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eFlora: Future of Plant Taxonomy and Conservation

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ABSTRACT

In the age of digital transformation editing, retrieving and rendering data via a non-tedious way of just referring to an e-repository has become effortless. This paper highlights the importance of e-taxonomy repository specifically eFlora that have been developed across the world. eFlora is an internet based tool that has reduced our efforts of taxonomic identification and study steps via a consolidated database of biodiversity informatics. eFlora aims at developing a structured data of hierarchical plant kingdom classification through huge published taxonomic and floristic research data of biodiversity. A taxon can be easily linked with data illustrations in more than one flora with the help of automated data links. These floras are immensely helpful in maintaining a long term digital preservation of taxonomic data. The publication of research work of botanists has also become readily available on a single platform of eFlora. Moreover, sharing and inviting contributions from the world community of taxonomists has never been easier.

Key words *: eFlora, eTaxonomy. Herbarium, Biodiversity, Database*

Introduction

Technological advancements in scientific fields are proceeding at a very rapid rate in today's era. The Earth's biotic catalog is under construction, taking information from numerous databases and records from various floras, monographs and plant herbaria having enormous value for building our knowledge of plant distribution and diversity. It will help in identification and understanding providing solutions related to various problems like conservation of plant diversity. Flora is not only the description of plants of a particular area but also consists of keys, description for identification along with content on the distribution and ecology of these plants. Flora being a primary database acts as a basic tool for all the people who are involved in identifying the plants.

Research done in Systematics helps in monitoring the world's natural resources by accurate diagnoses, providing data and keys about phytodiversity. The increasing role of E-taxonomy, an Internet-based science related to the biodiversity informatics is an emerging tool available for the elaboration and dissemination of floristic information resulting in much simplicity in understanding minute details regarding flora. It enables a shift from the traditional Flora concept as a static, printed account to a dynamic and interactive format, allowing for rapid updating and multiple uses of information (Roos *et al.*, 2011). Taxonomic descriptions are very necessary for a complete scientific study of biodiversity.

A rapid recent development of mobile phone applications assists in plant identification, using automated image recognition gives us an edge over using traditional technology. Websites and applications operating on such technologies provide an easy to access platform which keeps updating with

advances in devices, languages, internet access capabilities. Botanical data can now be accessed at a faster rate which wasn't available years ago to researchers is now available a click away. The aim is not only to have an easily accessible record of species, but to cross-link different types of biodiversity data, like biogeography, climate data and phylogenetic information and also to introduce new technologies like GPS tracking and advanced imaging techniques (Zauner, 2009). Recently Digital floras or E-floras have been developed using information systems both online and offline data which is the major identifying source now for botanists providing opportunities for detailed comparison and analysis among different species. The centralized relative databases on different characteristics of plant provide ways to create various links to digital taxonomic databases making it further easier for studies. Variation in vegetative, reproductive characters and other structures of each taxon can be linked with illustrating data with the help of automated data links not only in one flora but also amongst different floras.

A complete listing of the world's known plant species has long been considered desirable but has remained a huge task. Increasing availability of large databases of biological information over the Internet has demonstrated many of the obstacles which can only be resolved by adoption of a Global Strategy for Plant conservation by an urgent need for a global plant checklist to support, facilitate and monitor the conservation and sustainable use of plant diversity worldwide (Lughadha, 2004). With all information available on a single platform of E-flora will lead to revolutionary potential for research and conservation of phytodiversity all over the world.

Digital Flora- A virtual modern tool for taxonomists

Extensive knowledge and complex terminology are required for plant identification which is a tedious job for professional taxonomists. Plant systematics is an unending synthesis because information keeps on adding from research in different disciplines which makes it difficult for identification and classification of plant groups. The discipline of taxonomy, especially nomenclature has immense value in studies of all areas of plant sciences therefore digital flora is a modern tool which makes easy availability of all taxonomic data for scientific database constructions and information derivation.

Advancements in today's internet regime lead to easy availability of plant information just one search away disseminate taxonomic information and paves way for overall requirement fulfillment. Therefore, modern tools need to be more standardized and more efficient for appropriate identification of different taxa for biodiversity management and conservation**.** Electronic flora provides databases for broad information on our local, common, wild, endangered, and vulnerable species to employ in research, education, cultivation, and conservation. e-floras are imperative to modernize taxonomy as E-taxonomy, where e-floras include detailed accounts on plant taxa including scientific names, description and also special features based on images and distribution maps showing evolution of species variable over time. Access to properly constructed and documented research data is essential for biologists. Software tools enhancing the productivity of taxonomists provide the results of their work in dynamic and customary formats which will greatly benefit not only the science but also the broader community (Kathirvelu, 2014). Digital flora is based on a software-based program consisting of digital images and browsing descriptions in the systematic format by which users can search online taxonomic data via family, genus, species, common name, and regional locations also.

