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Review / Revisión

The online Flora of Mexico: eFloraMEX
La flora de México en línea: eFloraMEX

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Abstract

Background: Mexico is a megadiverse country with an elevated diversity of species of vascular plants. A comprehensive Flora that includes all of the vascular plants distributed in Mexico does not yet exist. Electronic Floras have demonstrated the value of a compendium based on existing knowledge and published Floras, checklists and revisions.
Questions: What is the best approach for publishing the Flora of Mexico? What resources are needed to create this Flora? What is the current status of these resources?
Objective: The objective of this paper is to summarize and evaluate the taxonomic and digital resources and the bioinformatic tools needed to develop an online Flora for the vascular plants of Mexico, as well as to discuss its content.
Results and Conclusions: An online flora using the EDIT Platform for Cybertaxonomy is proposed, with the collaboration of Mexican and international researchers. It will be based on approximately 5.3 million specimens deposited in Mexican herbaria, with an inter-operational portal to other biodiversity platforms. The name assigned to this online flora is "eFloraMEX". As a starting point, the taxonomic backbone, the checklist for the Mexican vascular plants including approximately 29,000 species, was published in a portal (efloramex.ib.unam.mx) to be revised and updated by specialists. A council of taxonomists and computer experts will lead the eFloraMEX project on two fronts: taxonomic and digital resources. The main challenges to completing this Flora are building the team, training taxonomists, digitizing the specimens for most of Mexican herbaria and obtaining the required long-term funding.
Key words: checklist, electronic Flora, EDIT Platform, Mexican plant diversity, vascular plants

Resumen

Antecedentes: México es un país megadiverso con una elevada diversidad especies de plantas, sin embargo, no se ha publicado a la fecha una flora sintética. Las Floras electrónicas han demostrado la relevancia de tomar en cuenta el conocimiento botánico previo de Floras, listados florísticos y revisiones.
Preguntas: ¿Cuál es la mejor estrategia para publicar la Flora de México? ¿Cuáles son los recursos necesarios para publicarla? ¿Se tienen los recursos necesarios?
Objetivo. El objetivo de este artículo es el de resumir y evaluar los recursos taxonómicos y digitales y las herramientas bioinformáticas para llevar a cabo una flora en línea para las plantas vasculares de México, así como discutir su contenido.
Resultados y Conclusiones: Se utilizará la plataforma "EDIT" para Cibertaxonomía. La denominación para la flora en línea de México es eFloraMEX y contará con la colaboración de taxónomos nacionales e internacionales, que estudien 5.3 millones de especímenes de herbarios mexicanos, con un portal propio e inter-operacional. Como punto de partida, se publicó la lista florística inicial incluyendo alrededor de 29,000 especies de plantas vasculares (efloramex.ib.unam.mx), la cual será actualizada y revisada. eFloraMEX se desarrollará tomando en cuenta obras existentes y será coordinada por un comité de taxónomos y bioinformáticos con base en dos ejes: taxonómico y de recursos digitales. Los desafíos más importantes que tendrá que enfrentar la eFloraMEX serán los de formar taxónomos que completen la flora mexicana, digitalizar especímenes de la gran mayoría de herbarios del país, así como logar financiamiento a largo plazo para apoyar este proyecto.
Palabras clave: diversidad vegetal mexicana, flora electrónica, EDIT Plataforma de Cibertaxonomía, listado florístico, plantas vasculares.

Mexico is a megadiverse country, particularly in vascular plants with between 23,500 and 26,500 species of vascular plants recorded (Espejo-Serna *et al.* 2004, Villaseñor 2016). It is the third or fourth most biodiverse country in the world at the species level and the richest at the family level (Myers *et al.* 2000, Villaseñor & Ortiz 2014, Ulloa-Ulloa *et al.* 2017). Mexico's plant diversity results from its complex geological and climate history, including numerous morphotectonic provinces, and more than fifty types of ecoregions (Rzedowski 1978, Ferrusquia-Villafranca 1993, Olson *et al.* 2001, Kottek *et al.* 2006). This geological and ecological complexity has supported the migration and establishment of a large number of plant species (*e.g.,* Dávila-Aranda *et al.* 2004, Farjon 2008, Godínez-Alvarez & Ortega-Baes 2007, de Nova *et al.* 2012, Sosa *et al.* 2018, Jiménez-Barrón *et al.* 2020).

While our knowledge of the Mexican Flora has advanced considerably, with fifteen regional Floras completed or underway, a Flora comprising the vascular plant species in Mexico has not yet been published. Floras are a crucial source of information and the starting point for many studies (Funk 2006). A complete Flora facilitates recognizing plant diversity patterns, analyzing endemism and identifying endangered species (Forest *et al*. 2007, Knapp 2008, Borsch *et al.* 2020, Lagomarsino & Frost 2020, Auffret 2021). Floras are the cornerstone of managing plant diversity in a region and for prospecting the potential uses of plants in a wide variety of areas: food production, industry, medicine, bioremediation, and soil conservation (Funk 2006, Cutts *et al.* 2020, Auffret 2021).

Bioinformatic tools and various biodiversity databases are currently used in the preparation of modern Floras and accelerate the publication of biodiversity data (Berendsohn *et al.* 2018, Palese *et al.* 2019).

The purpose of this paper is to summarize and evaluate the taxonomic and digital resources and the bioinformatic tools needed to develop an online Flora for the vascular plants of Mexico, and to discuss its potential content.

History of the online Flora of Mexico: eFloraMEX. The Global Strategy for Plant Conservation (GSPC) is one of the United Nations' programs in the Convention on Biological Diversity (CBD), created to promote conservation and to slow the pace of plant extinction (www.cbd.int/gspc). In particular, Target 1 of the GSPC refers to an online Flora of all known plants (www.cbd.int/gspc/targets). In Mexico, the National Biodiversity Commission CONABIO (*Comisión Nacional para el Conocimiento y Uso de la Biodiversidad*) developed a strategy that includes an inventory of the vascular plants of the country as one of its targets (www.biodiversidad.gob.mx/pais/emcv/EMCV). In 2015, a group of plant taxonomists and computer science specialists from various Mexican institutions and CONABIO discussed the most efficient approach to accomplishing this goal and concluded that an online Flora would be the optimal strategy and proposed it be called eFloraMEX.

There are several advantages of online Floras compared to conventional Floras published in print. Online Floras can be linked to other biodiversity platforms (Schnase *et al.* 1997, Brach & Song 2006, Brouillet 2014, Victor *et al.* 2014) and are easily accessible worldwide (Schnase *et al.* 1997, Brach & Song 2006, Brouillet 2014). They can be published in sections without waiting for all the treatments of all of the plant groups, nomenclatural and taxonomic changes can be easily updated, new species can be quickly incorporated and new collection records and the documentation of extinctions and changes in conservation status can also be continuously updated.

