Vegetation and climate

Siegmar W. Breckle - M. Daud Rafiqpoor

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* **Accompanying words to the book**
* **Foreword by the authors**
* **Content**
* **Physical units**
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* **Preliminary remarks**

[image]

Cultivation of sunflowers (Helianthus annuus) as a monoculture on fields in the Eastern part of North Rhine-Westphalia (Photo: Breckle)

**[IMAGE]**

**Accompanying** word

**Prof. em. Dr. Michael Succow**

**Professor of Geobotany and Landscape Ecology; winner of the "Right Livelihood Award" ("Alternative Nobel Prize"); Honorary Prize of the German Federal Foundation for the Environment; Chairman of the Michael Succow Foundation for the Protection of Nature https://de.wikipedia.org/wiki/Michael\_Succow**

The vegetation cover - the plant dress of our earth - is currently undergoing a strong change worldwide. No longer by natural processes, but by us humans, by our civilization! The emerging dramatic changes of the climate, the loss of the natural fertility of our soils, the humus, the loss of the fullness of life, the biodiversity, forces us to rethink our handling of nature - which will also be our basis of life in the future - and to act in a new way. This requires knowledge combined with responsibility.

Knowledge about the diversity and function, i.e. the natural balance of "our" earth, its ecosystems and their interaction. But also knowledge about how nature - driven by the principles of evolution - is able to perfect itself further and further, to optimize. Not to maximize and thus often enough to fail, as our daily actions in dealing with nature show again and again.

The dilemma of our time can be summed up in three sentences: If we leave nature unchanged, we cannot exist. If we destroy it, we perish. The narrow, ever-narrowing path between change and destruction can only be successfully trodden by a society whose economic activities are integrated into the natural balance and whose ethics make it feel part of nature.

Knowledge of nature, contact with nature, experience of nature, love of nature and the resulting responsibility for nature form the basis for the necessary reform, a rethinking of the way we deal with our biosphere, this so thin living skin of our earth. Today, more than ever, our own future viability is at stake, that is, the future viability of human civilization! We can be sure that the nature project will continue, but possibly without us!

Why am I writing these thoughts in the preface for this book in particular: Because I am very happy and grateful about its appearance - now even more in the updated edition. This textbook, once conceived and implemented by Heinrich Walter, then continued by Siegmar Breckle, accompanied my life. It fascinated me as a biology student at the University of Greifswald and was later indispensable for understanding the large ecosystems in various parts of the world. Today, this synopsis continues to be an important source of knowledge for the work of my foundation in the protection and sustainable use of ecosystems on a global scale. This book, so condensed in content, manages to show ecosystem knowledge, the "interplay" of the individual bio- and geo-components, starting with the individual organism, the auto-ecology, and then continuing at the ecosystem level, the syn-ecology. It helps to understand the so wonderfully ecologically built house earth, to understand its vulnerability and to lead to sustainable action. Admirable is the bringing together and linking of an enormously widening knowledge, especially in recent times, about the function and functionality of the ecosystems that support us. The experience of the regenerative power of many ecosystems gives us hope, if we give them time and space.

In the meantime, this university textbook or handbook reaches not only many students all over the world, but also land users, environmentalists, politicians, ... I am particularly pleased that the new edition, completely revised by Siegmar-W. Breckle and the renowned Afghan vegetation ecologist M. Daud Rafiqpoor, has now also been published in Dari. Let us hope that this "standard work" will be translated into many more languages, because all over the world we need more than ever textbooks at our colleges and universities that promote knowledge of nature and ecosystemic thinking, that enlighten us about the "miracle of nature" in all its complexity. Only in this way will it be possible to deal with the nature "entrusted to us" in a more responsible, future-oriented and sustainable way in the future and to better understand and use the self-healing powers of nature.

