

## Review Paper

## Mapping Asia plants: Current status on floristic information in Southwest Asia



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## ABSTRACT

Mapping Asia Plants (MAP) is a comprehensive project that aims to build a detailed infrastructure for integrating Asian plant distribution data a global-scale array of knowledge for plant biodiversity conservation. Here, we provide a brief historical review of botanical research in Southwest Asia – an understudied botanical region with high conservation priority. Nineteen countries were included in this study (from west to east): Turkey, Cyprus, Palestine, Israel, Jordan, Saudi Arabia, Lebanon, Syria, Iraq, Georgia, Yemen, Armenia, Iran, Azerbaijan, Kuwait, Bahrain, Qatar, United Arab Emirates, and Oman. We reviewed 132 resources comprising 125 Floras and Checklists, of which we describe in some detail at least one of the most important Floras or Checklists for each country. Complete and published national Floras exist for 13 countries; three countries (Jordan, Israel and Bahrain) do not have a Flora but have annotated Checklists, and national Floras are at different stages of completion for Iran, Iraq and Georgia. Where present, online resources are also given for references. We found major gaps in species concepts and taxonomic classification systems, and that many up-to-date Flora revisions remained unresolved, *i.e.* taxon ranks and species concepts varied among different countries, different systems were adopted or followed in the taxonomic treatments in the Floras and Checklists, and some of the current Floras are out of date. Floras are the first necessary step for many fields, including evolutionary biology, ecology, biogeography, and systematics, as well as environmental research and conservation of biodiversity at national and international levels. Here, we provide the progress updates on the main published floristic works of Southwest Asia, which continue to serve as references for the Flora of Southwest Asia, and will be the foundation of the MAP project.

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## 1. Introduction

Mapping Asia Plants (MAP) is a project of the Asian Biodiversity Conservation and Database Network (ABCDNet) that aims to provide infrastructure for mapping plant diversity in Asia. The MAP project will collect information and integrate Asian plant diversity data in a standardized interdisciplinary database for use in conservation and research. The central tenets of MAP are vascular plant species checklists and distribution databases (Ma, 2017).

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Southwest Asia is one of the most important regions of the world with both historical and modern significance. It was home to many of the earliest human civilizations and food crop domestication events, and has remained an area of broad geobotanical and floristic viewpoint (Ghazanfar and McDaniel, 2016; Zohary et al., 2012). Southwest Asia may be a vague region from biogeographical or floristic points of views, despite being considered a subregion of the MAP project (Heywood, 2004) and has been broken up – to various extents in the literature – into the Near and Middle East (Ghazanfar and McDaniel, 2016; Zohary, 1973). For the purpose of this paper, 19 countries in Southwest Asia are included (Fig. 1). These are (from west to east): Turkey, Cyprus, Palestine, Israel, Jordan, Saudi Arabia, Lebanon, Syria, Iraq, Georgia, Yemen, Armenia, Iran, Azerbaijan, Kuwait, Bahrain, Qatar, United Arab Emirates and Oman. Five major seas surround this area: Black Sea, Caspian Sea, Arabian Sea, Red Sea and the east part of the Mediterranean Sea.

The majority of Southwest Asia is located within the eastern limit of the Iranian plateau, the western limit of the Armenian volcanic plateau and Asia Minor plateau. This area contains dramatic changes in terrain, often in small geographic areas, such as the high mountains of Iran and northern Iraq, the Mesopotamian Plain, and the deserts of southern Iraq and Saudi Arabia. The climate ranges from cool temperate to Mediterranean, xeric, and monsoonal (Loutfy Boulous et al., 1994). The region lies in the transition zone between two floristic Kingdoms, the Holarctic and Palaetropical (Takhtajan, 1986), endowing it with rich

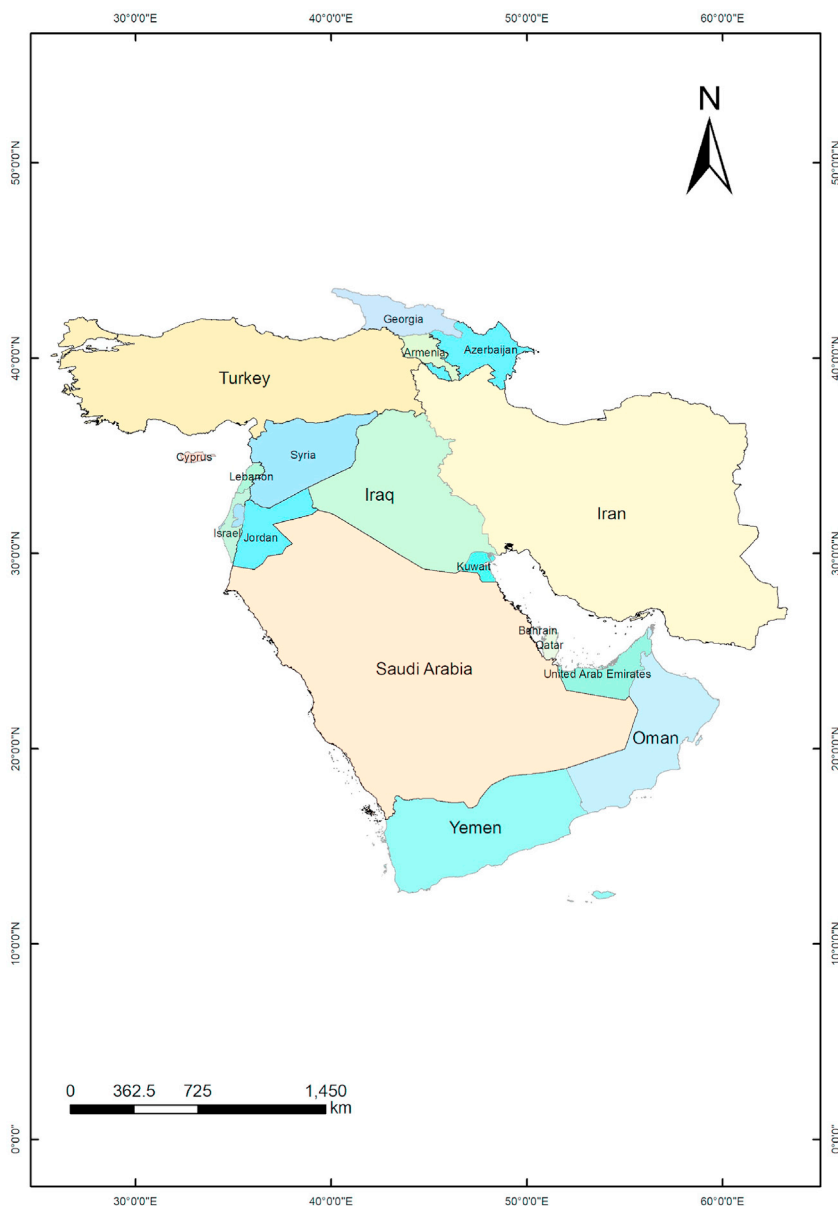


Fig. 1. The countries of Southwest Asia.

