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Basics, Methods and Case Studies

Elgene Owen Box *Editor*

Vegetation Structure and Function at Multiple Spatial, Temporal and Conceptual Scales

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Dedication

Photo 1 Kazue Fujiwara, April 2014

From the ninth to twelfth century, the Fujiwara clan was the most powerful political force in Japan, naming emperors and generally running the government. I learned this history a few days after first meeting Kazue Fujiwara, while we were standing in front of an explanatory historical sign in Nara, site of the early capital (just before Kyōto). Immediately, I turned to her and blurted out something to the effect of "You're royalty!" Even as late as the nineteenth century, the wife of the Emperor Meiji was a Fujiwara descendant, and to this day Fujiwara remains one of the more common and most respected family names in Japan.

As it turns out, the "Fuji" (藤) in Fujiwara (藤原) has nothing to do with Mt. Fuji (富士, = wealthy samurai). Instead, it is the name of an indigenous Japanese plant, *Wisteria floribunda*. The name Fujiwara ("wisteria field") was actually an honorific, bestowed by the emperor Tenji upon Nakatomi-no Katamari (614–669), whose descendants took Fujiwara as the name of their clan. This "fuji," along with its alternate pronunciation "tō" (like English "toe"; only in combinations), still appears in a surprising number of common Japanese family names, such as Fujimori (藤森), Fujita (藤田), Itō (伊藤), and Satō (佐藤).

Kazue Fujiwara (藤原一繪, Photo 1) was born in less auspicious circumstances, in the wartime Tōkyō of 1944, as it was being bombed, both conventionally and with incendiary bombs designed to destroy vast areas of mainly wooden houses. It's hard to imagine a time when Kazue was not strong, but at that time she was not, and so her mother took her to Tōhoku (northeastern Japan), near Sendai, where the Fujiwara family is still numerous. As Japan recovered after the war, Kazue returned to Kantō (the Tōkyō area) to attend primary school in Tōkyō and Chigasaki, and middle school in Chigasaki (Kanagawa Prefecture, down the coast from Yokohama). She graduated from high school in 1963, in Hiratsuka (also in Kanagawa).

In 1963, Kazue also entered Yokohama National University, where she studied general biology and was fond of road rallies. During this time, though, she also met the young [associate] professor Akira Miyawaki and became interested in his ideas of vegetation study, especially since he had relatively few students at the time. After graduating in 1967, she became a graduate researcher under Miyawaki in the Department of Biology (until 1973) and also a high-school biology teacher (1967–1969) in Fujisawa and Yokohama. In 1969, she received a CNRS stipend and studied terril vegetation (and French) with Prof. Reinhold Linder in Lille (April–June 1969). After France, she moved to Germany and joined the famous group of Reinhold Tüxen in Rinteln (July–September 1969), where she studied raised bogs and learned German. Kazue returned to Japan in the autumn of 1969, already the unusually cosmopolitan Japanese woman that we know now.

When she returned to Japan, Kazue applied her knowledge of wetlands to summarize the vegetation of the world-famous Ozegahara wetlands (Miyawaki and Fujiwara 1968a, 1969, 1970; cf. Tüxen et al. 1972). During the 1970s, much of her time was spent describing vegetation in cities, prefectures, and regions, with maps of actual and potential vegetation (e.g., Miyawaki and Fujiwara 1968b; Miyawaki et al. 1971), and writing on the creation of green environments in urban areas, around factory sites, and on reclaimed land (e.g., Fujiwara 1973a,b). In 1973, Kazue obtained the official title Assistant Professor (助手) at Yokohama National University, where she continued working while also finishing her Doctor of Science degree (from Tōhoku University in Sendai, in February 1978). She made an urban-ecology city tour of the Soviet Union and Europe (1977) and continued to write on the natural vegetation of Japan (e.g., Fujiwara 1979). She was also married during this time, to a taxonomist (who took the family name Fujiwara); built a house in Chigasaki; and had two daughters, Yōko (1975) and Maki (1980).

In the 1980s, Kazue was able to start publishing more independently. One of her most important publications came from this period, a detailed classification and analysis of the evergreen broad-leaved forests of Japan (Fujiwara 1981–1986). Her paper with Miyawaki on the evergreen and secondary forests of the Bōsō Peninsula, east of Tōkyō, helped demonstrate that evergreen broad-leaved forest is actually the potential natural vegetation of a large part of Japan, even where covered now by secondary deciduous forests (Miyawaki and Fujiwara 1983). In 1987, she wrote her paper on "Aims and Methods of Phytosociology," which to this day is still probably the best brief but sufficient explanation in English of how to do phytosociology (Fujiwara 1987a). Japanese and Chinese versions followed (Fujiwara 1997; Fujiwara and You 1999).