Prof. em. Dr. Michael Succow

Michael Succow Foundation for the Protection of Nature

Greifswald, July 2019

<http://www.succow-stiftung.de>

[IMAGE]

Accompanying word

Prof. em. Dr. Wilhelm Barthlott, Professor of Botany at the University of Bonn, long-time Director of the Nees Institute for Plant Biodiversity and the Botanical Gardens of the University of Bonn, member of several scientific academies, winner of the German Environmental Prize and other awards.

https://de.wikipedia.org/wiki/Wilhelm\_Barthlott

With the beginning of the 21st century we have finally arrived in the age of the Anthropocene: global changes determined by humans are dramatically and progressively changing our environment (e.g. climate change, extinction of species) and through digital media, 'influencers', advertising also our inner world and thoughts. Many of the classic statements of Enlightenment philosophy, once intended for an empty world, may no longer be valid for a full world of nearly eight billion people. The century-old maxim that "growth is progress" applies only to a very limited extent. In an interconnected hitherto Eurocentric but cosmopolitan world, Europe with its ideologies and values is, for the first time since the late Middle Ages, no longer the measure of all things for the rest of the globalized earth.

The clearly measurable current climate change is of existential importance to us. A few seemingly ridiculous Celsius degrees of average temperature are dramatically changing our environment and our livelihoods. Few still dismiss the reference to planetary boundaries as 'alarmism'. Often, this lacks the scientific knowledge that is well researched in the disciplines of geography and biology in their comprehensive sense.

Sea levels rise with the consequence of mass migration and probably wars; vegetation and therefore agriculture change. We humans are totally dependent on plants: They provide directly (cereals, vegetables, fruits) or indirectly (meat production is based on herbivores) all our food, but also provide us with materials (wood, coal, even the fossil oil, cotton, wool, medicines) and even the air we breathe: Oxygen is produced exclusively by plants.

Far more than 10 million different living organisms (scientifically known to date are only 1.8 million species) populate our planet and are the basis of our ecosystems and thus our life. Due to the exponentially increasing population and the high consumption of natural resources, these systems are threatened worldwide today. “Global change” is the term, incipient “Climate change” the omen. The prognoses are bad: Sea level rise alone will probably cause many millions of climate refugees from the coastal areas of the earth by the end of this century. We are also at the beginning of an extinction catastrophe of earth-historical dimensions with regard to biodiversity.

We can still shape our future. Data is provided by the natural sciences - but the decisions are determined by politics, economy and media, culture, religion, and often emotions, education and training are the basis.

With the textbook "Vegetation and Climate", a modern, easy-to-read overview - without being obtrusive about the incipient changes - of the fundamental relationships between the plant world, ecology and climate is now available from renowned and experienced authors.

Vegetation, soil and climate are the most important components of ecological systems. The book presents a compact synthesis of our current knowledge of the ecology of the Earth and is thus the basis for understanding the big picture in a global perspective. Education and training are the keys to our future: How we shape it depends on them. Now, with the completely revised and up-to-date new edition of the textbook classic "Vegetation and Climate Zones by H. Walter & S.-W. Breckle (1999)", a comprehensive modern textbook for students is available. It remains to be hoped that "Vegetation and Climate" will provide many young people worldwide with a basis for understanding the complex ecological relationships for shaping the future.

Prof. Dr. Wilhelm Barthlott, University of Bonn

Bonn, July 2019

**Foreword by the authors**

This richly illustrated textbook has a long history. The first paperback edition by H. Walter entitled "Vegetationszonen und Klima" (Vegetation Zones and Climate) was published by Ulmer-Verlag in 1970. It represented a short summary of the large two-volume work Vegetation of the Earth (Walter: Volume I, 2nd ed., 1964; Volume II, 1968). In the following editions, the ecological principles were increasingly elaborated. In parallel, the "Vegetation of the Earth" underwent a comprehensive and extensive revision with emphasis on ecological aspects and with a very consistent structure. It was then published in four volumes as "Ecology of the Earth" (Walter & Breckle, Volume I, 1983, Volume II, 1984; Volume III, 1986; Volume IV, 1991). In the meantime, the "Ecology of the Earth" has also been partly published in 2nd or 3rd editions. The 6th edition of the pocket book "Vegetation Zones and Climate" was completed by H. Walter in 1989 shortly before his death. The 7th edition of "Vegetation and Climate Zones" was revised and published by S.-W. Breckle in 1999.