plant diversity. Moreover, the region contains the Irano-Anatolian, Mediterranean Basin and the Caucasus biodiversity hotspots — three of 36 biodiversity hotspots located in the Southwest Asia (Myers et al., 2000; Mittermeier et al., 2011).

Formal floristic exploration of Southwest Asia started in the early 1640s, but the extensive plant collections of the 19th and 20th centuries from several Southwest Asian regions are what formed the basis of the first floristic accounts. Floristic history has been reviewed in several symposia proceedings of “Plant life of South-West Asia” (Hedge, 1990, 2004; Meikle, 1971) and a short history of floristic investigations of the Middle East was made to enumerate explorers and their numerous works in this region (Zohary, 1973). Frodin (2001) gives the history and reviews of standard Floras worldwide, of which earlier references for Southwest Asia are included.

Our work aims to briefly review the most significant descriptive national and regional Floras, national Checklists and online flora resources. Our survey is not comprehensive but we have tried to include all reference works that form an essential part of floristic research in Southwest Asia.

## 2. Brief history of floristic research and publications in Southwest Asia

The earliest botanical exploration of Southwest Asia can be traced to Leonhard Rauwolf (also spelled Leonhart Rauwolff) [1535–1596], a German physician and botanist who travelled to Mesopotamia, Syria, and Jerusalem in 1573–1575 to search for herbal medicines. The botanical descriptions of new species from Rauwolf and his colleagues were published in 1578, and an English translation of his collections and travels was done by Ray et al. (1738). Another early botanist was Joseph Pitton de Tournefort [1656–1708] who visited and made collections in Turkey, Armenia, Georgia, and the borders of the Black Sea. Tournefort's classification (De Tournefort, 1718) was accepted until the time of Linnaeus' system and published in 1753 (Anon, 1956). His explorations formed the basis for Linnaeus' treatment of the Southwest Asian flora and other subsequent pre-Boissier works. Engelbert Kaempfer was among the earliest explorers in Persia (modern day Iran) in 1684–1688. His collections from different parts of Iran — particularly central and southern parts of the country — are now part of the British Museum.

With all previous botanical findings incorporated and critically revised, the earliest regional Flora is *Flora Orientalis* written by Pierre Edmond Boissier [1810–1885], a five-volume work plus a supplement (Boissier, 1867–1888). The area covered by Boissier corresponds partly to the Near East today, with some additions further east. This Flora has been a model of floristic research and flora-writing for the region, and many taxonomic concepts used in the book remain valid to the present day (Frodin, 2001).

Following Boissier's *Flora Orientalis*, plant collections expanded throughout Southwest Asia (Davis, 1968). One of the most outstanding taxonomists, Pierre de Tchihatcheff [1812–1890], journeyed in northern Anatolia and Armenia and published several volumes of *Elements d'une Flore de l'Asie Mineure* in 1866 (Zohary, 1973). Georg August Schweinfurth [1836–1925], an eminent German explorer, collected in Arabia and northeastern Africa in 1874, 1881 and 1889. His collections are housed at the herbarium of Botanical Garden and Botanical Museum, Berlin-Dahlem (B) and remain crucial for Arabian taxonomic research. A part of his work was published between 1894 and 1899 under the title of *Sammlung arabisch-äthiopischer Pflanzen*. The *Flora of Syria, Palestine and Sinai* (1st edition) was published by George Edward Post [1838–1909] (Post, 1883–1896), and became the first standard Flora for this region. Post's collections formed the basis of the herbarium in American College in Beirut, in Lebanon (Zohary, 1962, 1973).

In the 20th century, modern taxonomical approaches were applied in floristic researches (Zohary, 1962). Joseph Friedrich Nicolaus Bornmüller [1862–1948], made vast contributions to the knowledge of the Southwest Asian flora and published nearly ten Floras between 1905 and 1942 (Zohary, 1973). The second edition of Post's *Flora of Syria, Palestine and Sinai* written by John Edward Dinsmore [1862–1951] (Dinsmore, 1932–1933), presented many new species and updated nomenclature. The *Flora Kavkaza* essayed by Alexander Alfonsovich Grossheim [1888–1948] is the only complete Flora of Caucasus (Grossheim, 1928–1934 (1st edition), 1939–1967 (2nd edition)). Subsequent novelties were included in *Flora of the USSR*, initiated by Vladimir Leontjevich Komarov [1869–1945] (Komarov, 1934–1964). Grossheim's 2nd edition of *Flora Kavkaza* (Grossheim, 1939–1967, incomplete) and *Opredelitel' Rastenij Kavkaza* (Grossheim, 1949) remain very important works. Recent progress in this area includes the *Caucasian Flora Conspectus* (Takhtajan, 2003–2016); but, unfortunately, the conspectus is incomplete, and only four volumes have been published to date.