The members of the committee called to accomplish Target 1 of the GSPC by CONABIO explain the strategies proposed for developing eFloraMEX, which include an inventory of the wild-growing native and naturalized vascular plant species of Mexico with their descriptions.

Floristic research and monographs. Efforts to document Mexico's plant diversity date back to the 16th century when Francisco Hernández wrote the History of the Plants of New Spain after the first exploration of Mexican territory from 1571 to 1576. More recently, Floras such as the *Flora of Yucatan* (Standley 1930), the *Flora of Baja California* (Wiggins 1980), the *Vegetation and Flora of the Sonoran Desert* (Shreve & Wiggins 1964) and two Floras of the Valley of Mexico (Sánchez 1980, Calderón de Rzedowski & Rzedowski 2001) were concluded. Others remained incomplete, such as the *Flora Novo-Galiciana* (McVaugh 1974) and the *Flora del Estado de México* (Martínez & Matuda 1979). Several other Floras are currently underway, including *Flora de Aguascalientes* (De la Cerda-Lemus

et al. 2004), *Flora del Bajío y de Regiones Adyacentes* (*e.g.,* Espejo-Serna *et al.* 2009), *Flora de Guerrero* (*e.g.,* Velázquez-Montes 2005), *Flora de Jalisco y Áreas Colindantes* (*e.g.,* Carvajal & González-Villareal 2010), *Flora del Valle de Tehuacán-Cuicatlán* (*e.g.,* Lira-Charco & Ochoterena 2012 and *Flora de Veracruz* (*e.g.,* Castillo-Campos 2008). Additionally, the *Flora Mesoamericana* includes the southern part of Mexico (*e.g.,* Bravo-Hollis & Arias 2011). Figure 1 shows the areas covered by these Floras and they are summarized in Table 1.

Figure 1. Geographic areas encompassing previously published floras, either completed or in progress. The floras are cited in Table 1.

Other efforts include floristic checklists, reviews, and monographs for several vascular plant groups, such as the checklist for the vascular plants of Mexico published by Villaseñor (2016). These Floras do not cover the entire Mexican land mass, so additional taxonomic research will have to be conducted. Furthermore, it is difficult to estimate the number of native and naturalized taxa that are in these Floras because many species are shared between regions. Taxonomic concepts also vary among these Floras and need to be reevaluated. The majority of these Floras were published in print rather than in digital format and therefore are not currently suitable for inclusion in eFloraMEX. To assist the taxonomists, it would be helpful to convert these Floras into a machine-readable and marked-up format.

Table 1. Regional floras in Mexico with their estimated number of vascular plant species. Percentage of species that have not been studied is also reported.

Flora	Region	Status	Total number species	%missing species	Studied species	Reference
Flora of Baja California	Peninsula of Baja California	Completed	2,958	8.6	2,705	Wiggins 1980
Sonoran Desert	Baja California and Sonora and southwestern Arizona, southeastern California in the U.S.	Completed	2,634	0	2,634	Wiggins 1964
Flora de Sinaloa	Sinaloa	In progress	5,000	Not mentioned	Not mentioned	Vega *et al.* 1989
Flora de Nayarit	Nayarit	In progress	4,500	Not mentioned	Not mentioned	Ortiz-Bernúdez *et al.* 1998
Flora de Durango	Durango	In progress	4,300	Not mentioned	Not mentioned	González *et al.* 1991
Flora de Jalisco	Jalisco	In progress	7,000	Not mentioned	Not mentioned	Carvajal & Acosta Sotelo 2010
Flora de Guerrero	Guerrero	In progress	6,500	77.4	1,470	López-Ferrari 1989, Diego 1997
Flora del Bajío y de Regiones Adyacentes	Guanajuato, Querétaro, Michoacán, México	In progress	5,700	Not mentioned	3,072	Calderón de Rzedowski 1991
Flora Novo-Galiciana	Jalisco, Colima and Aguascalientes, plus adjacent portions of Nayarit, Durango, Zacatecas, Guanajuato, and Michoacan.	Completed	5,000	29.5	3,523	McVaugh 1974
Flora Fanerogámica del Valle de México	Valley of Mexico	Completed	5,000	58.6	2,071	Calderón de Rzedowski & Rzedowski 2001
Flora del Valle de Tehuacán-Cuicatlán	Tehuacán-Cuicatlán Valley in the states of Oaxaca and Puebla	In progress	2,700	39	1,646	Dávila *et al.* 1993
Flora de Veracruz	Veracruz	In progress	5,500	62.6	2,056	Villarreal & Estrada 2021
Flora de Chiapas	Chiapas	Incomplete	5,390	90.6	506	Breedlove 1981
Flora de la Península de Yucatán	Peninsula of Yucatan	In progress	2,300	Not mentioned	Not mentioned	Duno de Stefano *et al.* 2010
Flora Mesoamericana	Southern Mexico and Central America	In progress	18,000	51.5	8,725	Davidse *et al.* 1994

Table 2. Specimens of vascular plants deposited in Mexican herbaria. Acronyms follow the Index Herbarium (sweetgum.nybg.org/science/ih). Herbaria not listed in this Index are marked with an asterisk.

Herbarium code	Institution	Number of Specimens
AMO	Instituto Chinoin, AC, Ciudad de México	26,700
ANSM	Universidad Autónoma Agraria "Antonio Narro", Saltillo, Coahuila	75,000
BCMEX	Universidad Autónoma de Baja California, Ensenada, Baja California	30,000
CEDESU*	Herbario de Centro de Estudios de Desarrollo Sustentable y Aprovechamiento de la Vida Silvestre, Campeche, Campeche	3,000
CFNL	Universidad Autónoma de Nuevo León, Linares, Nuevo León	33,000
CH	El Colegio de la Frontera Sur, San Cristóbal de las Casas, Chiapas	23,650
CHAP	Universidad Autónoma Chapingo, Texcoco, Edo. de México	51,600
CHAPA	Colegio de Posgraduados, Texcoco, Estado de México	160,000
CHIP	Herbario del Instituto de Historia Natural y Ecología, Tuxtla Gutiérrez, Chiapas	45,000
CIAN	Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), Pabellón de Arteaga, Aguascalientes	8,500
CIB	Universidad Veracruzana, Xalapa, Veracruz	20,000
CICY	Centro de Investigación Científica de Yucatán, A.C., Mérida, Yucatán	70,390
CIIDIR	Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR), Instituto Politécnico Nacional, Durango, Durango	70,500
CIMI	Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR) Instituto Politécnico Nacional, Jiquilpan, Michoacán	10,713
CMMEX	Universidad Autónoma de Baja California, Ensenada, Baja California, México	8,500
CODAGEM	Universidad Autónoma del Estado de México, Toluca, Estado de México	30,000
CORU	Universidad Veracruzana, Córdoba, Veracruz	18,500
CREG	Tecnológico Nacional de México, Tlajomulco de Zúñiga, Jalisco	15,622
EBUM	Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán	15,000