Subsequently, the publishing landscape has changed significantly. Many new textbooks have appeared. In the meantime, the Internet now dominates the textbook market in many cases. Nevertheless, the fragmented knowledge and the mixture with "fake news" still cannot replace a good textbook.

The complete re-editing of "Vegetation and Climate" is related to the translation of the book into Dari as a basis for a modern ecology textbook for Afghanistan. This gave rise to the idea of producing a translation of the 7th edition of "Vegetation and Climate Zones" into the local language (Dari), but adapted to the ecological and vegetation conditions of the country. However, it soon became clear that this would only be possible if the German edition were first completely revised and supplemented with suitable colour illustrations; only then would a good translation be feasible. Thus, this richly illustrated new edition is at the same time the basis for a new, modern ecology textbook in Afghanistan.

Almost everywhere in the country there is still a lack of the simplest textbooks; poorly legible, copied pages are often the only thing available. Or they are foreign textbooks that have been translated literally and hardly address the local conditions. In Afghanistan's universities, teaching is still frontal. Students depend on their notes during lectures; there are no good and modern standard textbooks for students and for teachers to prepare for classes and exams. This is why the translation of this pocket book was so important. Also, it enables us to deal with some terms that are wrong or not clearly clarified in Dari in biology. In the previous few Dari-language books, there are no adequate translations for scientific terms; they have been coined here in the Dari translation itself and all collected in a glossary.

The intensive occupation with the natural environment of Afghanistan had made possible the publication of a photo overview volume with an extensive introduction to the flora and vegetation of this country (Breckle & Rafiqpoor 2010) and an inventory of the flora as a checklist (Breckle et al. 2013); it resulted in about 5,000 species and an endemism of 25%. Both books are bilingual, English and Dari. Both books were funded by the German Academic Exchange Service (Deutschen Akademischen Austauschdienst, DAAD) from the German Federal Foreign Office's funds for peacemaking activities in Afghanistan. They were sent to schools, universities and institutions in the country for free distribution.

This ecology textbook "Vegetation and Climate" has been published separately as a German edition and a Dari edition. The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) has gratefully assumed the costs for printing and transport of the Dari edition for free distribution in Afghanistan. For the country, which has been ravaged by decades of war and civil strife, this is another building block for better education, which has seen some progress everywhere in recent years. Perhaps these scientific books are also a good examples for other countries.

In contrast to today's mostly technically oriented and analytical biological research down to the smallest details of gene function, ecology strives for synthesis, the representation of the large interrelationships. The results of analytical research are the many, also important, building blocks that, figuratively speaking, have to be put together to form a building or mosaic picture. That is why the ecologist needs a comprehensive interdisciplinary knowledge. No matter how good one's knowledge in a special field may be, it is not enough. Therefore, many experiences and scientific findings of own research journeys to all floral regions and climatic zones of the earth and essential results from the scientific literature are collected in this book in order to obtain possibilities of comparison on a global scale. This principle taught by Heinrich Walter, which he summarized in the guiding principle "the laboratory of the ecologist is God's nature and his working field the whole world", was also decisive for this edition. With numerous additional color pictures, many examples of "nature" are vividly presented and the natural vegetation is highlighted as the basis in the various climatic zones. The activities of man can only be touched upon marginally, even if the anthropogenic changes and destruction of natural areas have assumed a threatening scale today.

The new edition of the textbook "Vegetation and Climate" is particularly characterized by a consistent structure. After the introductory chapters, which provide the basic knowledge of scientific ecology, the large areas of the earth, the zonobiomes, are dealt with. The introductory chapters lay the foundation for understanding the geobotanical and ecological treatment of the Earth's natural large spaces. The zonobiomes, the large areas determined by climate, are presented comparatively; numerous colour graphics and photographs provide a clear picture of the zonobiomes. The special features are highlighted and certain focal points are discussed in more detail. In the last part, some conclusions are drawn with regard to the activities of man, which are often controlled only by actionism without being sustainable. The consequences leave little hope. This can best be countered by good education and, in addition to the all-important digitization that is now ubiquitous, mechanization must be geared to human survival and well-being and to sustainable land use. The basics for ecological understanding can be provided by this textbook.