Also during the 1980s, Kazue continued her work on the vegetation of Japan (e.g., Fujiwara 1985); its mapping (Miyawaki et al. 1983b; Miyawaki and Fujiwara 1988); and on revegetation projects (e.g., Miyawaki et al. 1983a). The largest project during the 1980s, though, was the exhaustive description and analysis of the "Vegetation of Japan" (10 volumes, Miyawaki 1980–1989), for which Kazue was a major field researcher and author of text, tables, and maps. She was also a main field researcher and co-author for a four-year project on the mangroves of Thailand (Miyawaki et al. 1985; Fujiwara 1987b). In 1985, she began lecturing officially, as a part-time Lecturer at Hōsei University in Tōkyō. Finally in 1986, she obtained the position of Associate Professor (助教授 — *jokyōju*) at Yokohama National University, in the Department of Vegetation Science of the only recently established (1978) Institute of Environmental Science and Technology.

Kazue's first trip to China was in autumn 1985, and this began a long interest in Chinese evergreen broad-leaved forests (cf. Box et al. 1989, 1991a,b; 1998) and Chinese vegetation in general (see below). In 1986, she visited the warm-temperate region of the southeastern USA for the first time, began studying its forests (e.g., Box and Fujiwara 1988), and subsequently became a most knowledgeable and valuable member of the three-year Eastern North American Vegetation Survey (1988–1990), funded by Japan and summarized by Miyawaki et al. (1994). In addition to planning and fieldwork, she also played a major role in plant identification and vegetation analysis, and wrote chapters describing the evergreen broad-leaved forests and mangroves of the southeastern USA, in comparison with East Asia (Fujiwara and Box 1994a,b).

In 1993, on the mandatory retirement of Prof. Miyawaki at age 65, Kazue was able to obtain his position as Professor (教授) of the Department of Vegetation Science. From this time on she quickly accumulated many graduate students, from overseas as well as from Japan. Among other things, this led to more wide-ranging fieldwork with the students. This involved study of forests and their rehabilitation in Japan (e.g., Fujiwara et al. 1993) but also in Malaysia (Alias et al. 1995, Fujiwara et al. 1995, Alias and Fujiwara 1998, Hamzah and Fujiwara 2000); Thailand (Kawla-ierd et al. 1995; Tejajati et al. 1999); Myanmar (Aung et al. 2004); and in other parts of tropical Asia (cf. Fujiwara 1993); as well as in Bhutan, Nepal, and China. One result was an encyclopedia piece on "Ecosystems of Asia" (Box and Fujiwara 2001). Work with students also took Kazue to other continents, for fieldwork and vegetation analyses in Brazil (Euler et al. 2005) and Senegal (Abdulaye and Fujiwara 2007). She also continued comparative work in eastern North America (e.g., Fujiwara and Box 1999) and was a Fulbright Fellow at the University of Georgia in 1999.

An increase in the number of Chinese graduate students around 2000 led to more fieldwork in China, as well as [Chinese] Mongolia and Manchuria. This led to first vegetation descriptions and syntheses on *Fagus* forests of China (Wang and

Fujiwara 2003; Wang et al. 2005, 2006b); the widespread *Quercus mongolica* forests of northern China (You et al. 2001); and on north-Chinese deciduous forests in general (Wang et al. 2006a). A major new project on "Integrated Vegetation Mapping in Asia" brought the opportunity for even wider-ranging field study in East Asia, including the Russian Far East (Primorye, Sakhalin, Kamchatka), central and northern Siberia (Yakutia), and dry areas of Central Asia (Dzungaria and the Tarim Basin). This work resulted in a major synthesis of East Asian vegetation (Fujiwara 2008) as well as syntheses on cool-temperate deciduous forests (Tang et al. 2008, 2009; Zhi-Rong et al. 2010) and on warm-temperate forests (e.g., You et al. 2008) (see Fig. 1).

When forced in 2010 to retire from the national university at age 65 (*teinen* system), Kazue moved to Yokohama City University. There she continues her vegetation study and revegetation work in China (e.g., Li et al. 2013; cf. Fujiwara et al. 2000) and other countries, including Nepal (since 2010), Turkey, and most recently Indonesia. She first visited Kenya in 1990 in connection with world mapping (project of Shunji Murai, Tokyo University) and has studied its forests, for revegetation work, since 2006 (e.g., Hayashi et al. 2006; Furukawa et al. 2011a,b). Using her extensive experience with Asian coastal vegetation (e.g., Hayasaka and Fujiwara 2005, 2007; Fujiwara et al. 2010), Kazue and her students were also quick to study effects on coastline vegetation by the great tsunami events in the Indian Ocean in December 2004 (Hayasaka et al. 2009) and in northeastern Japan in 2011 (Fujiwara et al. 2012).