Herbarium code	Institution	Number of Specimens
ECO-CH-H (CH)*	Colegio de la Frontera Sur (ECOSUR), Chetumal, Quintana Roo	18,250
ENCB	Instituto Politécnico Nacional, Ciudad de México	1,080,000
ENSJ	Escuela Normal Superior de Jalisco, Guadalajara, Jalisco	5,000
FCME	Universidad Nacional Autónoma de México, Ciudad de México	95,700
FEZA	Universidad Nacional Autónoma de México, Ciudad de México	25,000
GBH	Herbario de Geo. B. Hinton. Galeana, Nuevo León	16,000
GUADA	Universidad Autónoma de Guadalajara, Zapopan, Jalisco	45,000
HCIAD*	Herbario del Centro de Investigación y Desarrollo, AC. (CIAD), Mazatlán, Sinaloa	2,307
HCIB	Centro de Investigaciones Biológicas del Noroeste (CIBNOR), La Paz, Baja California Sur	30,000
HEM	Universidad de Ciencias y Artes de Chiapas, Tuxtla Gutiérrez, Chiapas	20,000
HERB-UACJ*	Herbario de la Universidad Autónoma de Ciudad Juárez, Chihuahua	
HGOM	Universidad Autónoma del Estado de Hidalgo. Pachuca, Hidalgo	7,000
HJBC	Jardín Botánico Culiacán, Sinaloa	300
HUAA	Universidad Autónoma de Aguascalientes, Aguascalientes, Aguascalientes	30,000
HUAP	Benemérita Universidad Autónoma de Puebla, Puebla, Puebla	50,000
HUMO	Universidad Autónoma del Estado de Morelos, Cuernavaca, Morelos	40,000
HZAC*	Herbario del Centro de Investigaciones Biológicas de Zacatecas, Zacatecas	3,550
IBUG	Universidad de Guadalajara, Zapopan, Jalisco	210,000
ICF	Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), Ciudad de México	S/Inf
IEB	Instituto de Ecología, AC, Pátzcuaro, Michoacán	245,000
IMSS*	Herbario Medicinal de México del IMSS: Unidad de Investigación de Plantas Medicinales, Ciudad de México	16,000
INEGI	Instituto Nacional de Estadística y Geografía, Aguascalientes, Aguascalientes	50,503

Herbarium code	Institution	Number of Specimens
INIF	Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP), Ciudad de México	57,300
ITCV	Instituto Tecnológico de Ciudad Victoria. Ciudad Victoria, Tamaulipas	9,000
IZTA	Universidad Nacional Autónoma de México (UNAM), Ciudad de México	32,870
JES	Universidad Autónoma Chapingo, Toluca, Estado de México	33,000
MEMO	Instituto Tecnológico y de Estudios Superiores de Monterrey, Monterrey, Nuevo León	4,270
MEX	Museo de Historia Natural de la Ciudad de México, Ciudad de México.	-
MEXU	Universidad Nacional Autónoma de México (UNAM), Ciudad de México	1,550,000
OAX	Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR), Instituto Politécnico Nacional, Xoxocotlán, Oaxaca	35,024
QMEX	Universidad Autónoma de Querétaro, Querétaro, Querétaro	35,000
RELC	Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP), Chihuahua, Chihuahua	9,000
SLPM	Universidad Autónoma de San Luis Potosí, San Luis Potosí, San Luis Potosí	50,733
UADY	Universidad Autónoma de Yucatán, Mérida, Yucatán	23,471
UAGC	Universidad Autónoma de Guerrero, Chilpancingo, Guerrero	11,500
UAMIZ	Universidad Autónoma Metropolitana-Iztapalapa, Ciudad de México	85,000
UAS	Universidad Autónoma de Sinaloa, Culiacán, Sinaloa	23,000
UAT	Universidad Autónoma de Tamaulipas, Ciudad Victoria, Tamaulipas	21,000
UCAM	Universidad Autónoma de Campeche, Campeche, Campeche	24,700
UCOL	Universidad de Colima, Tecomán, Colima	2,500
UJAT	Universidad Juárez Autónoma de Tabasco, Villahermosa, Tabasco	42,195
UNL	Universidad Autónoma de Nuevo León, Monterrey, Nuevo León	43,000
USON	Universidad de Sonora, Hermosillo, Sonora	19,943

Herbarium code	Institution	Number of Specimens
WLM	Jardín Botánico El Charco del Ingenio, San Miguel de Allende, Guanajuato	1,158
XAL	Instituto de Ecología, A.C., Xalapa, Veracruz	350,000
XALU	Universidad Veracruzana, Xalapa, Veracruz	30,000
XOLO	Universidad Autónoma de Chapingo, Texcoco, Estado de México	14,675
ZEA	Universidad de Guadalajara, Autlán de Navarro, Jalisco	16,000
	Total	**5,229,624**

Herbaria and collections. According to the Index Herbariorum (sweetgum.nybg.org/science/ih), the 68 active herbaria for Mexico house approximately 5,300,000 specimens of which 66 % are located in the five largest herbaria in the country (acronyms assigned by the index): MEXU, the National Herbarium, at the Universidad Nacional Autónoma de México, with 1,550,000 specimens; ENCB at the Instituto Politécnico Nacional, with approximately 1,080,000 specimens; XAL at the Instituto de Ecología AC, in Xalapa, Veracruz, with 350,000 specimens; IBUG at the Universidad de Guadalajara in Jalisco with approximately 210,000 specimens; and IEB at the Instituto de Ecología, AC, in Pátzcuaro, Michoacán, with 245,000 specimens. The Mexican Botanical Society assembled an additional database of the Mexican herbaria, including 16 herbaria not yet registered in the Index Herbariorum. Five of them reported their specimens, adding approximately 45,000 to the total. Thus, there is a good number of collections, crucial to developing the online Flora of Mexico. Table 2 summarizes the number of specimens deposited in Mexican herbaria.

The National Herbarium, MEXU, has a virtual herbarium comprising 1,600,000 specimens (www.ibdata.abaco3.org/web/), and some of the herbaria in the Network of the Herbaria of Northwestern Mexico have approximately 5,000 images of herbarium collections (www.herbanwmex.net). In addition, the New York Botanical Garden Herbarium has digitized 72,500 specimens of Mexican plants (Thiers *et al.* 2016). Approximately 3,900,000 specimens are not yet digitized and their inclusion in eFloraMEX represents a challenge that should be addressed by a specific project. To this end, previous experiences with large-scale specimen digitization, for example that of the New York Botanical Garden Herbarium, should be applied (Thomas & Tulig 2015, Thiers *et al*. 2016).

