys, they eventually master the systematics methodology.

In recent years, several applications (apps) have emerged (e.g., Picture This, PlantNet, iNaturalist, Flora Incognita, or Google Lens); all designed to employ image recognition mechanisms and access digital databases, facilitating species identification through AI. This automatic recognition of plants has attracted numerous developers, contributing to the realm of citizen science by disseminating insights into the biological diversity within our cities and gardens. Certain investigations even posit that these apps have the potential to alleviate burdensome tasks and streamline identification processes, consequently enhancing efficiency (Guo & Gao 2017, Wäldchen & Mäder 2018), since AI algorithms can process vast amounts of plant images quickly, enabling rapid species identification and facilitating research and monitoring effort. Nevertheless, 21st century students, continuously connected, are acutely aware that species identification is a 'click' or two away in their smartphones, which will quickly solve their practical inquiries. However, relying on such apps may lead students to miss out on acquiring a comprehensive understanding of the differential morphological traits essential for taxonomical differentiation at the family and genus level. In addition, how reliable are those IDs? The limited number of studies addressing this concern suggest that not all identifications obtained through such apps can be considered entirely dependable.

Jones (2020) conducted an assessment of nine tools for the automated identification of British wild and naturalized species across various plant groups, underscoring the evident necessity for cross-validation of these IDs (either through expert verification or comparison with taxonomic literature). Bilyk *et al.* (2020) acknowledged the superior informativeness and practicality of PlantNet and Flora Incognita, although their precision lagged behind that of other evaluated approaches. In addition, some studies have revealed the challenges inherent in identifying species belonging to intricate taxonomic

Accepted by Robert Philipp Wagensommer: 7 Aug. 2023; published: 17 Aug. 2023

groups. For example, McMullin & Allen (2022) demonstrated that numerous lichen observations on iNaturalist suffer from misidentification or lack the indispensable microscopic information required for accurate identification. Consequently, a substantial number of inaccurately identified observations permeates global databases when apps and repositories are linked, requiring expert knowledge to detect and filter them for eventual downstream analyses.

Our recent studies (Martín-Escobar 2021, Sánchez-Romero 2022), based on the endemic flora of Andalusia, have shown that all the evaluated apps fail when identifying the most uncommon taxa. In general, in contexts involving common and ruderal species, the count of accurately identified specimens barely exceeded the number of mistakes. Notably, the apps falter in identifying rare and/or endemic taxa (Figure 1). Evidently, such apps heavily rely on their databases, which frequently lack entries for endemic taxa, yet consistently offer the most optimal identification match for each image. It would be fair to acknowledge that, at the genus and family levels, the results are usually reliable, thereby presenting a clear opportunity for employing these tools in citizen science and outreach activities. However, if not approached with due diligence, the resulting identifications could potentially lead to misunderstanding.