The mid-20th century has been considered as the “Great Age of Floras” in botanical history (Frodin, 2001; Meikle, 1971). At that time there was an emphasis on writing modern scientific Floras throughout the world to resolve taxonomic and nomenclatural issues. For Southwest Asia, several national Floras started more-or-less simultaneously in the 1960's based on extensive collections in countries by avid collectors such as Peter Hadland Davis [1918–1992] (Turkey), Karl Heinz Rechinger [1906–1998] (Iranian plateau), Michael Zohary [1898–1983] (Palestine, Syria), Evan Rhuvon Guest [1902–1992] (Iraq) and Paul Mouterde [1892–1972] (Lebanon). These Floras, such as *Flora of Turkey and the East Aegean Islands* (Davis, 1965–1985, 1988; Güner et al., 2000), *Flora Iranica* (Rechinger, 1963–2015, incomplete), *Flora Palaestina* (Feinbrun-Dothan, 1978–1986; Zohary, 1966–1973), *Flora of Iraq* (Ghazanfar et al., 2013–2019; Guest and Al-Rawi, 1966; Townsend et al., 1966–1985, incomplete), and *Nouvelle Flore du Liban et de la Syrie* (Mouterde, 1966–1983) are descriptive Floras that provide deep knowledge on the plant diversity of Southwest Asia. These texts were, and still are, used for plant identification and as a source of other regional floristic information.

*Conspectus Florae Orientalis* (1980–1994) is a quintessential example of the advanced floristic research of the mid-20th century and serves as a supplement to Boissier's *Flora of the Middle East* (Zohary et al., 1980–1994). Concentrating only on

the countries of the Arabian Peninsula, *Flora of the Arabian Peninsula and Socotra*, Vol. 1 (Miller and Cope, 1996) and Vol. 5 (part 1) (Cope, 2008) intended to publish 3500–4000 species in 5 vols but remains incomplete. To implement the *Conspectus Florae Orientalis* project (Zohary et al., 1980–1994), the Organization for Phyto-Taxonomic Investigation of the Mediterranean Area (OPTIMA) was established in 1974. This international community gathers experts from different countries to exchange data and taxonomic and nomenclatural information relating to plants of the Mediterranean area. OPTIMA conferences are held periodically, and the 16th conference was held in Greece in October 2019.

The 300th anniversary of the foundation of the Royal Botanic Garden Edinburgh fell during the preparation of the *Flora of Turkey and the East Aegean Islands* (Davis, 1965–1985, 1988; Güner et al., 2000). To celebrate, “Plant Life of Southwest Asia” (PloSWA) meetings were established, which would be held regularly, dedicated to taxonomic and floristic development in Southwest Asia. The first meeting was held at the Royal Botanic Garden, Edinburgh in June 1970. The meetings have been continued every two or three years (with some disruptions), and have been held at various venues including Berlin (Germany), Izmir (Turkey) and Tashkent (Uzbekistan). The 10th Symposium was held in Karachi (Pakistan) in February 2020 to celebrate the completion of the *Flora of Pakistan* (Qaiser and Abid, 1971–2020). The Center for Middle Eastern Plants (CMEP) was established in 2009 as a distinct unit within the Science Directorate of the Royal Botanic Garden Edinburgh (RBGE). CMEP aims to initiate and undertake projects in Middle Eastern countries, such as Lebanon Red Listing (Forrest et al., 2013).

### 3. Key publications on the flora of countries in Southwest Asia

Appendix S1 presents the complete list of regional and national Floras. The main features of these Floras are highlighted as below (bold in Appendix S1 and with hyperlinks when available).

#### 3.1. Regional floras

*Flora Orientalis*, Vols. 1–5; supplement 6 (Boissier, 1867–1888).

*Flora Orientalis* was written in Latin and published before the International Code of Nomenclature. 131 genera and 5990 taxa are described, many for the first time, including those described in Boissier's *Diagnoses Orientalum Plantarum Novarum*. Despite the obsolete nomenclature and incomplete information, the Flora is still a broad and accurate review and reference of floristic and taxonomical knowledge of this area, and many taxonomical delimitations are still valuable (Löve, 1968). Narrow species concepts are adopted in the Flora, but are frequently quite justified (Stafleu, 1970a). Botanical exploration, floristic regions, limits of the Flora, as well as philosophical and methodological considerations are covered in volume 1.

*Conspectus Florae Orientalis*, Vols. 1–9 (Zohary et al., 1980–1994).

The *Conspectus Florae Orientalis* lists 200 families, 2543 genera and 18,377 vascular species. Accepted names, synonyms, distribution, new species, etc. are encompassed. The order of families follows the Engler-Diels Syllabus (ed. 12) (Melchior and Werderma, 1964) and species are arranged alphabetically within genera. The Flora also enumerates a list of key references and phytogeographical data for each taxon.

#### 3.2. Turkey

*Flora of Turkey and the East Aegean Islands*, Vols. 1–9 (Davis, 1965–1985); vol. 10 (Davis et al., 1988); Vol. 11 (Güner et al., 2000).

Volume 9 marks the completion of *Flora of Turkey and the East Aegean Islands*, and volumes 10 and 11 contain new taxa, records and additional information. The Flora further covers most of the eastern islands of the Aegean Sea (part of Greece) excluded from *Flora Europaea* (Tutin et al., 1964–2010) that have floristic similarities to Anatolian. A total of 9753 taxa belonging to 1146 genera and 163 families are described and included in identification keys. Extensive synonyms with references, distributions together with maps, habitat descriptions, phytogeographical information etc. are included. The order of the families is based mainly on Boissier's *Flora Orientalis*, but with some revisions according to modern taxonomic concepts (Merton, 1969; Nelson, 1966; Pickersgill, 1968). This Flora further includes some cultivated and alien plants which were often neglected or dismissed in earlier compendia (Rowley, 1971). The Flora was produced for scientific purposes (Stafleu, 1966) and remains the main reference for the region and a necessary addition to the collections of libraries and herbaria worldwide (Nelson, 1966).

*Check-List of Additional Taxa to the Supplement Flora of Turkey*, I–IX (Özhatay et al., 1994, 1999, 2009, 2011, 2013, 2015, 2017, 2019, Özhatay and Kültür, 2006).

An additional 1685 taxa, 1238 new species and new records for 447 taxa are enumerated for the Turkish flora in a series of Checklists.

*Türkiye Bitkileri Listesi*, Damarlı Bitkiler (Güner et al., 2012); Karayosunları (Erdağ and Kürschner, 2017); (Taskın, 2019), incomplete.