One of Kazue's particular talents was to identify topics of general interest and to organize appropriate special sessions at major national, regional, and international meetings. At the INTECOL symposium in 1990 in Yokohama, she organized a special session on evergreen broad-leaved forests and coordinated three other symposia, combining their proceedings into a book on "Forest Ecosystems of East and Southeast Asia" (Box et al. 1995). For the INTECOL meeting in 1998 (Firenze), she organized a special session on "Climate Change and Vegetation Shift," focusing on early evidence of vegetation responses to warming. For the International Botanical Congress in 1999 (St. Louis), she organized a session on "Vegetation of Analogous Environments of the Northern versus Southern Hemisphere." In 2002, for the INTECOL meeting in Seoul, she organized a first session on "Ecology in Beech and Oak Forests," following it up 10 years later with "*Quercus* versus *Fagus* in Asian and other Temperate Deciduous Forests," for the annual IAVS meeting, also in Korea (Mokpo). Tatsuō Kira (1949) had recognized that deciduous forests could constitute stable, zonal forests in the warm-temperate zone under certain conditions, and in 2010 Kazue organized a special session on this topic for the annual IAVS symposium, in Lyon. This resulted in a book on "Warm-Temperate Deciduous Forests around the Northern Hemisphere" (Box and Fujiwara 2014a), which included Kazue's syntheses of East Asian warm-temperate deciduous forests (Fujiwara and Harada 2014; Tang et al. 2014) and comparison with counterparts in eastern North America and southern Europe.

In addition to topical sessions, Kazue has also served on the organizing committees for the 1984 IAVS meeting, the 1990 INTECOL symposium, and the 1993

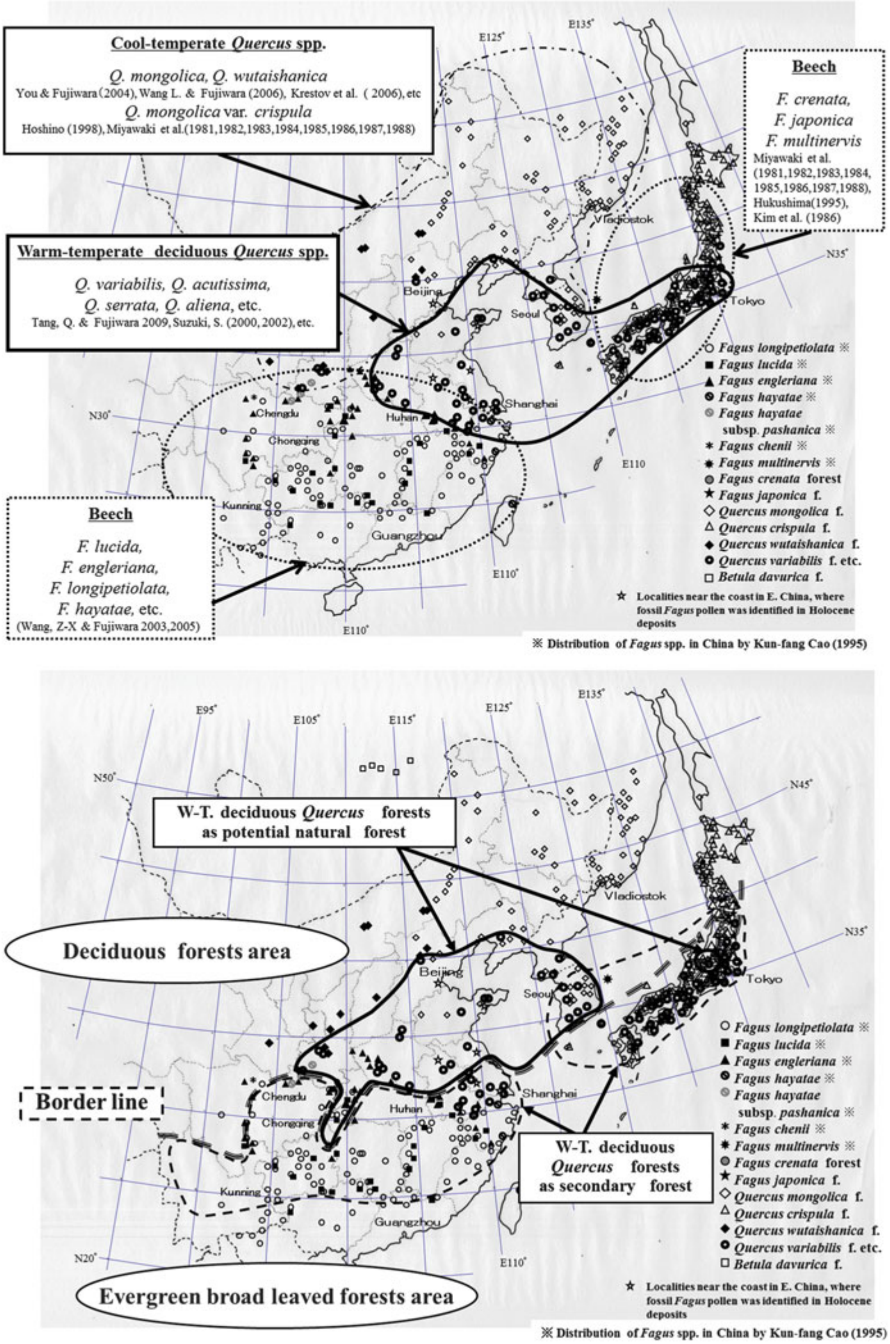

Fig. 1 Areas of cool-temperate and warm-temperate deciduous broad-leaved forests in East Asia (from Fujiwara and Harada 2014)

Botanical Congress, all held in Japan. In 2000, she was the overall organizer of the IAVS symposium in Nagano and its excursions throughout Japan. She was an IAVS Vice-President from 2000 through 2007, still serves on the IAVS Advisory Council (since 1994), and is a familiar figure at IAVS annual meetings (Photo 2), missing only one meeting since 1991. She also served as an INTECOL board member (2001–2008), has long been a major contributor to the Japanese Ecological Society, and has organized special sessions for them and for meetings of the East Asian Society for Ecology.