By using a web interface, taxonomists with online authority can edit, correct, modify, and update the data. Plants identification by E-floras is majorly based on electronic or interactive keys which provide algorithms that detect variation in morphological characteristics depending on digitized electronic files for coloured images of various plants. Interactive keys consist of pictures and field guides including electronic data up to 2-4 hierarchical levels. There are different other types of keys like Indented key, bracketed keys, interactive key like Delta Int Key etc. which consists of HTML data linked amongst different taxa of same flora and same taxa in different flora. E-floras are unlike the traditional keys where it includes multi-access entry points and reduces the queries of the key couplet method via a predefined path. The software for eFlora contributes a broad range of applications consisting the maintenance of specimen records, phylogenetic analysis, biogeographic relations as well as ecological data. International projects like GBIF (Global Biodiversity Information Facility), EDIT (European Distributed

Institute of Taxonomy), Catalogue of Life, Encyclopedia of life, e-flora of India, share a common aim for sharing knowledge and giving free data access to Biodiversity Information.

Database Structure and Standards

Some well accepted key points followed by all researchers throughout the world are based on plant record identification group, collection group, location group, habitat group, additional data group, loan group, data entry and edit group while most of the digital databases only record the last accepted taxon data standardized the data at the time of data entry (Kathirvelu, 2014).

With extensive research and analysis some relevant herbarium development standards like HSPID I, II and III have been developed (Croft 1989; Conn 1996). Many authorities like ABRS (Australian Biological Resource Study), BGCS (Botanical Garden conservation secretariat), DSTI (Database standard for Taxonomic information), ICBN (International Code for Botanical Nomenclature) and TDWG (Taxonomic Database Working Group) has also described e-flora Database standards. Digital Databases are created with the help of many softwares like MS-access software, Oracle, Visual fox pro etc. which even helps in creating our own digital herbarium database (Kathirvelu, 2014). With more than 350,000 known plant species on earth makes it the most difficult task to identify (Botella *et al*., 2018). Therefore, a collaborative effort at international level has to be done to record all flora digitally. Another techniques which are helping to identify plants are some digital applications which are available free to use like Bing, Candide (Plant ID), Flora Incognita, iPlant Plant identifier, Plant Net, Plant Snapb, Seek (iNaturalist) and google lens which can be assessed by taxonomist to identify plants which ultimately supports in developing an efficient eFlora.

Another technique Convolutional Neural Networks (CNNs) which rely on vast numbers of training images helps in superior recognition and supports successful automated plant species identification (Boho *et al*, 2020). Some applications like Pl@ntNet also use CNN based image representations to make plant diversity available digitally (Affouard, 2017). The World Checklist of Vascular Plants (WCVP) is a broad list of scientifically described plant species, which is compiled from scientific databases, observations, peer-reviewed literature and various herbaria over four decades by experts to make eFlora available worldwide (Govaerts *et al.*, 2021).

International Scenario

According to Brach and Song (2006) many current flora projects provide online access to taxonomist like Flora of North America (Flora of North America Editorial Committee, 1993), Flora of Australia (Orchard and Thompson, 1999), Flora of China (Wu and Raven, 1994), Flora Europaea (Tutin *et al.*, 1993), Flora Mesoamericana (Davidse *et al.*, 1994–) and Flora Zambesiaca (Exell and Wild, 1960). Many international organizations like International Organisation of Plant Information (IOPI) working on Global Plant Checklist database project which will help to avoid the widely made error of oversimplification, loss in data accuracy and quality of taxonomic data (Berendsohn, 1997). e-Flora has become very popular amongst taxonomists because of the ease it provides to study enormous data on biodiversity. Many countries have published and made their e-flora freely available to all in the last few years. An interactive image-based plant identification system and collaborative workflow boosted by semi-automated annotation tools has helped to make 2200 plant species of France digitally available since May 2010 (Joly *et al.*, 2014).

The Australian Biological Resources Study (ABRS) includes an online database structure for digital flora of Australia having multi-volume publication. ABRS is presently checking their database structure and schema according to TDWG (International Union of Biological Sciences Taxonomic Databases Working Group) to meet the new standards organized by the international botanical community. Australia even has started maintaining its virtual herbaria and house over eight million specimens. A commendable effort has been done by many African countries in recording eFlora of their area. In south-central Africa 6 e-floras has been created of Botswana, Malawi, Mozambique, Zambia, Zimbabwe and Namibia and have recorded 2,877 native species in the database. E herbarium of Common plants of western desert of Egypt has also been created. Flora and plant communities of South-Western Morocco with 14524 illustrations has also been created. A total of 1902 records covering about 460 taxa with around 14000 pictures has been created by Namibia.

South African National Biodiversity Institute

(SANBI) of South Africa has also documented around 1850 plants till now. The National Inventory of Natural Heritage (INPN) of France is also involved extensively in maintaining record of flora online. All the published information has been summarized in current 3rd version of the Flora of Greece web. Many other European countries like Italy, Portugal and United Kingdom has also documented their flora digitally. United States of America has extensively recorded their flora on various digital platforms like Jepson eFlora. The Jepson Herbarium University of California, Berkeley, Illinois Plants database, New York Flora Atlas, New York Flora Association, Flora of Missouri, Flora of North Dakota checklist, Flora of North America, Online Virtual Flora of Wisconsin and Tropicos database maintained by Missouri botanical garden. Phillipines has maintained an eFlora of around 10,000 plant species in the country. New Zealand has also maintained continually updated, electronically-based Flora of their plants. A digital eFlora of Chile is maintained by Center for Advanced Studies in Ecology & Biodiversity and currently present more than 2202 species with over 20353 photos. Brazil has also described over 22000 species of their indigenous flora digitally. Flora of China checklists include indispensable data of plant names and literature data at local, regional, and global scales. A list of website addresses of different eFlora has been mentioned in Table 1.