*Türkiye Bitkileri Listesi* was proposed to be in 30 vol, three of which have been published so far. It is a contribution from 102 scientists under the editorship of Adil Güner, and is the first step in producing the Illustrated Flora of Turkey in the Turkish language. This is a Checklist of all known plants of Turkey with all plants given vernacular (Turkish) names. Detailed botanical drawings accompany each species.



### 3.3. Cyprus

*Flora of Cyprus*, Vols. 1–2 (Meikle, 1977–1985).

The earliest national bibliography devoted exclusively to Cyprus is *Flora of Cyprus*, which is considered to be different from the 'Kew Style' Floras, and represents an important step in understanding the flora of the Eastern Mediterranean (Davis, 1979; Holub, 1979). A special part of this book includes a modified Bentham and Hooker's system of Genera Plantarum for a taxa survey (Holub, 1979). The taxonomic concepts in this flora vary significantly, e.g. a rather broad concept for genera *Althaea* (incl. *Alcea*), *Delphinium* (incl. *Consolida*), etc., but a narrower concept in *Kohlruschia* and *Turritis* (Holub, 1979). Nomenclatural types are always given and some of them determined here for the first time (Holub, 1979).

This edition comprises 1712 taxa, 636 genera, and 128 families, accepted names and synonyms are given with full literature citations. The identification keys to genera and species are particularly practical, and a key to families is included in the 2nd volume.

*Illustrated Flora of Cyprus* (Christofides, 2017).

In this illustrated Flora, 1805 species in 654 genera and 116 families (excluding Poaceae) are described with vernacular language. New records, recent taxonomic changes, keys for difficult genera, distribution, phenology, and conservation status are incorporated in the book, as well as and photographs of representative species from each genus. Most endemic species, bulbs and orchids are illustrated.

### 3.4. Palestine, Israel, and Jordan

*Flora Palaestina*, Vols. 1–2 (Zohary, 1966–1973); Vol. 3–4 (Feinbrun-Dothan, 1978–1986).

This is the first Flora to include Palestine, Israel, western Jordan, the West Bank and the Gaza Strip. The Flora treats about 2400 species in 818 genera and 130 families. The applied species concept, with some exceptions, follows a biosystematic approach (Löve, 1968). Brief but adequate description notes on habitat and phenology are also included. The Flora is presented in eight volumes (four of text and four of illustrations, where every species is illustrated), which makes for an exemplary Flora (Löve, 1968).

*Checklist and Ecological Data-Base of the Flora of Israel and its Surroundings* (Fragman et al., 1999).

This Checklist covers Israel, Palestine, Jordan and the Sinai Peninsula (Egypt). It treats almost 3000 species. Native, alien and endangered species are specified. Basic geographic and climatic distributions, growth forms, chorotypes, and abundance are given for each species.

*The plants of Jordan – An Annotated Checklist* (Taifour and El-Oqlah, 2017).

Initiated by an EU project, it is the first Checklist produced for Jordan as a precursor to a descriptive Flora. It covers 2531 species belonging to 112 families of vascular plants. At least one specimen or a reference to the species name is cited or given for each taxon. Families names and circumscription follow the Angiosperm Phylogeny Group (APG IV) system of classification, but specific and generic names are arranged alphabetically within each family. Taxa have been updated based on recent classification and nomenclature. The introduction contains an account of vegetation habitats, biogeography, and list of herbaria (national and international) used for the preparation of the Checklist.

### 3.5. Saudi Arabia

*Flora of Saudi Arabia*, 1st edition (Migahid and Hammouda, 1974); 2nd edition (Migahid, 1978); 3rd edition, Vols. 1–3 (Migahid, 1988–1989); 4th edition, Vol. 1 (Migahid, 1996, incomplete).

Migahid's *Flora of Saudi Arabia* was the first attempt to describe the vascular plants of the country. Four editions were produced. The 1st edition included descriptions of taxa, the orders and families of vascular plants, and identification keys for families and genera. Color illustrations and more than 100 new species were added in the 2nd edition. The 3rd edition is an atlas-flora in 3 vols, but without keys. It covers 115 families (6 more than in previous editions), 30 additional genera, and 156 species and varieties newly recorded in the country. The 4th edition of *Flora of Saudi Arabia* is also an atlas-flora that enumerates 98 families of vascular plants.

*Flora of Eastern Saudi Arabia* (Mandaville, 1990).

This Flora has been the standard work for eastern Saudi Arabia for a long time and have been praised for both its accurate descriptions and completeness (Wilcock, 1991). It includes 565 species, 322 genera, and 73 families illustrated with 270 photographs. Information on habitat, distribution, and economic uses follow the description of each species. The user-friendly keys are a model for any Floras (Wilcock, 1991), and the sequence of families follows Stebbins' (1977) *Evolution above the species level* based on the classification of Cronquist (Wilcock, 1991). The introduction presents a short history of botanical investigations, geography, climate, and vegetation of the region.

*Flora of the Kingdom of Saudi Arabia*, Vols. 1–3 (Chaudhary, 1999–2001).

This descriptive Flora is an important and comprehensive reference to the plants of Saudi Arabia, the country richest in species in the Arabian Peninsula. It includes 2282 taxa, with keys to genera and species, as well as vernacular names; most species are illustrated. The introductory chapter delineates the historical geography, geology and ecology, soil and meteorology, and the natural vegetation.

### 3.6. Lebanon and Syria

*Flora of Syria, Palestine and Sinai*, Vols. 1–2 (Dinsmore, 1932–1933).

A total of 142 families, 955 genera and 4200 vascular plant species are documented in this Flora, with good dichotomous keys to families, genera, and species. The arrangement of families and genera follows the Candolle system as in *Flora Orientalis* (Boissier, 1867–1888). Common names of plants in English and Arabic are added after the Latin names and many plant species are accompanied with line drawings in the text. This Flora has been the only English plant guide and informative Flora of this region for many years, but it has serious shortcomings, such as brief descriptions and some poor keys that are of little value to users (Meikle, 1968).

*Nouvelle Flore du Liban et de la Syrie*, Vols. 1–3 (Mouterde, 1966–1983).