Photo 2 Kazue Fujiwara, at an IAVS meeting in the 1990s

Kazue Fujiwara is perhaps best known as one of the world's foremost phytosociologists, adhering closely to classical standards and procedures but also able to use phytosociology in all kinds of environments worldwide and to apply it to vegetation analysis and rehabilitation efforts. She is also known for her extensive knowledge of the vegetation of the whole world, having studied vegetation in the field in about 50 countries or comparable regions (e.g., Baja California, see Photo 3), on all continents except Antarctica. In this regard, she has been a valuable author of cross-continental and global-scale comparisons and syntheses (e.g., Box and Fujiwara 2005, 2012, 2013, 2014a, 2014b).

Photo 3 Kazue Fujiwara, during the IAVS excursion in Baja California, Mexico, 2010 (photo by Andy Greller)

Some of Kazue's publications include me as [alphabetic] first author because they were written in English. I can assure you that she provided as much input to those pieces as I did, sometimes more. She has certainly been a valuable co-author, critic, and colleague. I would like to take this opportunity to thank Kazue, publicly and most profoundly, for all I have learned from working with her — in the field, in data analysis, in writing (especially generalization), and in scientific life in general.

We the authors all hope that this book will be a fitting honor to Kazue, and we join her other admirers in wishing her many more active and rewarding years.

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Introduction: Scales and Methods

This book of invited papers is both a commemorative volume (*Festschrift*) honoring Prof. Kazue Fujiwara and a potential textbook for graduate-level courses or seminars in vegetation study. Heinrich Walter, who probably knew world vegetation better than any of his contemporaries, sometimes showed a certain disdain for what he called "*Schreibtisch-Ökologie*" (desk ecology), saying also: "*Weiß man nichts, so schreibt man über Methode*" (When one does not know anything, he writes about methodology). But methodology has an important place in science, since it responds to particular scientific questions and often raises others. Kazue Fujiwara herself was one of the world's foremost phytosociologists, among other things, and wrote one of the best explanations of that methodology (Fujiwara 1987). Appropriately, therefore, this book presents a wide variety of methodological approaches in vegetation science.

The sections and chapters in this book also represent a full range of objectives, scales, regions, and vegetation types. Book sections are organized from global to local scale. Objectives range from more or less global perspectives involving zonation and plant functional types, to regional and local vegetation description and analysis, to revegetation, woodlot management, and other aspects of conservation. Regions and vegetation types range from tropical and temperate forests to continental steppes and Mediterranean-type scrub to fine-scale turf, sedge, and moss communities (or synusiae) embedded in wider landscapes. Southern Hemisphere perspectives are also included.

As Dieter Mueller-Dombois points out in his chapter, study of vegetation dynamics requires study at various temporal as well as spatial scales, often simultaneously. Temporal scales may range from seasonal to annual to longer term, as over the course of succession or other stand development. And even regional and global studies require understanding of processes at landscape, stand-level, and finer spatial scales. Methodology and scale are thus often closely interrelated, and the studies in this book illustrate this interdependence.

Some basic methodologies and other organizing concepts in vegetation science are listed in Table 1. The relevance or validity of some of these items is currently

Table 1 Methodologies of vegetation study

Classification	Clustering	Envelope modeling
Gradient analysis	Ordination	Phytosociology
Plant functional types	Potential natural vegetation	Zonation
Allometry	Description	Generalization
GIS analysis	Inventory	Mapping
Measurement	Modeling	Sampling
Satellite monitoring	Scaling	Validation
Adaptation analysis	Bioclimatic analysis	Dynamics analysis
Ecological analysis	Environmental analysis	Integrity analysis
Regional synthesis	Synusial analysis	Topographic analysis
Transition analysis		
Autecology	Comparative ecology	Cultural ecology
Ethnobotany	Geobotany	Physiological ecology
Sustainability science		
Biodiversity management	Conservation biology	Conservation strategy
Ecosystem services	Invasion biology/ecology	Plantation management
Production ecology	Reforestation	Rehabilitation
Restoration	Revegetation	