Many colleagues, especially Wilhelm Barthlott, Bonn; Hans Breckle, Karlsbad; Eberhard Fischer, Koblenz; Helmut Freitag, Göttingen; Reinhard Fritsch, Gatersleben; Jürgen Homeier, Göttingen; Frank Joisten, Stettiner Hof; Michael Keusgen, Marburg; Ernst Kluge, Frankfurt/M; Georg Miehe, Marburg; Stefan Porembski, Rostock; Christian Opp, Marburg; Khaled Rafiqpoor, Roermond; Michael Richter, Erlangen; Michael Succow, Greifswald; Kim Vanselow, Erlangen; Karsten Wesche, Görlitz have supported us and also provided additional photographic material, for which we sincerely thank them all.

The German edition is published by Springer Verlag. Special thanks go to the publisher for the very good cooperation, the great obligingness and the help.

We would like to thank Uta Breckle and Sadeka Rafiqpoor especially for their help, but also for their inexhaustible patience.

Bielefeld and Bonn, July 2019

Amendment to the English edition.

Springer Nature, as one of the leading knowledge publishers, is convinced that this book will play a major role in the future. This statement was based on the great demand for the e-version of the book in particular. As part of a novel attempt to translate selected German-language books into English with the help of artificial intelligence, "Vegetation and Climate" was selected in order to make the book accessible to a broad international readership. Aware of the shortcomings compared to a native speaker, the swift translation of the book was to be done with the help of AI software. The automatic translation of the text was astonishingly good, only little had to be changed. The linguistic perfection is certainly not quite optimal yet, but it enables the rapid provision of scientific literature in other languages. The transcription of the graphics was somewhat more difficult, a lot of "manual work" was still required. The ambiguity of some terms had to be critically questioned. We are convinced that being able to provide students and interested parties with a well-founded textbook will continue to be of great importance in the future - despite the wealth of information on the internet. The preparation of the English edition has enabled us to eliminate some minor errors from the German edition and to improve one or the other graphic, as well as to add instructive photos.

Mr. Simon Shah-Rohlfs from the Springer Nature team has made valuable suggestions for the realisation of the project and Apura Sarwade in India has managed the technical processing. We are once again indebted to Springer-Verlag and all those involved who have contributed to the success of this interesting project and hope that, especially in times of the ever increasing importance of scientific knowledge, this illustrated textbook will be well received and used worldwide.

Bielefeld and Bonn, July 2021

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[IMAGE]

Golden temple and sophisticated traditional garden and landscape architecture in the warm temperate climate of zonobiome V in Kyoto, Japan (Photo Breckle)

**Physical units and conversion factors**

**Basic units**

|  |  |  |
| --- | --- | --- |
| Length | Meter | m |
| Mass | Kilogram | kg |
| Time | Second | s |
| Temperature | Kelvin | K |
| Light intensity | Candela | cd |
| Amount of substance | Mol | mol |

**Other units**

Force Newton N



Pressure Pascal Pa



Energy Joule J



Heat units





Power Watt W



Radiation, illuminance Lux lx



Luminous flux Lumen lm

Luminous intensity cd-m-2









**Further conversions**





**Transformation energy for changes in the state of water:**

Solid ↔liquid (melting; freezing): 0.3337 MJ-kg-1 (79.5 cal-g-1)

Liquid ↔gaseous (evaporation, vaporization; condensation): 2.26 MJ-kg-1 (539 cal-g-1)

Gaseous ↔solid (sublimation): 2.86 MJ kg-1 (684 cal-g-1)

**Internationally defined prefixes for units and the associated factors (English designations):**

|  |  |  |  |
| --- | --- | --- | --- |
| 101 | Ten  | Deka | as |
| 102 | Hundred  | Hecto | h |
| 103 | Thousand | Kilo | k |
| 106 | Million | Mega | M |
| 109 | Billion | Giga | G |
| 1012 | Trillion | Tera | T |
| 1015 | Quadrillion | Peta | P |
| 1018 | Quintillion | Exa | E |
| 10-1 | Dezi | d | (tenths) |
| 10-2 | Zenti | c | (hundredths) |
| 10-3 | Milli | m | (thousandths) |
| 10-6 | Micro | µ | (millionths) |
| 10-9 | Nano | n |  |
| 10-12 | Piko | p |  |
| 10-15 | Femto | f |  |
| 10-18 | Atto | a |  |