Lebanon and Syria have always been grouped together for floristic purposes, partly for historical reasons (both were under French mandates after World War I). The first volume of Zohary's *Flora Palaestina* (1966) and Mouterde's Floras were almost simultaneously published, and represent the latest manifestation of floristic research in the Near East (Davis, 1968).

Over 3600 species, 910 genera, and 139 families are dealt with in this Flora. Species description are brief with notes on ecology, distribution, and citations of collections. This Flora covers a less well-studied area and offers new combinations and descriptions for numerous taxa (Davis, 1968). The Flora adopts the Engler system, as in *Flora Palaestina*, but the species concept is somewhat narrower than that of Zohary's Flora (Davis, 1968). Serious omissions include the keys to families and genera, which is a disadvantage for users (Kramer, 1968). Nevertheless, it remains the most comprehensive and a standard reference for Lebanon and is likewise the most important Flora for Syria.

*Illustrated Flora of Lebanon*, 1st edition (Tohmé and Tohmé, 2007); 2nd edition (Tohmé and Tohmé, 2014).

The 1st edition assembles 124 families, 757 genera and 2597 vascular plant species, following the nomenclature of Mouterde's Flora. There are 2612 wild plants belonging to 792 genera and 132 families in the 2nd edition in both English and French. Plants are arranged in alphabetical order of families, genera, and species in both editions. Additional information about new localities or if the species is extinct are given in the 1st edition. In the 2nd edition, besides additional localities for many species, 119 new species were added.

### 3.7. Iraq

*Flora of Lowland Iraq* (Rechinger, 1964).

This masterful flora of Iraq, excluding the highlands, includes description of 74 families, 460 genera, and 1289 species. Keys to genera and species, descriptions, synonymy, distribution including altitude, and citations of individual collections are listed.

*Wild Plants of Iraq: with Their Distribution* (Al-Rawi, 1964).

This annotated systematic list contains 3300 species, 908 genera and 136 families of vascular plants of Iraq. Physical features, climate, vegetation, floristic zones, and progress in botanical exploration are described in the introductory part; indices to generic and family names and the geographical distribution of Iraqi plants are essayed.

*Flora of Iraq*, Vol. 1 (Guest and Al-Rawi, 1966); Vol. 2, Vol. 9 (Townsend et al., 1966–1968); Vol. 3 (Townsend and Guest, 1974); Vol. 4(1)–4(2); Vol. 8 (Townsend et al., 1980–1985); Vol. 5(1)–5(2) (Ghazanfar and Edmondson, 2013–2016); Vol. 6 (Ghazanfar et al., 2019), incomplete.

The complete Flora was planned in nine volumes, including historical collections from 180 to 50 years ago (Beentje, 2014). A background of Iraq's flora and vegetation is provided in the introductory volume. Volumes 2, 3, 4 (1), 4 (2), 8 and 9 appeared from 1965 to 1985, dealing with almost 1800 species of the estimated 3300. Vol. 5(1) and 5(2) published in 2013 and 2016, respectively, describe 27 families. Vol. 6, describing the Compositae, was published in 2019. The final volume (Vol. 7) will include 11 families of which Lamiaceae, Boraginaceae, and Scrophulariaceae are the richest in species. The descriptive part follows Hutchinson's system of classification (Davis, 1967; Hutchinson, 1959), and is retained in newly published volumes with explanatory notes on the treatment of families in the APG IV classification. Large numbers of line drawings are one of the most helpful features of the *Flora of Iraq* (Davis, 1975). The taxonomic treatment of genera and species are moderately conservative, and broadly agreed with *Flora of Turkey and the East Aegean Islands*, but with some well-justified reductions (Davis, 1975).

### 3.8. Georgia

*Flora Gruzii* Vols. 1–8, 1st edition (Makashvili et al., 1941–1952).

About 4100 species, 881 genera, and 134 families of Georgian vascular plants are described following the Engler classification system. Species distributions are given in accordance with a scheme of botanical divisions of Georgia. The 1st edition of the Flora was finished before the edition of *Flora of USSR* (1934–1964) was completed and is the reason why the nomenclature and taxonomy of plants in these two books differ.

*Flora Gruzii*, Vols. 1–16, 2nd edition (Ketskhoveli et al., 1971–2011, incomplete).

Sixteen volumes of the Flora have been published including 3874 species, 901 genera, and 171 families. Volumes contain identification keys for all genera and species. Rare and endemic species are accompanied by distribution maps.

*Vascular Plants of Georgia, a nomenclatural checklist* (Gagnidze, 2005).

There are 182 families, 1016 genera and 4130 species in the Checklist, mainly based on the 2nd edition of the *Flora Gruzii* of Vols. 1–14 (Ketskhoveli et al., 1971–2003), including the unpublished 15th volume at that time. The extent of the families and their arrangement traditionally corresponds to the Engler system.

*Nomenclatural Checklist of flora of Georgia* (Nakhutsrishvili, 2018).

The Checklist includes 185 alphabetically ordered families, 1048 genera and 4275 vascular plant species, all in alphabetical order. The Checklist is also based on the 2nd edition of the *Flora Gruzii* of Vols.1–16 (Ketskhoveli et al., 1971-2011), including the unpublished 17th volume (Poaceae) and new materials from herbaria and new publications. The taxonomy is critically revised and compared with the current fundamental work on *Caucasian Flora Conspectus* (2003–2012).

### 3.9. Yemen

*Handbook of the Yemen Flora (Northern Yemen)* (Wood, 1997).

This handbook was written in 1982 but remained unpublished until 1997, but does include updates. This is the first complete account of vascular plants occurring in North Yemen before its union with Southern Yemen. The handbook covers 1750 species, 768 genera and 151 families of plants with a brief description and notes on species distribution. It also includes appendices with Arabic plant names, a list of poisonous plants, a list of geographical names and indices to genera and families. A botanical history, topographical regions, and vegetation types are given in the introduction. Cronquist's system of classification is followed. Dichotomous identification keys are provided only for genera and species (Hjertson, 1999). As for the species with uncertain taxonomy, the author preferred to give a provisional informal designation than a valid description of new names (Kaplan, 2001).

*Flora of Yemen* (Al-Khulaidi, 2013).