Listed here are major methodologies of vegetation study and of ecology and other organismal biology in general. The groupings represent: (1) widely used methodologies and some currently debated “hot topics”; (2) more general tools and other aspects of research; (3) other analytical methods of inquiry, involving established objectives (usually with the word “analysis”); (4) related fields of study; and (5) applied activities in conservation, land management, and ecosystem restoration or rehabilitation, which require their own as well as more basic methodologies. Some are relevant only at a particular spatial or other scale, but all are listed here, as a checklist. Most are described briefly in this Introduction, in boldface type, with literature references where possible

debated, including phytosociology (cf. Carrión and Fernández 2009; Ewald 2003), the concept of potential natural vegetation (cf. Chiarucci et al. 2010), and (climatic) envelope modeling. Also included are more “accepted” methods such as ordination and gradient analysis. As Ewald (2003) has pointed out, classification (as by phytosociology) and ordination are both clustering methodologies that may have much in common, including a common numerical basis in statistics (see also Kent and Coker 1992; Legendre and Legendre 1998). Finally, also listed in Table 1 are more general aspects of vegetation research such as basic description, sampling, measurement, and mapping; some more targeted analytical perspectives, such as bioclimatic, environmental, and ecological analysis; related perspectives and fields of study, such as ethnobotany and cultural ecology; and applied activities such as biodiversity management, revegetation efforts, and other aspects of conservation. Most of these methods are treated somewhere in this book and are identified briefly (in boldface type) in the relevant sections of this Introduction.

This book and Introduction are organized from global to local scale, followed by sections on conceptual methodologies, applications, and perspectives for the future. We hope that this book will be useful to both students and practitioners, for its reviews and examples, and as a potential reference. We also hope it will be a fitting tribute to Kazue Fujiwara, who has always been comfortable thinking and working at local to global scale and over different temporal scales, from present day to the 30 years or more involved in succession and most revegetation projects.

Global Scale

At global and other broad scales, one of the most basic methodologies is the inductive process called **generalization**. This involves inference of broad relationships, including broad geographic patterns, based on recognition of patterns and relationships seen at finer scales. The product of good generalization should be a "complete" general conceptual system. Both chapters in this global section present such systems.

Generalization is perhaps best illustrated at global scale and may also involve **modeling**, which puts general ideas to the test. Models may be conceptual or quantitative. At broad scales, quantitative models are usually driven by climatic data or satellite imagery — but rarely by both, although such integration could be very useful, and I suggested it to NASA very early. The question of rigorous model **validation** was first treated by Caswell (1976) and was considered subsequently by Rastetter (1996) and Rykiel (1996) at global scale, and more locally by Box et al. (1993) and Araújo et al. (2005), among others. Whether conceptual or quantitative, though, broad-scale models and other generalizations are inherently *geographic* in nature, since the world has a great variety of different conditions in different, often disjunct geographic regions. So geographic models and other generalizations should also be *validated geographically* (Box and Meentemeyer 1991), i.e., in a stratified manner that tests under the different environmental conditions that obtain in all relevant regions, such as the world's different biomes.

The first chapter, on "World Bioclimatic Zonation" (Box), treats this need by providing a more complete global bioclimatic **zonation** system, based on the "genetic" principles implied by global atmospheric circulation patterns. Bioclimatic zonation and its relationship to global atmospheric circulation were well recognized more than 100 years ago, and some systems were presented that are still in use, including the quasi-zonal Köppen (1931) climates used for most atlas and wall maps. This chapter is both a review of the development of zonation concepts and an attempt to patch some of the remaining flaws. First comes a somewhat detailed history of the development of genetic (i.e., mechanism-based) classification systems. The most widely used genetic system of world climate types, namely that of Walter (1977), is then expanded to resolve its one major flaw, to cover subtypes and transitions more explicitly, and to provide a still relatively simple global (terrestrial) system that corresponds well with biomes and broad-scale vegetation types (cf. Walter 1954; Box 1995; Box and Fujiwara 2013). Genetic systems have advantages especially under changing climatic conditions, since they are tied more directly to mechanisms and do not rely on empirically based boundaries, as in the Köppen system. It may also be possible to quantify such systems, focusing not only on physiological limits but also on required durations of warm-wet conditions, as suggested already by Lauer and Rafiqpoor (2002).

The other global-scale chapter expands the concept of **plant functional types** (PFTs), which were an outgrowth of the "life forms" of Drude (1896) and other early, mainly German-educated ecologists (e.g. Warming 1895; D'Arcy Thompson 1917; cf. Barkman 1988; Fekete and Lacza 1970, 1971; Szuko-Lacza and Fekete 1969, 1972). Basic ecological plant types were first used in modeling in a world **climatic envelope** model involving 90 types (Box 1981; the term "climatic envelope" was probably first used in this context by Dobson 1978). The present-day term "plant functional type" was anticipated, in the same year, by the "plant functional attributes" of Gillison (1981). The PFT concept is now not only used in vegetation analysis and modeling (cf. Foley 1995; Cramer 1997; Peng 2000) but has been proclaimed the veritable "holy grail" (!) for unifying ideas of plant–environment relationships (Lavorel and Garnier 2002). Concepts of PFTs, however, have always differed (cf. Box 1996; Smith et al. 1997; Wullschleger et al. 2014).