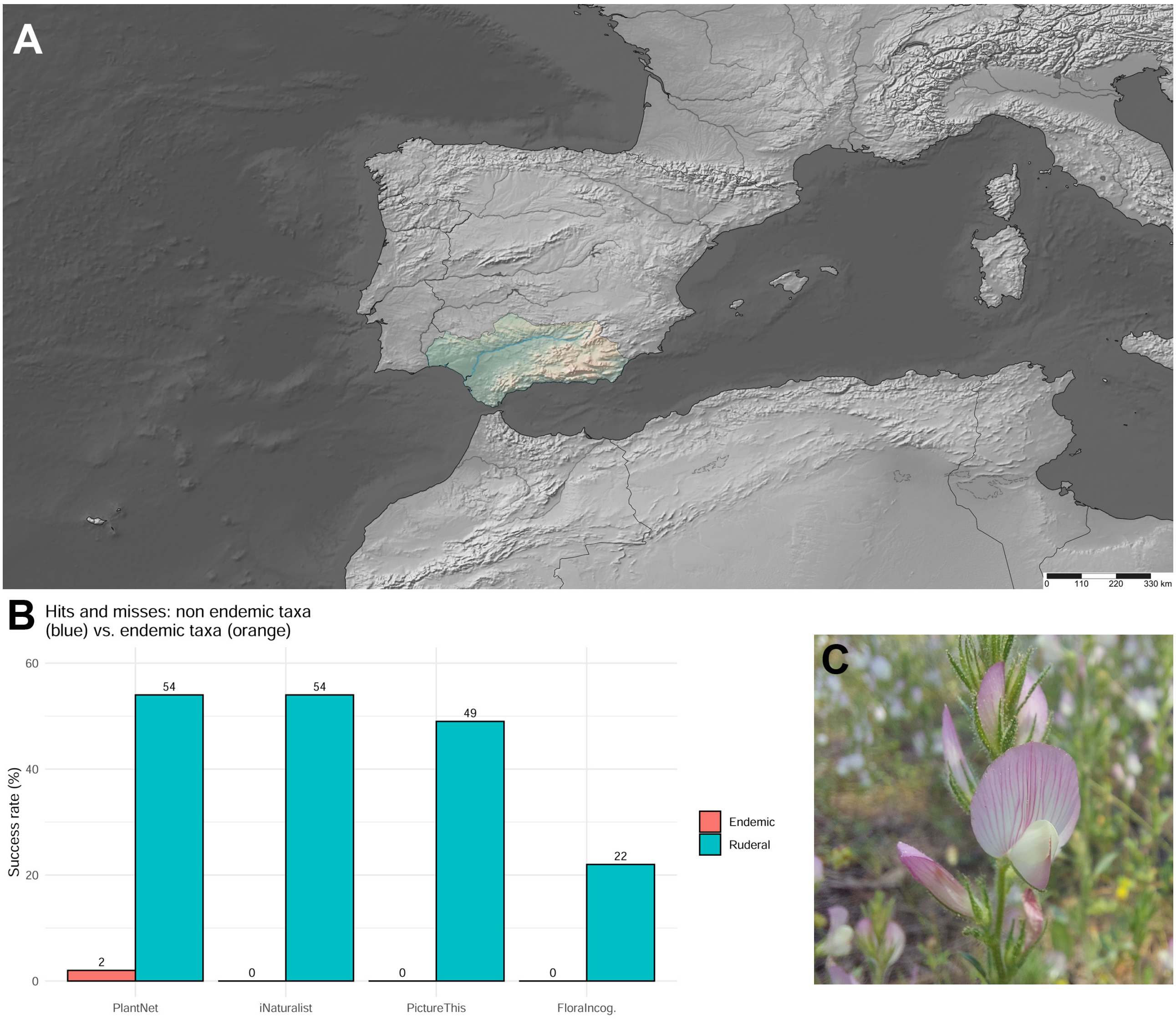

FIGURE 1. Plant ID applications performance in Andalusia (south Spain). (A) Study area by Sánchez-Romero (2022) (B) Percentage success rate for the apps analyzed. (C) *Ononis varelae* Devesa (1986: 84), an endemic Leguminosae taxon from the southwestern Iberian Peninsula, not correctly identified by any of the apps tested.

On one hand, traditional identification methods, unlike apps, are slower and require more attention from people interested in acquaint themselves with the surrounding flora (Jones 2020). These time-honored approaches commonly undergo validation and scrutiny, usually through peer review or exhaustive editorial procedures. On the other hand, apps can inadvertently instill a sense of unwarranted confidence among their users.

As plant identification apps continue to permeate wider audiences, their effect could simultaneously be a stimulation of botanical interest (Jones 2020) and a decrease in plant blindness (Balding & Williams 2016). However, the inherently user-friendliness of these apps might become a disincentive to gain deeper botanical knowledge (Jones 2020). Apps have arrived to stay; therefore, it is important to be cautious in their use, particularly within educational programs of aspiring biologists and related disciplines. Educators should be capable of transmitting to students that while apps for plant species identification offer utility, they are not infallible.

Apps, image recognition and artificial intelligence play a significant role in automatic identification tools and will inexorably continue to improve. It is undeniable that these tools will become increasingly sophisticated and effective, showing a great potential to revolutionize plant knowledge accessibility for ordinary citizens. However, the fact that these apps always provide a definitive response to the question "Which plant is this?" could endanger cryptic species, taxa yet to be formally described, or as previously noted, geographically restricted endemics.

Our students live in an online world, wherein these apps (along with many others to come) will stay in our pockets, while books grace the shelves of libraries. The potential detrimental effect is generally caused by the increasing time spent within our classrooms utilizing tools that feature cryptic scientific language, creating confusion and leading our students to erroneous outcomes, and frequently perpetuating outdated taxonomies. We need that our undergraduate students, being trained in the age of digital tools, to understand that completely replacing traditional identification protocols (i.e., studying herbarium specimens and the use of floras and specific taxonomic literature) could engender unreliable results, potentially leading to misidentification of endemic and/or endangered taxa. This would generate conflicts and problems in downstream measures that politicians and decision-makers will take and may lead to a higher biodiversity extinction risk that we should be aware of. For all these compelling reasons, we argue that such apps should proactively alert their users that their databases encompass only a fraction of the known diversity, that certain cryptic species pose challenges for differentiation by automatic image recognition, and that a large part of plant diversity is still unknown. Additionally, they should also flag how the IDs were obtained when uploading their findings to global databases (e.g., GBIF). More systematic and in-depth studies are required to further infer the future apps' effects in taxonomy and conservation.

Acknowledgments

We thank the Editors Zhi-Qiang Zhang and Robert P. Wagensommer for their work, and one anonymous reviewer for comments and discussion on the manuscript. This contribution is based on the BSc and MSc Theses by I.M.-E. and J.S.-R. (supervised by M.d.l.E. and D.N-L.). This work was supported by the DIVEREND project UCO-1380837R (Programa Operativo FEDER de Andalucía 2014-2020).

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