This is a Checklist that is a part of report funded by United Nations Development Programme (UNDP) implemented by the Agricultural Research and Extension Authority of Yemen. It lists 179 families, 1068 genera, and 2838 species based on extensive field work carried out from 1990 to 2012 by author. Families and genera are arranged alphabetically. Synonyms, distributions and vernacular names are given for all taxa — which are illustrated by photographs. Classification and nomenclature follow the APG IV system. Due to constraints, plant distribution data is limited especially for southeastern part of Yemen. The Checklist is an important contribution to the knowledge of plants and the biogeography of southern Arabia.

### 3.10. Armenia

*Flora Armenii*, Vols. 1–11 (Takhtajan, 1954-2009).

This is the first Flora in Armenia written in Russian. In the Flora, 156 families, 879 genera, and 3260 species are listed. The 11th volume also includes a non-critical list of additional 4 new families, 33 genera, 445 species, and 16 subspecies. Representatives of all genera and about one-third of the species are shown using line drawings. Keys are provided to the families, genera, species and subspecies. A generic description of species and subspecies is characterized by habitat descriptions, distribution in Armenia by floristic regions, and the total range, also with original pollen delineation. Critical comments are given for many species, and the basionym is listed first among the synonyms (Fedorov, 1971). The 10th volume does not split genera into many narrowly defined units as many other Floras or Checklists of the former Soviet Union, and follows traditional concepts comparable with the most recent West-European Floras (Kaplan, 2003).

### 3.11. Iran

*Flora Iranica*, Vols. 1–181 (Rechinger, 1963-2015), incomplete.

*Flora Iranica*, is a cooperative international effort, written by more than 100 taxonomists from 20 countries including Austria, Germany, UK, Sweden, and Netherland, etc. (Akhani, 2006). It deals with a natural boundary (Sales and Hedge, 2013) stretching from North Iraq, east to Pakistan and Sind river, and north to the highlands of Azerbaijan (Talış) and Turkmenistan — an area crucial to the phytogeography of southwestern Asia (Constance, 1988).

181 fascicles have been published which include almost 12,000 species, 1500 genera and 170 families. Completion of *Flora Iranica* is awaiting the remaining volume, ferns and fern-allies. Being a multi-authored Flora, it is based mainly on herbarium material, and in some instances limited to a few sheets with limited or no field knowledge by the authors (Akhani, 2006). Descriptions, as well as keys to the genera and species are in Latin; key literature references are provided. The citation of specimens seen makes this Flora very useful for this region where herbaria are generally poor, but specimens cited may be available on-line from major herbaria in Europe and the United Kingdom.

Even though the Flora is written in Latin and difficult to follow at times, it is one of the most important sources on the flora of Iran, Afghanistan and adjacent areas, and will remain so for some time (Akhani, 2006; Stafleu, 1970b).

*Color Flora of Iran*, Vols. 1–27 (Ghahreman, 1976-2014, incomplete).

Different plant species of Iran are illustrated with high-quality photos, presenting information mostly in three languages: Farsi, French, and English. Distribution maps and habitat notes are given for each taxon. It is expected in 80 vol of which 27 have been published that include about 3000 species from more than 150 families.

*Flora of Iran*, Vols.1–149 (Assadi, 1989-2018, incomplete).



Another published contribution to the plants of Iran is the *Flora of Iran*, written in Farsi. So far 149 fascicles including the Pteridophytes have been published. Almost 6500 plant taxa in 145 plant families are enumerated in the Flora following Cronquist's system of classification. Grid maps are given for each species. Detailed descriptions, synonyms, geographical distribution, habitat, and phenology are also given. One of the most helpful features of this flora is the line-drawings of the many species described.

*Biodiversity of Plant Species in Iran*, Vol. 1 (Ghahreman and Attar, 1999).

The *Biodiversity of Plant Species in Iran* was originally planned to be published in three volumes, but only the first one has been published. The first volume includes several sections: the vegetation of Iran, an updated Checklist of plant species, endemic species, and rare and threatened species. 167 families, 1215 genera and 7576 vascular taxa (species and subspecies) are listed.

Besides the national Flora mentioned above, there are also some subregional Floras such as *Flora of Ilam* (Mozaffarian 2008), *Flora of Khuzestan* (Mozaffarian 1997), *Flora of Gilan* (Mozaffarian 2019), *Illustrated Flora of Golestan National Park* (Akhani 2005), *Plants and vegetation of north-west Persian Gulf: the coasts and islands of Khore Musa, Mahshahr and adjacent areas* (Akhani 2015), etc.

### 3.12. Azerbaijan

*Flora Azerbaydzhana*, Vols. 1–8 (Karjagin, 1950–1961).

A total of 125 families, 900 genera and 4027 species are documented in the Flora. Keys are provided for genera and species. A concise description of genera and species, relevant synonyms, and hand-drawn pictures for some species are contained.

*Flora of Azerbaijan (1961–2009) - Additions and Changes* (Äsgärov, 2011).

This is a Checklist written in Azerbaijani, with 176 families, 1142 genera and 5000 species. After the priority names of families and genera arranged alphabetically, species, their synonyms and their distributions across five large botanical-geographical regions of Azerbaijan are presented.

*Flora of Azerbaijan: Higher Plants – Embryophyta* (Äsgärov, 2016).

This book in Azerbaijani includes wild flora prevalent in the country and provides detailed information about 4557 species. About 400 rare and/or endangered species, their conservation status, and how they could be preserved for future generations gives value to this Flora.

### 3.13. Kuwait

*Flora of Kuwait*, Vol. 1 (Daoud, 1985); Vol. 2 (Al-Rawi, 1987).

This outstanding two volume contribution was the first written Flora of Kuwait. Volume 1 covers most of the dicotyledonous plants comprising 210 species belonging to 129 genera in 37 families and Volume 2 covers Compositae and the monocotyledons comprising 73 genera belonging to 103 species in 8 families. The family arrangement follows the Hutchinson's classification system. Identification keys to families, genera, and species, and references for the type specimens, as well as within-country distribution ranges of species are documented. For most species, synonyms are given.

*Checklist of the Flora of Kuwait* (Boulos and Al-Dosari, 1994).