The chapter by Gillison herein, on "Vegetation Functional Types and Traits at Multiple Scales," presents a complete system for describing both plants and vegetation in terms of functional attributes that are also related to plant morphology. This system has been applied in many parts of the world, yielding a large database for use in inferring broad plant–environment relationships (Gillison 2013). This chapter also includes good summaries of several other widely discussed, potentially global systems for relating plant structure and environmental conditions, including the CSR strategies of Grime (1979), the Leaf-Height-Seed (LHS) strategies of Westoby (1998), the Leaf-Economics Spectrum of Wright et al. (2004), and the Gillison (2002, 2013) system of Leaf-Life Form-Root (LLR) strategies. According to Gillison, "a key question concerns whether the relatively new trait-based ecology is better placed than traditional methods to cast light on how functional characteristics interact across varying environmental scales and whether functional types and traits can be exploited to improve our understanding of ecosystem dynamics." This chapter reviews the more traditional scale-related aspects of vegetation classification and then compares these with recent advances involving plant functional types and traits, especially those involving holistic plant strategies.

Regional Scale

This section presents a wide variety of studies, objectives, and methodologies, including basic analytical description, environmental and ecological analysis, regional synthesis, comparative ecology, and mapping. Some studies analyze the vegetation of a region, while others look at the ecology of certain vegetation types over a region. For these chapters we start in East Asia, with evergreen broad-leaved forests, continue with tropical evergreen forests and mountains, and then proceed to largely drier situations in higher latitudes, from inner-Asian steppes and scrub to the vegetation of Mediterranean-type climates in Europe and California.

Environmental analysis involves relating vegetation and plant taxa to the environmental conditions where they occur. One should look at all relevant environmental factors, but two main approaches are represented herein: climatic and topographic.

Bioclimatic analysis relates vegetation and its component taxa, especially the main structural elements, to climatic conditions. This involves not only identification of limiting factors but also estimating the quantitative values of variables that can be used to express these factors. Factors may be "negative" in the sense of hard limits, such as limiting cold temperatures, or "positive" in the sense of plant or vegetation requirements, such as length of a warm-wet growing season.

The first chapter is on "Evergreen Broad-Leaved Forests of East Asia," by Song Yong-Chang[1] and Da Liang-Jun (East China Normal University, Shanghai), and actually represents a **comparative ecology** (cf. Cole et al. 1991) and zonation of this general forest type around the Northern Hemisphere. Prof. Song has written extensively over his long career on evergreen broad-leaved forests, both in Asia and in comparison with other Northern Hemisphere regions, based on his long association with colleagues in Europe (including Tüxen) and in the International Association for Vegetation Science. Song's results are synthesized in a recent, exhaustive two-volume treatment of the *Evergreen Broad-Leaved Forests of China* (Song 2014, in Chinese). The present chapter serves as a summary of these Chinese types of evergreen broad-leaved forest (all called "subtropical" herein) and similar forests in other parts of East Asia, in small areas of eastern North America, and in the Mediterranean region, where the evergreen broad-leaved forests and woods are mainly sclerophyllous but where some laurophyllous taxa also occur. This chapter also serves as an introduction to the Chinese system for naming vegetation types based on two dominant taxa (cf. Wu 1980/1995).

The second chapter, by Song Kun and Da Liang-Jun, involves what might be called **transition analysis** (or ecotone analysis) as applied to the "Evergreen-Deciduous Broad-Leaved Forest Ecotone in Eastern China." Part of this region was identified already by Eyre (1968) as a region of mixed evergreen-deciduous broad-leaved forest, a combination which usually is not stable. (The more shade-tolerant evergreen trees usually win.) This region has long been of interest because there are few places in the world where such a transition could occur over a large area and because even the quasi-natural vegetation of this region was destroyed many centuries ago. The location of the ecotone is estimated by Song and Da by relationships to temperature but also to topographic factors, as done in the "Vegetation of China" (Wu 1980/1995) and by some other authors (e.g., Fang et al. 2002), whose ideas are summarized herein. The ranges of the main evergreen broad-leaved trees are considered to determine the boundary of the ecotone, providing a model for defining ecotones in general. Forests in this transitional

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[1] Note that family names (usually one syllable) come first in Chinese, followed by given names that may be one or more commonly two syllables.

region have also been described phytosociologically and interpreted bioclimatically by Fujiwara and Harada (2014) and by Tang et al. (2008, 2014).

A third chapter from China involves the "Ecology of Relict Tertiary Deciduous Trees in Subtropical China," by Shang Kan-Kan, Song Kun, and Da Liang-Jun. China is well known for its rich diversity of Tertiary relict conifers, due to the general lack of Pleistocene glaciation but also to the fact that southern China represents the world's largest upland region in a humid warm-temperate/subtropical climate. Relict deciduous trees are less well known, except perhaps for *Ginkgo biloba* and the deciduous conifer *Metasequoia glyptostroboides*. Southeastern China and the adjacent Himalayan region represented an important Pleistocene refugium for the Tertiary relict flora, but the region is covered now (where natural vegetation exists) by evergreen broad-leaved forests. This chapter uses both bioclimatic analysis and **topographic analysis** to explain the survival and ecology of relict deciduous trees, many with isolated, disjunct distributions in this mountainous area. Resulting forests of these relict deciduous trees are called "topographic climax" forests, often reproducing vegetatively and forming mosaics (on particular landforms) within the zonal vegetation. Most species are clearly pioneer species and function as "gap-repairing" species.