Taxonomists. Approximately 200 systematists are associated with the 71 active herbaria, according to a census by the Mexican Botanical Society conducted on its members. They specialize in very diverse groups, such as Asteraceae, Euphorbiaceae, Fabaceae, Orchidaceae, Rubiaceae, and groups of monocots, the most important being Asparagaceae, Cyperaceae and Poaceae (Table 3). Additionally, taxonomists from all over the world have become interested in groups of Mexican plants and many form part of international networks of specialists in Compositae (www.compositae.org), Caryophyllales (www.caryophyllales.org), Euphorbiaceae (www.euphorbiaceae.org) and Solanaceae (solanaceaesource.myspecies.info) (to mention the most widely known), and they will be invited to participate in this project. In order to sustain a project as ambitious as the online Flora of Mexico, it is also necessary to continue training young specialists to update and complete the treatments. To achieve this, it is important to organize special programs for taxonomists in different graduate programs at universities and research centers in Mexico.

Virtual resources. In addition to the virtual herbaria mentioned above, a number of digital resources are needed to assist collaborators in developing floristic treatments. CONABIO handles the National Biodiversity Information System (SNIB), which contains information derived from research projects on Mexican plant species. The SNIB

Table 3. Families for which taxonomists are researching plant species in Mexican herbaria according to the Mexican Botanical Society. Herbarium acronyms correspond to those cited in Table 2.

Family	Herbarium acronym
Acanthaceae	ENCB
Achariaceae	XAL
Actinidiaceae	QMEX
Adoxaceae	ANSM
Agavaceae	CIIDIR
Aizoaceae	HUAA
Alstromeriaceae	ENCB
Amaranthaceae	MEXU
Amaryllidaceae	MEXU, IBUG, QMEX
Anacampserotaceae	HUAA
Apocynaceae	MEXU, FCME
Apodanthaceae	FCME
Aquifoliaceae	SLPM
Araceae	CICY, HEM
Asparagaceae	FEZA, MEXU, CHAP, QMEZ, IBUG
Asphodelaceae	ENCB
Asteraceae	CICY, INEGI, CIIDIR, HJBC, MEXU, CIIDIR, IEB, UACH-HER, IBUG, XAL
Balanophoraceae	FCME
Begoniaceae	FCME
Betulaceae	SLPM
Bignoniaceae	UJAT
Brassicaceae	COLPOS, QMEX
Bromeliaceae	CICY, GUADA, HGOM, UAMIZ, MEXU
Buddlejaceae	HUAA
Buxaceae	ENCB
Cactaceae	CIBNOR, CIIDIR, HJAAA, MEXU, QMEX, UAT, IBUG
Caprifoliaceae	ANSM
Caryophyllaceae	IEB
Ceratophyllaceae	IBUG
Convolvulaceae	SLPM, CICY
Crassulaceae	IBUG, IEB
Crossosomataceae	XAL
Cucurbitaceae	IZTA, ENCB, XAL
Cycadaceae	HEM, UV, XAL
Cyperaceae	CIIDIR
Cytinaceae	FCME

Family	Herbarium acronym
Dichapetalaceae	XAL
Droseraceae	CICY
Ericaceae	CIIDIR
Euphorbiaceae	QMEX, FCME
Fabaceae	CFNL, CICY, FCME, INEGI, MEXU, UAMIZ, ZEA
Fagaceae	FCME, IZTA, INEGI, HUAP
Gentianaceae	ANSM
Gesneriaceae	MEXU
Heliconiaceae	UCAM
Icacinaceae	CICY
Iridaceae	IBUG, UAMIZ
Lamiaceae	FCME, MEXU, CIIDIR, EBUM, IEB, XAL
Lentibulariaceae	IBUG, MEXU
Linaceae	COLPOS
Loganiaceae	FCME, SLPM
Magnoliaceae	IBUG
Malvaceae (Sterculioideae	IBUG
Melastomataceae	FCME
Meliaceae	UJAT
Menispermaceae	IBUG
Musaceae	COLPOS
Myrtaceae	XAL
Nyctaginaceae	IEB
Ochnaceae	UV
Orchidaceae	AMO, CICY, FCME, UACJ, MEXU, OAX, UAMIZ, XAL
Oxalidaceae	XAL
Passifloraceae	FCME
Pinaceae	IBUG, EBUM, CIIDIR, HUMO, IZTA, FCME, IEB, ENCB, HJBC, FEZA, HUAA, HJAAA, HUMO, INEGI, IZTA, MEXU, INEGI, QMEX, SLPM, UAMIZ, UAT, UCAM, UJAT, UV,
Plantaginaceae	IEB
Plocospermataceae	FCME
Poaceae	CIIDIR, IEB, IIBUG, HUAA, INEGI, MEXU, QMEX, UAAN, UADY, XAL
Portulacaceae	HUAA
Ranunculaceae	QMEX
Rosaceae	MEXU
Rubiaceae	FCME, FESCM, INEGI, MEXU, XAL

Family	Herbarium acronym
Rutaceae	MEXU
Sabiaceae	XAL
Saxifragaceae	XAL
Schrophulariaceae	XAL
Setchellanthaceae	XAL
Solanaceae	EBUM, IBUG, QMEX
Zamiaceae	HEM, UV, XAL

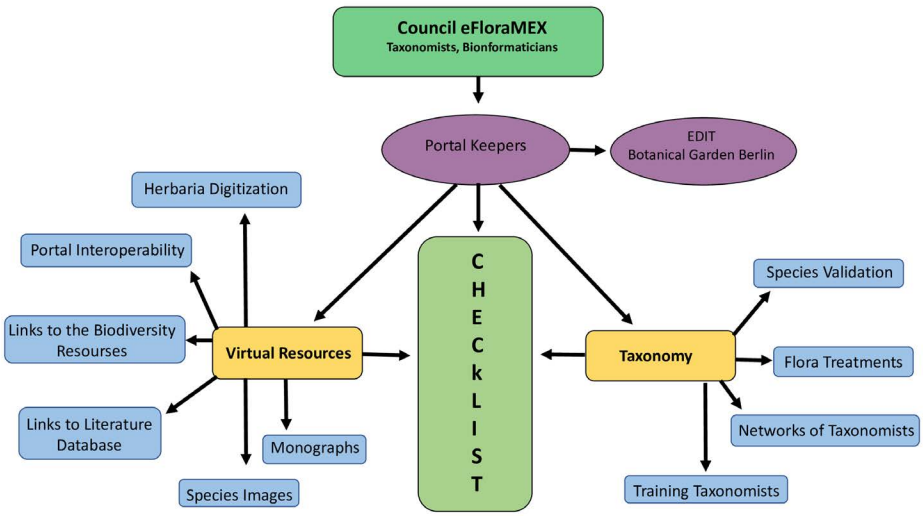

Figure 2. Workflow for eFloraMEX: the online flora of Mexico.

also contains data from specimens housed in various national and international herbaria from which data was entered during a special project. Also, portals, such as the herbaria of western Mexico (herbanwmex.net) and the Flora of the Yucatan Peninsula (www.cicy.mx/sitios/floradigital/) will be helpful.