Table 1. Web Resource Table for E-flora

Web address for E-flora	Brief Description
https://eFloraofindia.com/	Website links for eFlora of India
https://www.philippineplants.org/	Website links for eFlora of Philippines
https://www.nzflora.info/index.html	Website links for eFlora of New Zealand
http://www.chileFlora.com/index.html	Chile
http://reFlora.jbrj.gov.br/reFlora/PrincipalUC/PrincipalUC.do	Brazil
https://ucjeps.berkeley.edu/eFlora/	Website links for various eFloras of USA
https://www.inhs.illinois.edu/data/plantdb	
https://newyork.plantatlas.usf.edu/	
https://www.tropicos.org/Project/MO	
http://ashipunov.info/shipunov/fnddb/	
https://wisflora.herbarium.wisc.edu/index.php	
https://www.anbg.gov.au/abrs/online-resources/flora/	Website links for Various
https://profiles.ala.org.au/opus/foa/search	eFloras of Australia
https://plantnet.rbgsyd.nsw.gov.au/floraonline.htm	
http://eFlora.nt.gov.au/	
https://vicflora.rbg.vic.gov.au/	
http://www.flora.sa.gov.au/	
https://florabase.dpaw.wa.gov.au/	
https://apps.lucidcentral.org/rainforest/text/intro/index.html	
https://www.botswanaflora.com/	Website links for Various
http://westerndesertflora.geolab.cz/electronic_herbarium.php	eFlora of African countries.
https://www.teline.fr/en	
http://pza.sanbi.org/	
https://www.zimbabweFlora.co.zw/	
https://inpn.mnhn.fr/accueil/index?lg=en	Website links for some European
http://portal.cybertaxonomy.org/flora-greece/intro	eFlora of various countries like France, Greece,
http://dryades.units.it/floritaly/?procedure=intro_en	Italy, Portugal and United Kingdom.
https://flora-on.pt/	
https://www.brc.ac.uk/plantatlas/Online	
https://eunis.eea.europa.eu/references/1780/species	
https://powo.science.kew.org/	
https://flora-of-cyprus.eu/	Website links for eFlora of Cyprus
https://flora-iran.com/	Website links for eFlora of Iran
https://herbaria.plants.ox.ac.uk/bol/florajapan	Website links for eFlora of Japan
http://www.eFloras.org/flora_page.aspx?flora_id=110	Website links for eFlora of Nepal

Indian Scenario

The information regarding eFlora of India remains scattered in various publications which is compiled at a single open-access online database of India's plant diversity aiming to an updated correct data on the status of plants diversity of higher plants and make it widely available. Similarly, the Botanical Survey of India provides digital data of plants of various regions in India online on e-Flora of India. Botanical Survey of India (BSI) documented digital data of over 18000 plants belonging to 21558 taxa of angiosperms under 268 families and 2744 genera based on about 3 lakhs images of these plants. It also provides 1404 cultivated taxa, and a total of 1907 infraspecific taxa including 1518 varieties, 337 subspecies. Indian eFlora platform is very easy to access and can be searched for many Angiosperms, Gymnosperms, Pteridophytes, Bryophytes, Lichen, Fungi and Algae. Botanical Survey of India and NBRI (National Botanical Research Institute), Lucknow also provides plant lists that can be searched by using common name, family, genus and class.

Conclusion

The information evolved with botanical exploration, taxonomic and phylogenetic research throughout the world has helped in development of adoption of an updated Global Strategy for Plant Conservation (GSPC) in 2011 provided the essential impetus for the development of the World Flora Online (WFO) project which represents an electronic Flora of all plants (Borsch *et al*., 2020). In the last many decades a huge increase in digital data information in the field of taxonomy has been recorded which reveals to be addressed with proper management and storage and this task is only possible with the help of new and efficient database creation.

Many international programs are working on this project which is also inspiring Indian organizations to create their own databases in collaboration with others to make every possible information available on minute details of flora online. Increased trend of using molecular techniques, DNA sequencing and digital pictures on flora identification for systematic organization can only be possible with digital software tools and not with traditional paper and word-based floras. The other important point why we need to record these e-floras is that Indian geographical conditions support enormous biodiversity which is still needed to be explored and making a digital e-flora will be a great step towards its conservation. The past experience of our country where we proudly fought for our rights regarding revoking patent of Turmeric and Neem plants which has been an indispensable part of our culture since centuries has compelled us to document our flora. Making available all information regarding biodiversity on a single platform of E-flora accessible to the whole world which will also help in protection of traditional knowledge by minimizing chances of biopiracy which has been a challenging task for developing countries in the last few decades.

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