Classification involves creating groupings for entities that are similar and separating them from entities that are different. This is also an inductive procedure, and was done first somewhat intuitively and empirically, based on the most obvious similarities, such as physiognomy and climatic affinities. Phytosociology provided a standardized methodology for classification of plant communities by floristic composition, based on large numbers of full-floristic vegetation samples. This approach was expanded with the advent of computers and statistical algorithms, one of the first of which was actually based on the famous "traveling salesman" algorithm (Lieth and Moore 1971). Statistical ordination provided a completely automated means of classification by clustering, based on algorithms such as that of Bray and Curtis (1957; cf. Whittaker 1974). The word "ordination" came from Goodall (1954) but was suggested originally by the *Ordnung* of plant lists by Ramensky (1930).

We see classification procedures of various kinds throughout this book, beginning with a "Classification of Lower-Montane Evergreen Forests in Southern India and Sri Lanka," by Andrew Greller and colleagues. Among other things, this study provides basic quantitative **description** of the composition of taxon-rich humid tropical forests from three mountain areas in Sri Lanka and several ranges in the Western Ghats of Kerala (windward southwestern India) and adjacent (leeward) Tamil Nadu. These forests are dominated by members of typical tropical-rainforest families (e.g., Myrtaceae, Sapindaceae, Anacardiaceae), as well as by Dipterocarpaceae, but cultivation of cardamom has led to massive disturbance of such forests, which are unusually rich in endemics. The forests were sampled by belt transects, and dominant tree taxa were identified. The forests were then classified into 12 distinct types by **cluster analysis** using dendrograms based on the Bray–Curtis algorithm. This classification demonstrates a clear compositional distinction between lowland and nearby lower montane forests. Results are compared with classifications of other tropical mountain forests, including proposed elevational trends in leaf morphology and other tree and forest attributes. There is also a brief comparison with forests from the Southern Hemisphere.

Another, but much less diverse situation of humid tropical forests is that of oceanic islands such as Hawaii, where Dieter Mueller-Dombois and James D. Jacobi report on the "Dynamics of the Hawaiian Rainforest at Multiple Scales." This chapter is a truly multi-scale study and begins with a clear model statement of **dynamics analysis** and of the spatial and temporal scales that it requires. This chapter also summarizes a recently published book that resulted from five decades of multi-scale study on native Hawaiian rainforests (Mueller-Dombois et al. 2013). Unlike most rainforests, less-diverse island rainforests do generally have clear dominant taxa. In the Hawaiian Islands, the dominant is a single species, *Metrosideros polymorpha*, well known for its cohort dieback phenomena described by Mueller-Dombois (1980, 1985, 1987). Dynamics in these mono-dominant forest stands includes establishment, development, turnover by auto-succession, bog formation, and fragmentation, which occur over different temporal scales but must also be studied at different spatial scales, from small plots to whole stands. "Forest decline" usually involves some outside factor such as disease and is not the same as cohort senescence, which is a natural process of simpler forest stands and may include various aspects, such as premature senescence. This chapter demonstrates how different perspectives through scale changes were needed for synthesizing the subject matter into a coherent story.

The remaining chapters in this regional section involve vegetation of climates that have some aspect of significant dryness. The first study is an analytical **description** of "Steppes and Shrub Thickets in Onon Dahuria," by Irina Safronova and Ekaterina Golovina of the Komarov Botanical Institute in St. Petersburg. Outside Russia, Dahuria is not well known and appears as a regional name only rarely in atlases and dictionaries. On the other hand, Dahuria has provided many botanical names, such as *Betula dahurica*, *Larix dahurica*, *Rhododendron dahuricum*, and *Rosa davurica*. This somewhat mountainous steppe region is in southern Siberia, just north of Mongolia. It has an extremely continental climate, with deeply frozen soils. The so-called "expositional" forest-steppe vegetation is influenced strongly by elevation and topographic position, especially north versus south-facing slopes. There is no statistical analysis but rather a detailed **inventory** of species and community types, including basic description of stand composition and dimensions, and of dominant and other main species. Species richness is moderate, and these are true steppes, i.e., there is usually some bare space not covered completely by the vegetation (projective cover of 50–80 %). The main community types are described as grass steppes, forb and forb-grass steppes, and shrub steppes, with localized areas of shrub thickets. Forbs play a large role in these steppes, as can be seen in the many photos.

Mapping is another central activity in vegetation study, and vegetation mapping has a long history rich in different approaches and techniques, as illustrated, for example, by Faliński (1991), Pedrotti (2004/2013), Bohn and Neuhäusl (2003), and Küchler and Zonneveld (1988). The next chapter herein, by Carlo Blasi, summarizes "The Vegetation Series of Italy and Applications in Biodiversity Conservation," describing various mapping methods. Blasi describes the aim of this Italian program as a "complete overview of the basic naturalistic knowledge in Italy" bearing in mind that the primary objective was conservation. One result of this project was a map of the Vegetation Series of Italy (Blasi et al. 2004), accompanied by a monograph for each region. Another result was definition and mapping of environmental heterogeneity, by integrating phytosociology (and synphytosociology) with ecological land classification. The project produced an extraordinary wealth of data that can be used for updating knowledge of floristic and vegetation biodiversity, for land planning and biodiversity assessment and monitoring. These data also permit defining and evaluating connectivity and assessing the structural and functional topology of ecological networks, particularly the land network.