The content of eFloraMEX. For every species, eFloraMex will provide: nomenclature, morphological description, distribution (indicating endemic and introduced species), uses, the main specimens upon which the description was based, illustration, conservation status (if available), and important literature with links, if available. The eFloraMex will also provide identification keys, related searchable data, images, guidelines for contributors, and information on the council and its members, the networks of taxonomists collaborating on plant groups and designated coordinators, and on the people involved in the eFloraMEX project. Links to the Mexican herbaria will be included too (Figure 2). The classification of plants for orders and families will follow APG IV (APG 2016).

For the morphological descriptions of species in the eFloraMEX, ontologies and descriptive terminologies may be standardized or not, however a controlled vocabulary will be utilized for treatments developed specifically for this Flora. Descriptions can be added from other sources, like previous floras or protologues, with the corresponding credit. The selection of characters will be based on comparative observations of a documented set of specimens for each taxon. Specimens will be cited and, if possible, links to images will be included.

The eFloraMEX platform will have wider applications in addition to the flora treatments. It will include distribution maps, the conservation status of species and common names. It will also document uses of native plants since Mexico is an important region for plant domestication, the origin of agriculture and for an ample knowledge of plant uses (Bye 1993, Casas *et al.* 2016, 2019). Illustrations and images for individual species will be included where possible, either prepared specifically for eFloraMEX or obtained from other previously published Floras with the corresponding permission.

Workflow and organization of eFloraMEX. The backbone of eFloraMEX is the checklist and an initial version, a starting point based on previous research and on CONABIO databases, was published in its portal, including approximately 29,000 vascular plant species (efloramex.ib.unam.mx/). The number of species resulted more elevated in comparison with previous estimations (Villaseñor 2016). It will constantly be updated based on taxonomic research from eFloraMEX collaborators, both in Mexico and worldwide.

eFloraMEX will be managed by a council consisting of systematists and bioinformaticians from Mexican universities, research institutes and CONABIO (Figure 2). The council will make the main taxonomic and technical decisions. It will also organize networks of expert botanists who manage the taxonomic backbone and content of plant groups within their expertise, thus integrating and encouraging participation and collaboration among national and international taxonomists. The lead botanists in charge of organizing contact among plant group specialists should be active researchers on the taxonomy and evolution in their respective plant group. Networks of taxonomists will be organized according to the species richness or complexity of the group, at the level of large genera, tribes, subfamilies, families or groups of related small families. Group leaders will work closely with the council, serving as a bridge to individual systematists. The council will have two chairs, one in charge of coordinating virtual resources and another in charge of coordinating taxonomic research. Proper acknowledgment of and attribution to the authors and contributors will be explicitly required in the eFloraMEX portal.

Technical implementation of eFloraMEX. The EDIT Platform for Cybertaxonomy (cybertaxonomy.org/) will be used for developing eFloraMEX. It is a collection of open source tools that cover all aspects of the taxonomic workflow, including (but not limited to) editing taxon names, preparing taxonomic treatments, generating distribution maps, adding factual data of various kinds, such as morphological descriptions in various formats, diagnoses, common names, distribution, ecology, and much more (Ciardelli *et al.* 2009). The EDIT Platform consists of three components: an instance (database) that stores the information, the TaxEditor, a graphical user-friendly interface that allows data to be entered and edited, and a data portal which displays the data and can include additional textual information. The EDIT Platform covers the whole taxonomic workflow including publication; components for print-publications, for example checklists or taxonomic treatments can be produced directly from the database (Berendsohn *et al.* 2018). The EDIT Platform is already being used for several online Flora projects. Examples include the Flora of Greece (portal.cybertaxonomy.org/flora-greece/), the Flora of Cuba (portal.cybertaxonomy.org/flora-cuba/), and the Flora Malesiana (portal.cybertaxonomy.org/flora-malesiana). The management of the data, web portal and technical support will be provided by a working group of bioinformaticians associated with the eFloraMEX council, in collaboration with the specialists of the Botanical Garden Berlin, Germany, where the EDIT Platform is being further developed.

Interoperability. The eFloraMEX will make use of existing sources of information and incorporate the scientific community, with the proper identification of authors and contributors. This will be facilitated by the digital resources mentioned above. Also, data bases such as the Global Biodiversity Information Facility GBIF (Telenius 2011), which provide free, open access to an enormous array of digital resources in the taxonomic literature, as well as specimen and observation records, will be linked in the eFloraMEX portal. Additionally, eFloraMEX will include connections to important plant diversity databases such as *Tropicos* curated by the Missouri Botanical Garden, which includes more than one million links to scientific names, references and publications (www.tropicos.org). The *World Flora Online* (WFO), the international initiative providing a global overview of the diversity of plant species is another important link for the eFloraMEX (www.worldfloraonline.org). The *Biodiversity Heritage Library* (BHL) is an open

access digital library for biodiversity literature and archives and an important resource for taxonomists interested in the vascular plants of Mexico (www.biodiversitylibrary.org). These databases and others considered in particular for certain plant groups will be linked in the portal of the eFloraMEX.

The benefits of eFloraMEX. The eFloraMEX will present the most up-to-date taxonomic information on the Flora of Mexico to a global audience and contribute to biodiversity conservation and sustainable development. eFloraMEX will focus on the needs of users by providing original data and links to searchable online databases. For instance, data on the habitats of species, elevation ranges, conservation status and uses can be obtained via searches. Students, botanists and amateurs interested in a particular plant group or in plants from a geographic region will be able to directly contact experts associated with eFloraMEX and provide new information on species or their concepts, increasing the interest and participation of botanists.