This Checklist updates the *Flora of Kuwait*, with 374 species belonging to 55 families of native and naturalized vascular plants (except cultivated plants) listed with their authorities and references. Synonyms given mainly to refer to earlier published names.

*Checklist of the Flora of Kuwait-Ph.D. Thesis* (Abdullah, 2017).

This latest and updated Checklist is part of the author's Ph.D. research on conserving flora through DNA barcoding techniques. It lists 400 species from 254 genera belonging to 58 families following APG IV. This chapter summarizes the latest status of knowledge of plants in Kuwait, including family names, nomenclatures, authorities, common synonyms, floristic analyses and plant status are included.

### 3.14. Bahrain

*The Wild Flowering Plants of Bahrain – an Illustrated Guide* (Cornes and Cornes, 1989).

The work provides the first good overview of desert plant diversity of Bahrain's flora. There are 55 families, 175 genera, and 254 species described. Identification key charts, a glossary, bibliography, and references, and an index of plant names are contained. Plants are described according to the Takhtajan and Cronquist systems, except where an alternative arrangement is suitable.

*A Checklist of Vascular Plants of Bahrain* (El-Oqlah and Abbas, 1994).

It lists 307 species, 198 genera, and 54 families of vascular plants, but without any specimen citations or distribution data (Al-Eisawi, 2001). This was followed by an addition of two families, five genera, and 14 species to the Checklist of flora in Bahrain (Al-Eisawi, 2001).

### 3.15. Qatar

*Ecology and Flora of Qatar* (Batanouny, 1981).

This is one of the earliest standard floras for Qatar, systematically describing 301 species, 207 genera and 55 families. The ecology section gives the main vegetation types for saline and non-saline habitats; most of non-saline habitats are dominated by grasses and chenopods.

*An Illustrated Checklist of the Flora of Qatar* (Norton et al., 2009).

The Checklist lists all species of vascular plants occurring in Qatar, including 63 families, 260 genera, and 397 species. Families and species are arranged in alphabetical order. Synonyms, vernacular names, growth form, and flowering periods are also contained.

*Flora of Qatar*, Vols. 1–2 (Bary, 2012).

The Flora is in two volumes, well-illustrated with photographs, and includes 383 species in 66 families, following the APG III system. Descriptions include life form, habitat and distribution, and local names in both Arabic and English. The introduction describes the main features of Qatar's geography and vegetation.

### 3.16. United Arab Emirates

*The Comprehensive Guide to the Wildflowers of the United Arab Emirates* (Jongbloed et al., 2003).

The book presented the 20-year work essential for anyone studying plant species of the UAE. There are 775 species and 81 families of plants including various records, and descriptions based on specimens collected in the UAE. Synonyms are given after the accepted scientific names if necessary. Descriptions are non-technical and brief, but give the main features of the plants; additionally, flowering time, habitat, distributions and traditional uses are given briefly.

*Flora of the United Arab Emirates*, Vols.1–2 (Karim and Fawzi, 2007).

There are 600 species noted in the book, including about 70 taxa not enumerated in earlier works. Line illustrations are given for several taxa.

### 3.17. Oman

*Flora of Oman*, Vols. 1–4 (Ghazanfar, 2003-2018).

This four-volume comprehensive Flora is a key published contribution to the native plants of Oman, which contains 1209 taxa from 118 families. Cronquist's classification system is followed, with explanatory notes to the APG IV classification where the classification and nomenclature of taxa differ (Byng et al., 2016). Identification keys are provided for genera and all species. Species descriptions accompanied by relevant synonyms and vernacular names. Notes on distribution, habitat, flowering and fruiting times, conservation status, and any uses are also listed. Grid maps for the presence of each taxon in a 25 km<sup>2</sup> area are a unique feature of this Flora. The first three volumes are accompanied with a CD-ROM of plant photos, and the fourth volume gives links to photos on an accompanying published site.

## 4. Web resources to corresponding countries

With the popularization of informatics techniques to floristics, the replacement of traditional methods of writing Floras by continually updated databases is seen as irresistible and inevitable (Pankhurst, 2004). This will hopefully lead to a global biodiversity information system (Bisby, 2000), and improve the way floristic data are assembled, circulated, reviewed and accessed. Such online databases have been established in Southwest Asia and outlined below.

*Euro + Med PlantBase* (<http://www.emplantbase.org>) (Euro + Med, 2006) partly overlaps with the Southwest Asia region, involving all countries of Europe and the Mediterranean region (i.e. Georgia, Armenia, Azerbaijan, Syria, Israel, Turkey, Lebanon, Palestine, and Cyprus). The Euro + Med database integrates regional and national Floras and Checklists from the area, as well as additional taxonomic and floristic literature.

*Flora of Turkey* (<https://www.bizimbitkiler.org.tr/v2/liste.php>) currently records 11,707 species and subspecies or varieties. Turkish names of the vascular plants, along with distribution maps and some taxonomic notes, can be found in the database.

*Flora of Cyprus – a Dynamic Checklist* (<http://www.flora-of-cyprus.eu>) (Hand et al., 2011-) provides access to a total of 2027 taxa (species and subspecies), where: 1649 taxa are indigenous on the island, 254 taxa are introduced and occurring in the wild, 43 are hybrids, and 81 species have unclear statuses.

*Flora Syria On Line* (<http://www.florasyrria.com>) is in Arabic, listing about 1200 species of which 561 species with photos and illustrations, as well as distribution maps of species that have special importance.

*Flora of Israel Online* (<http://flora.org.il/en/plants>) (Danin and Fragman-Sapir, 2006-) contains all plant species from Israel, the Palestinian territories and western Jordan. It lists 2943 species from 910 families, with scientific information supplemented by images, distributions and morphological features data, etc.

*Lebanon e-flora* (<http://www.lebanon-flora.org>) (Bou Dagher et al., 2013) brings together all the floristic information available for Lebanon in a systematic and consistent way. It provides access to a total of 2500 species and subspecies. For each species, an identifying sheet is made available containing botanical, ecological, and genetics information.