The last two chapters in this section focus specifically on the vegetation of regions with a Mediterranean-type climate, in its two occurrences in the northern Hemisphere. Many adaptations have been attributed to this climatic situation, one of which is marcescence, i.e., the holding of brown leaves on their branches through the winter. This has been interpreted as a vestige of evergreenness but occurs also in various situations transitional from deciduous to potentially evergreen forest. It occurs mainly in Fagaceae, especially oaks (*Quercus* spp.), including several oak species in southern Europe, where marcescence appears to be confined mainly to the submediterranean transition and to species such as the widespread *Quercus pubescens* (Abadía et al. 1996; Garcia et al. 2014). The chapter by Beatríz Vilches de la Serna and colleagues, on "Marcescent *Quercus pyrenaica* Forest on the Iberian Peninsula," is a kind of **adaptation analysis** that looks at the autecology of another, endemic marcescent species, which is seen as an indicator of the southern limit of Euro-Siberian broad-leaved forests. This chapter is also a good study in the history of plant names and problems of taxonomic nomenclature, including a herbarium-label error that led to the original name. (*Q. pyrenaica* is almost completely absent from the Pyrenees). Another feature of this chapter is the treatment of plant occurrence in *dehesa*, i.e. the *bocage* (hedgerow) system of open grassland within wooded margins, as occurs in other parts of Western Europe.

The second chapter on Mediterranean vegetation concerns the "Mediterranean Ultramafic Chaparrals of California," by Daniel Sánchez-Mata and María Pilar Rodríguez-Rojo. The term "mafic" refers to silicate minerals that also contain magnesium and iron (but less silicon), as are derived from the less viscous mafic magma and lava that may extrude over larger areas without forming volcanic cones. Ultramafic rocks are found worldwide but especially in some areas, where their chemical composition results in serpentine soils that give rise to distinctive vegetation (see many photos) and numerous local endemics. This study in California involved locating stands of serpentine vegetation and describing the vegetation composition and dynamics, including seral stages. Sampling was by phytosociological relevés, with analysis by several clustering procedures, including de-trended correspondence analysis and canonical correlation analysis (with "beta-flexible linkage" and Sorensen distance). Clustering analysis resulted in recognition of five species groups, four of which were given new syntaxonomic names at the association level. Understanding the plants and vegetation of serpentine soils must also include study of their **physiological ecology**, including how they are able to function despite accumulations of heavy metals. This ability makes some such species useful in revegetation efforts, especially on previously mined landscapes.

Landscape Scale

Vegetation study at local (landscape) scale usually involves detailed vegetation sampling and description, sometimes along environmental gradients, classification of communities, and sometimes more complete inventory of all types and taxa in an area. The data collected are often analyzed by statistical **ordination** (see Kent and Coker 1992; Whittaker 1974) or by **phytosociology** (see Conceptual Methodologies section), both of which involve some kind of clustering procedure. Ordination and gradient analysis are well accepted methods of what has been called "exploratory data analysis" (Tukey 1977; Chatfield 1986; Sibley 1987), as opposed to "confirmatory data analysis," i.e. hypothesis testing based on statistical probabilities (see Kent and Coker 1992). True analysis of vegetation, however, requires insight into environmental limitations and causal mechanisms, not just statistics.

The first chapter in this section represents just such an **ecological analysis**, in which Ulrich Deil treats "Amphibious Vegetation in the Afro-Alpine Belt and the Role of Cryoturbation in Creating Regeneration Niches." This is a regional study but involves analysis of vegetation in very small areas of annual turfs embedded in tussock grasslands, which occur on several of the high volcanoes of East Africa (3500–4500 m). The stands are compared, by means of a constancy table (168 relevés), with similar situations from the Ethiopian Highlands, the Drakensberg of southern Africa, and Marion Island (South Africa). The ecology of the short-living herbs is described in terms of regeneration and establishment in open patches created (in the perennial turf) by cryo- and bioturbation and by needle ice and frost-heaving. On such a dynamic but cold substrate, geocarpy becomes an important adaptation. The plants colonize the shores of oligotrophic lakes with fluctuating water levels and germinate under water (tenagophytes). There are even some similar floristic and ecological characteristics with boreal and subarctic littoral vegetation and with *Crassula* communities in the oro-tropical Andes.

The next chapter is also a kind of regional analysis that studies a particular vegetation type and its dynamics at landscape scale. This study, by Dan Gafta and Sorana Muncaciu, treats the case of "Large Habitat Range but Low Floristic Variation" in *Festuco rubrae-Agrostietum capillaris* grasslands of Romania. It represents a good example of the use of Bray–Curtis **ordination** and a "fuzzy C-median algorithm" to classify 414 grassland stands and infer the main ecological factors underlying the observed floristic variation. Clusters were evaluated in terms of species fidelity and plant functional groups identified, including grazing-tolerant versus truly ruderal species and species of acidic versus basic substrates. The facies