Challenges, Prospects and Conclusions. The Brazilian Flora represents an admirable achievement that has demonstrated the utility and feasibility of an online flora of a megadiverse country. Over 12 years, a joint effort by approximately 1,000 taxonomists using cybertaxonomy has produced an updated account of algae, fungi and plants totaling ca. 47,000 species (BFG 2022). The remarkable progress of this flora was only achieved by supporting hundreds of graduate and undergraduate students who conducted research alongside experienced systematists, contributing to the professional development of the next generation of botanists (BFG 2022). Also, the World Flora Online has demonstrated the relevance of a compendium of the world's species based on a collaborative international effort that builds on existing knowledge and published floras, checklists and revisions (Borsch *et al.* 2020).

There is a worldwide deficiency in essential taxonomic information, gaps in taxonomic knowledge and a shortage of experienced taxonomists and curators. This has come to be known as the taxonomic impediment (Lipscomb *et al.* 2003, Wheeler *et al.* 2004, Crisci 2006). In this regard, one of the most difficult challenges to overcome in order to complete the Flora of Mexico is the very low number of Mexican specialists (approximately 200 according to the Mexican Botanical Society). The pace and progress of eFloraMEX will therefore greatly depend on bringing aboard undergraduate and graduate students to be trained in taxonomic research alongside experienced taxonomists. Innovative strategies should be designed for attracting young scientists to conduct research in taxonomy.

An additional endeavor, and one that will require a concerted effort, is digitizing the majority of the specimens deposited in Mexican herbaria. This can be only accomplished with a project dedicated to the Mexican herbaria, with the exception of MEXU, the National Herbarium, and the specimens in the Network of the Herbaria of Northwestern Mexico which already have virtual herbaria, the rest have not yet digitized their specimens.

Best practices in taxonomy are crucial to completing the Flora of Mexico and equally important is the need for taxonomists to come together and request sufficient funding, training and employment opportunities for curators, the personnel associated with herbaria and researchers in systematics. Furthermore, E-infrastructures require long-term funding policies because they are of public interest and the eFloraMEX will need continuous support (Canhos *et al.* 2015). International pleas to consider taxonomy as a modern and active discipline have been expressed previously in many international forums (Ebach *et al.* 2011, Grieneisen *et al.* 2014, Baldini *et al.* 2021, Engel *et al.* 2021). The online Flora of Mexico should be seen as a project that foments broad participation, and generates understanding of its value and funding from national and international organizations.

eFloraMEX: the online Flora of Mexico is crucial to advancing the inventory of one of the most biodiverse regions on planet Earth (Raven *et al.* 2020). Mexican botanists have always dreamed of producing the Flora of Mexico and creating the checklist in the portal of eFloraMEX (efloramex.ib.unam.mx) is a first step toward completing this Flora and documenting an important component of the world's biodiversity.

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Literature cited

APG [The Angiosperm Phylogeny Group] Chase MW, Christenhusz M, Fay MF, Byng JW, Judd WS, Soltis DS, Mabberley DJ, Sennikov AN, Soltis PS, Stevens PF. 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society* **181**: 1-20. DOI: https://doi.org/10.1111/boj.12385

Auffret AG. 2021. Historical floras reflect broad shifts in flowering phenology in response to warming climate. *Ecosphere* **12**: e03683. DOI: https://doi.org/10.1002/ecs2.3683

Baldini RM, Cota-Sánchez H, Aedo C. 2021. Is the demise of plant taxonomy in sight? Maybe yes, maybe no. *Journal of Plant Taxonomy and Geography* **76**: 3-10. DOI: http://dx.doi.org/10.36253/jopt-10802

Berendsohn WG, Borsch T, Güntsch A, Kohlbecker AA, Korotkova N, Luther K, Müller A, Plitzner P, VonMering S. 2018. Using the EDIT platform for cybertaxonomy to prepare and publish a treatment for the Caryophyllales network: an online synthesis of the Nepenthaceae. *Willdenowia* **48**: 335-344. DOI: https://doi.org/10.3372/wi.48.48301

BFG [Brazilian Flora Group]. 2022. Brazilian Flora 2020: Leveraging the power of a collaborative scientific network. *Taxon* **71**: 178-198. DOI: https://doi.org/10.1002/tax.12640

Borsch T, Berendsohn W, Dalcin E, Delmas M, Demisse S, Elliot A, Fristsch P, Fuchs A, Geltman D, Güner A, Haevermans T, Hai-Ning Q, Knapp S, Le Roux MM, Loizeau P-A, Miller C, Miller J, Miller JT, Palese A, Parnell H, Pendry C, Sosa V, Sosef M, Von Raab-Straube E, Ranwashe F, Raz L, Selimov R, Smetz E, Thiers B, Thomas W, Tulig M, Ulate W, Ung V, Watson M, Wyse Jackson P, Zamora N. 2020. World Flora Online: placing taxonomists at the heart of a definitive and comprehensive global resource on the world's plants. *Taxon* **96**: 1311-1341. DOI: https://doi.org/10.1002/tax.12373

Brach AR, Song H. 2006. eFloras: new directions for online floras exemplified by the Flora of China project. *Taxon* **55**: 188-192. DOI: https://doi.org/10.2307/25065540

Bravo-Hollis H, Arias S. 2011. Cactaceae. *Flora Mesoamericana* **2**: 1-78.

Breedlove DE. 1981. *Introduction to the Flora of Chiapas. Flora of Chiapas Part 1*. USA: California Academy of Sciences.

Brouillet L. 2014. Towards an eFlora of Canada: perspectives and challenges. Botany-*Botanique* **92**: 626.

Bye R. 1993. The role of humans in the diversification of plants in Mexico. *In*: Ramamoorthy R, Bye E, Lot A, Fa J. eds. *Biological Diversity of Mexico: Origins and Distribution.* New York: Oxford University Press. pp. 707-731.

Calderón de Rzedowski G. 1991. Papaveraceae. *Flora del Bajío y Regiones Adyacentes* **1**: 1-36.

Calderón de Rzedowski G, Rzedowski J. 2001. *Flora Fanerogámica del Valle de México*. Pátzcuaro, México: Instituto de Ecología AC.

Canhos DAL, Sousa-Baena MS, de Souza S, Maia LC, Stehmann JR, Canhos VP, De Giovanni R, Bonacelli MBM, Los W, Peterson AT. 2015. The importance of biodiversity E-infrastructures for Megadiverse countries. *Plos Biology* **13**: e10002204. DOI: https://doi.org/10.1371/journal.pbio.1002204

Carvajal S, González-Villareal LM. 2010. *Flora de Jalisco y Áreas Colindantes*. Guadalajara, Jalisco, México: Instituto de Botánica. Universidad de Guadalajara.

Carvajal S, Acosta Sotelo LL. 2010. Muntingiaceae. *Flora de Jalisco y Áreas Colindantes* **24**: 1-8.