*Plant Diversity in Saudi Arabia: Flora of Saudi Arabia-Checklist* (<http://www.plantdiversityofsaudi Arabia.info>) (Thomas, 2011) is displayed in a table format with columns of topography, vegetation, flora, history of botanical studies, herbarium, literatures, natural resources, and floristic checklist. The Checklist contains 2285 species, belonging to 855 genera and 131 families.

*e-Flora of Sultanate of Oman* (<http://omanflora.myspecies.info/en>) (Oman, 2019) is being developed; so far it only contains 49 species, 29 genera and 4 families.

## 5. Status, limitations and ways forward

Southwest Asia is a vast area with mountains, plateaus, and depressions, unique temperate forests, Mediterranean scrub, open dry forests, grasslands, dunes and gravel deserts (Ambarli et al., 2018; Browicz, 1982; Zohary 1973). Some areas of this region were investigated and documented long ago, resulting in standard, or even landmark, Floras such as *Conspectus Florae Orientalis*, *Flora of Turkey and +the East Aegean Islands*, and *Nouvelle Flore du Liban et de la Syrie*, etc. For some countries, such as those of the Arabian Peninsula, formal investigation and documentation of the flora and vegetation were developed in the 1980s. Too often, floristic research has been neglected due to a lack of funds and interest in vegetation surveys; hence, many Floras remain unfinished. Most of the development of floristic studies of the past few decades are thanks to professional studies conducted by many explorations of European botanists.

According to our statistics (which remain incomplete), there are at least 132 Floras, Checklists, and online resources devoted to the flora of countries of Southwest Asia. Countries can be arranged by the status of their most important documents (Appendix S2: Table 1): 1) countries only having national Checklists (Bahrain, Jordan, Israel, and Yemen); 2) countries with incomplete national Floras (Iran, Iraq, and Georgia); 3) countries with published Floras requiring major update/revision (Syria, Lebanon, Palestine, Kuwait, Cyprus, Azerbaijan, Turkey (majority parts of this flora were published before 2000)); and 4) the countries with recently published Floras (after year 2000) (Oman, Saudi Arabia, Qatar, the United Arab Emirates, and Armenia).

A limited number of copies of publication of some Floras such as *Flora of the Kingdom of Saudi Arabia* and *Flora of Qatar*, and their unavailability is a major issue. Besides their rarity, some Floras are priced exorbitantly — making them out of reach for many researchers. Language barriers (if written in national languages) are another issue hindering taxonomic works in Southwest Asia, and notes on ecology, uses, and distributional information are often difficult to follow. *Flora of Azerbaijan (1961–2009) - Additions and Changes* (2011) and *Flora Gruzii* (1971–2011, incomplete) published in Azerbaijani, and Georgian, respectively, are two examples. The various classification systems adopted in different Floras in Southwest Asian countries also pose an issue, and cause remarkable changes in taxonomic position within and between studied plant families. For instance, Cronquist's classification system was used in majority of volumes of the *Flora of Iran* (1989–2018, incomplete), Engler's system in *Flora Gruzii* (1971–2011, incomplete), the Candolle system in *Flora of Syria, Palestine and Sinai* (1932–1933), and APG IV in *Flora of Qatar* (2012), *The plants of Jordan-An annotated checklist* (2017) and the *Lebanon e-flora*. In *Flora of Syria, Palestine and Sinai*, the genus *Alhagi* is in the family Papilionaceae of the Candolle system, but in the family Leguminosae of Engler's system in *Flora Gruzii* (2<sup>nd</sup> edition), and in the family Fabaceae of APG IV in *The plants of Jordan-An annotated checklist*.

Many of the larger southwestern Asiatic Floras were worked out and published in Western Europe. Generic and species concepts adopted in different countries' Floras pose inconsistencies in species delimitation of a wider regions. National traditions and schools of taxonomy in different countries have led to the situations where the same species may be treated quite differently (Heywood, 1967). For example, the monographic *Flora of the former USSR* is based on a narrow species concept of V. L. Komarov (Kirpicznikov, 1969; Lavrenko, 1965), and many of the national Floras of Caucasian countries follow that (Fedorov, 1971). On the other hand, a fairly broad generic and species concept was adopted in the *Flora of Turkey* and two infra-specific categories — subspecies and variety — are recognized in this *Flora* (Davis, 1965–2011).

Taxonomy and species conservation are often assumed to be inseparable. The lack of taxonomic information and the confusion of species concepts cause problems for biodiversity conservation (Mace, 2004). One important step for developing a regional Checklist of vascular plants is to assess the most important available taxonomic resources in the region. World Checklist of Vascular Plants (WCVP, <https://wcvp.science.kew.org/>), Plants of the World Online ([www.plantsoftheworldonline.org](http://www.plantsoftheworldonline.org)) and Catalogue of Life (CoL, <http://www.catalogueoflife.org/>) (Roskov et al., 2019) might be applied as the standards to harmonize and compile the species list of the Southwest Asia. The compilation approach taken will only be effective if the synonyms are properly worked out, but will promote the development of a relatively reliable list of taxa that will inform a range of fields, such as conservation, distribution mapping, evolutionary biology, ecology, phytogeography, and biosystematics.

Since the beginning of the 19th century, diverse floristic knowledge initiated in Southwest Asian countries has been available in different forms of taxonomic treatments, such as *Flora books*, *Checklists*, *Monographs*, and *online databases* — the most important of which are mentioned above. Indeed, the future harmonization of taxonomic treatments among these Floras will depend to some extent on the willingness of researchers to take on the treatment of entire families or large genera across their ranges rather than in geographical slices.

Centralized databases allow taxonomists to work on dynamic floristic treatments, i.e., CoL, IPNI, IOPI, etc. (Brach and Song, 2006). The integration of distribution data from Southwest Asia into a global scale array of knowledge is critical for conservation of plant diversity both at national and international levels. To meet the Global Strategy for Plant Conservation

(GSPC) Target 1 (Paton and Lughadha, 2011), the Plants of the World Online Portal (POWO) was launched by the Royal Botanic Gardens, Kew in 2015 ([www.plantsoftheworldonline.org/](http://www.plantsoftheworldonline.org/)), which is continually updated. The coexistence of print publications and 'virtual flora' is most likely the way forward (Frodin, 2001; Kirkup et al., 2005).

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.gecco.2020.e01257>.

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