Casas A, Blancas J, Lira R. 2016. Mexican ethnobotany: interactions of people and plants in Mesoamerica. *In*: Lira R, Casas A, Blancas J. Eds. *Ethnobotany of Mexico*. New York: Springer, pp. 1-19. ISBN: 978-1-4614-6669-7

Casas A, Ladio AH, Clement CR. 2019. Ecology and evolution of plants under domestication in the Neotropics. *Frontiers in Ecology and Evolution* **7**: 231. DOI: https://doi.org/10.3389/fevo.2019.00231

Castillo-Campos G. 2008. Illiciaceae. *Flora de Veracruz*. **144**: 1-7.

Ciardelli P, Kelbert P, Kohlbecker A, Hoffmann N, Güntsch A, Berendsohn WG. 2009. The EDIT Platform for Cybertaxonomy and the taxonomic workflow: selected components. *Lecture Notes in Informatics (LNI)*. 154: 625-638.

Crisci JV. 2006. One-dimensional systematics: perils in a time of steady progress. *Systematic Botany* **31**: 217-221.

Cutts V, Hanz DM, Barajas-Barbosa MP, Algar AC, Steinbauer MJ, Irl SDH, Kregt H, Wigetlt P, Fernández-Palacios JM, Field R. 2020. Scientific floras can be reliable sources for some trait data systems with poor coverage in global trait databases. *Journal of Vegetation Science*: **32:** e12996. DOI: https://doi.org/10.1111/jvs.12996

Dávila P, Villaseñor JL, Medina R, Ramírez A, Salinas A, Sánchez-Ken J, Tenorio P. 1993. Listados florísticos de México X. *Flora del Valle de Tehuacán-Cuicatlán.* Ciudad de México: Instituto de Biología, Universidad Nacional Autónoma de México.

Dávila-Aranda P, Lira-Saade R, Valdés-Reyna J. 2004. Endemic species of grasses in Mexico: a phytogeographic approach. *Biodiversity and Conservation* **13**: 1101-1121. DOI: https://doi.org/10.1023/B:BIOC.0000018147.54695.b3

Davidse G, Sousa M, Chater AO. 1994. Alismataceae a Cyperaceae *Flora Mesoamericana* **6**: 1- 134.

De la Cerda-Lemus M, García-Regalado G, Gonzáles-Adame G. 2004. Contribución al conocimiento de la flora del estado de Aguascalientes: Familias Agavaceae, Alliaceae, Amaryllidaceae, Anthericaceae, Asphodelaceae, Calochortaceae, Hyacinthaceae, Hypoxidaceae, Melanthiaceae y Nolinaceae. *Scientiae Naturae* **6**: 19-106.

De Nova JA, Medina R, Montero JC, Weeks A, Rosell JA, Olson ME, Eguiarte LE, Magallón S. 2012. Insights into the historical construction of species-rich Mesoamerican seasonally dry tropical forests: the diversification of *Bursera* (Burseraceae, Sapindales). *New Phytologist* **193**: 276-287. DOI: https://doi.org/10.1111/j.1469-8137.2011.03909.x

Diego N. 1997. Cyperaceae. *Flora de Guerrero* ***5***: 1-50.

Duno de Stefano R, Carnevali Fernández-Concha G, Ramírez-Morillo IM, Tapia Muñoz JL, Can Itzá LL, Hernández-Aguilar S. 2010. *Flora de la Península de Yucatán*. https://www.cicy.mx/sitios/flora%20digital/index.php

Ebach MC, Valdecasas AG, Wheeler QD. 2011. Impediments to taxonomy and users of taxonomy: accessibility and impact evaluation. *Cladistics* **27**: 550-557. DOI: https://doi.org/10.1111/j.1096-0031.2011.00348.x

Engel MS, Ceríaco LM, Daniel GM, Dellapé PM, Löbl I, Marinov M, Zacharie CK. 2021. The taxonomic impediment: a shortage of taxonomists not the lack of technical approaches. *Zoological Journal of the Linnean Society* **193**: 381-387. DOI: https://doi.org/10.1093/zoolinnean/zlab072

Espejo-Serna A, López-Ferrari AR, Salgado-Ugarte I. 2004. A current estimate of angiosperm diversity in Mexico. *Taxon* **53**: 127-130. DOI: https://doi.org/10.2307/4135497

Espejo-Serna A, López-Ferrari AR, Ceja-Romero J. 2009. Commelinaceae. *Flora del Bajío y de Regiones Adyacentes*. **162**: 1-122.

Ferrusquia-Villafranca I. 1993. Geology of Mexico: a synopsis. Oxford: Oxford University Press. pp: 3-107.

Farjon A. 2008. Biodiversity of *Pinus* (Pinaceae) in Mexico: speciation and palaeo-endemism. *Botanical Journal of the Linnean Society* **21**: 365-384. DOI: https://doi.org/10.1111/j.1095-8339.1996.tb00762.x

Forest F, Grenyer R, Rouget M, Davies TJ, Cowling RM, Faith DP, Balmford A, Manning JC, Proches S, van der Bank M, Reeves G, Hedderson TAJ, Savolainen V. 2007. Preserving the evolutionary potential of floras in biodiversity hotspots. *Nature* **445**: 757-760. DOI: https://doi.org/10.1038/nature05587

Funk VA. 2006. Floras: a model for biodiversity or a thing of the past? *Taxon* **55**: 581-588. DOI: https://doi.org/10.2307/25065635

Godínez-Alvarez H, Ortega-Baes P. 2007. Mexican cactus diversity: environmental correlates and conservation. *Boletin Sociedad Botánica de México* **81**: 81-87. DOI: https://doi.org/10.17129/botsci.1767

González M, González S, Herrera Y. 1991. Flora de Durango. Listados florísticos IX. Mexico: Instituto de Biología, Universidad Nacional Autónoma de México,

Grieneisen ML, Zhan Y, Potter D, Zhang M. 2014. Biodiversity, taxonomic infrastructure, international collaboration and new species discovery. *BioScience* **64**: 322-332. DOI: https://doi.org/10.1093/biosci/biu035

Jiménez-Barrón O, García-Sandoval R, Magallón S, García-Mendoza A, Nieto-Sotelo J, Aguirre-Planter E, Eguiarte LE. 2020. Phylogeny, diversification rate, and divergence time of *Agave* sensu lato (*Asparagaceae*), a group of recent origin in the process of diversification. *Frontiers in Plant Science* **11**: 536135. DOI: https://doi.org/10.3389/fpls.2020.536135

Knapp S. 2008. Taxonomy as a team sport. *In*: QD Wheeler. Ed. *The New Taxonomy*. Boca Raton: CRC Press. 33-53 pp. ISBN 878-0849390883

Kottek M, Grieser M, Beck J, Bruno R, Franz R. 2006. World map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrif* **15**: 259-263. DOI: https://doi.org/10.1127/0941-2948/2006/0130

Lagomarsino LP, Frost LA. 2020. The central role of taxonomy in the study of Neotropical biodiversity. *Annals of the Missouri Botanical Garden* **105**: 405-421. DOI: https://doi.org/10.3417/2020601

Lira-Charco EM, Ochoterena H. 2012. Boraginaceae. *Flora del Valle de Tehuacán-Cuicatlán* **110**: 1-105.

Lipscomb D, Platnick N, Wheeler Q. 2003. The intellectual content of taxonomy: a comment on DNA taxonomy. *Trends in Ecology and Evolution* **18**: 65-66. DOI: https://doi.org/10.1016/S0169-5347(02)00060-5

López-Ferrari AR. 1989. Araliaceae. *Flora de Guerrero*. **1**: 1-23.

Martínez M, Matuda E. 1979. *Flora del Estado de México*. Tomos I, II y III. Edición facsimilar de los fascículos publicados en los años de 1953 a 1972. DF. México: Biblioteca Enciclopédica del Estado de Méxcio.

McVaugh R. 1974. *Flora Novogaliciana.* Contributions from the University of Michigan Herbarium.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GA, Kent J. 2000. Biodiversity Hotspots for conservation priorities. *Nature* **403**: 853-858. DOI: https://doi.org/10.1038/35002501

Olson DM, Dinerstein E, Wikramanayake ED, Burgess ND, Powell GVN, Underwood EC, D'amico JA, Itoua I, Strand HE, Morrison JC, Loucks CJ, Allnutt TF, Ricketts TH, Kura Y, Lamoreux JF, Wettengel WW, Hedao P, Kassem KR. 2001. Terrestrial Ecoregions of the World: A New Map of Life on Earth. *BioScience* **51**:933-938. DOI: https://doi.org/10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2

Ortiz-Bermúdez E, Villaseñor JL, Téllez O. 1998. La familia Asteraceae en el estado de Nayarit (México). *Acta Botanica Mexicana* **44**: 25-27. DOI: https://doi.org/10.21829/abm44.1998.805

Palese R, Boillat C, Loizeau PE. 2019. World Flora Online (WFO): quality control workflow for an evolving taxonomic backbone. *Biodiversity Information Science and Standards* **3**: e35307. DOI: https://doi.org/10.3897/biss.3.35307

Raven PH, Gereau RE, Phillips PB, Chatelain C, Jenkins CN, Ulloa-Ulloa C. 2020. The distribution of biodiversity richness in the tropics. *Science Advances* **6**: eabc6228. DOI: https://doi.org/10.1126/sciadv.abc6228

Rzedowski J. 1978. *Vegetación de México.* DF, México: Limusa.

Sánchez O. 1980. *La Flora del Valle de México.* DF. México: Ed. Herrero.

Schnase JL, Kama DL, Tomlinson KL, Sánchez JA, Cunnius EL, Morin NR. 1997. The Flora of North America digital library: a case study in biodiversity data base publishing. Journal of Network and Computing Applications 20: 87-103. DOI: https://doi.org/10.1006/jnca.1996.0041

Shreve F, Wiggins IL. 1964. *Vegetation and Flora of the Sonoran Desert*. Stanford: Stanford University Press.

Sosa V, De-Nova JA, Vásquez-Cruz M. 2018. Evolutionary history of the flora of Mexico: dry forests cradles and museums of endemism. *Journal of Systematics and Evolution* **5**: 523-536. DOI: https://doi.org/10.1111/jse.12416

Standley PC. 1930. Trees and shrubs of Mexico. *Contributions from the United States National Herbarium* **23**: 1-1721.

Telenius A. 2011. Biodiversity information goes public: GBIF at your service. *Nordic Journal of Botany* **29**:378-381. DOI: https://doi.org/10.1111/J.1756-1051.2011.01167.x

Thiers BM, Tulig MC, Watson KA. 2016. Digitization of the New York Botanical Garden Herbarium. *Brittonia* **68**: 324-333. DOI: https://doi.org/10.1007/s12228-016-9423-7

Thomas WW, Tulig M. 2015. Hard copy to digital: Flora Neotropica and the World Flora Online. *Rodriguésia* **66**: 983-987. DOI: https://doi.org/10.1590/2175-7860201566404

Ulloa-Ulloa C, Acevedo-Rodríguez P, Beck S, Belgrano MJ, Bernal R, Berry PE, Bracko L, Celis M, Davidse G, Forzza RC, Gradstein SR, Hokche O, León B, León-Yánez S, Magill RE, Neill DA, Nee M, Raven PH, Stimmel H, Strong MT, Villaseñor JL, Zarucchi JL, Zuloaga FO, Jørgensen PM. 2017. An integrated assessment of the vascular plant species of the Americas. *Science* **358**: 1614-1617. DOI: https://doi.org/10.1126/science.aao0398

Vega AR, Bojórquez BGA, Hernández AF. 1989. Flora de Sinaloa. Coordinación General de Investigación y Postgrado, Universidad Nacional Autónoma de Sinaloa, Culiacán, Sinaloa, México.

Velázquez-Montes E. 2005. Discksoniaceae, Osmundaceae y Plagiogyriaceae. *Flora de Guerrero*. **24**: 1-34.
Victor J, Smith GF, Turland NJ, le Roux M, Paton A, Figueiredo E, Crouch NR, van Wyk AE, Filer D, van Wyk E. 2014. Creating an online world flora by 2020: a perspective from South Africa. *Biodiversity and Conservation* **23**: 251-263. DOI: https://doi.org/10.1007/s10531-013-0595-0
Villarreal JA, Estrada E. 2021. Asteraceae Tribu Vernonieae. *Flora de Veracruz* **188**: 1-101.
Villaseñor JL. 2016. Checklist of the native vascular plants of Mexico. *Revista Mexicana de Biodiversidad* **87**: 559-902. DOI: https://doi.org/10.1016/j.rmb.2016.06.017
Villaseñor JL, Ortiz E. 2014. Biodiversidad de plantas con flores (División Magnoliophyta) en México. *Revista Mexicana de Biodiversidad* **85**: 134-142. DOI: https://doi.org/10.7550/rmb.31987
Wheeler QD, Raven PH, Wilson EO. 2004. Taxonomy: impediment or expedient? *Science* **203**: 285. DOI: https://doi.org/10.1126/science.303.5656.285
Wiggins IL.1964. Flora of the Sonoran Desert. *In*: Shreve F, Wiggins IL, eds. *Vegetation and flora of the Sonoran Desert*. Vols. 1, 2, California: Stanford University Press.
Wiggins IL. 1980. *Flora of Baja California*. CA, USA: Stanford University Press.

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