**Abbreviations and symbols**

|  |  |
| --- | --- |
| a | Year |
| A | A horizon for soils (with predominantly organic material) |
| a s l | Above sea level |
| B | B-horizon in soils (transitional horizon between organic overburden and weathered bedrock) |
| BHD | Breast Height Diameter of tree stems, trunks in centimetres |
| C | C horizon for soils (subsoil: weathered bedrock in the soil profile) |
| °C | degree Celsius |
| cal | Calorie |
| CAM | Diurnal acid metabolism in photosynthesis (Crassulaceae Acid Metabolism) |
| CEC | Cation Exchange Capacity |
| d | Day (24 h) |
| DI | Diversity Index |
| Dm, dw | Dry matter, dry weight |
| E | Einstein (light quantum quantity) |
| E | East |
| Ea | Current actual evaporation |
| Ep | Potential evaporation |
| ET | Evapotranspiration (total evaporation) |
|  |  |
| FK | Field capacity |
| FW | Fresh weight |
| g | Gram |
| G | G horizon in soils (waterlogged, low-oxygen gley horizon) |
| GPP | Gross primary production |
| h | Hour |
| ha | Hectare (104 m2) |
| J | Joule |
| K | Kelvin |
| kg | Kilogram |
| kW | Kilowatt |
| l | Litres |
| LAI | Leaf areaindex |
| LR | Available light, photic ratio  |
| lx | Lux |
| m | Meter |
| M | Mass (substance production) |
| mg | Milligram |
| min | Minute |
| ml | Milliliter |
| mm | Millimeter |
|  |  |
| mol | Mol |
| μm | Micrometer |
| N | Newton |
| N | North |
| OB | Orobiome |
| P | Precipitation |
| Pa | Pascal (1Pa = 10 -5bar) |
| PB | Pedobiome |
| pF | Water potential |
| pH | Negative decadic logarithm of hydrogen ion concentration (H+, acid strength) |
| Ph | Photosynthesis |
| PhAR |  Photosynthetically active radiation |
| ppb | Parts per billion |
| ppm | Parts per million |
|  π\* | potential osmotic pressure |
| R | Respiration |
| RF | Relative humidity |
| RQ | Respiration quotient (carbohydrates = 1, fats = 0.7) |
| s | Second  |
| S | South |
| sZB | Subzonobiome |
| t | Time |
| t | Ton (103 kg) |
| T | Transpiration |
|  |  |
| Torr | = mm Hg, obsolete pressure measurement (= 105Pa) |
| UV | Ultraviolet (short-wave light) |
| W | West |
| WC | Water content |
| WSD | Water saturation deficit |
| ZB | Zonobiome |
| ZE | Zonoecotone |

**Preliminary remarks**

1. **The scientific ecology**
2. **Importance of systematics and taxonomy for biology**
3. **Importance of scientific documentation (e.g. in museums)**
4. **Importance of field trips for young scientists**
5. **Literature**

Nomad tents of a Kochi family in the surroundings of Mazare Sharif, N-Afghanistan (Photo: F. Joisten)

1 **The Scientific ecology**

Ecology is a biological science and thus just like life (according to our current knowledge) in our solar system, it is limited to the earth. Life as a whole is connected with open cycles and energy flow - i.e. a build-up of substances with binding of solar energy as well as a decomposition with release of the bound energy mostly in the form of heat.

The smallest independent unit of life is the cell, whose compartments, structure and function are the subject of molecular biology, biochemistry and physiology. Ultrastructural research using the latest techniques plays a major role here today, as does the recording and manipulation of the genetic material.

The unicellular organisms are primarily the object of study in microbiology. The next higher living unit is the organism with its multicellular tissues and organs. We distinguish plant, fungal and animal organisms, which are morphologically, anatomically and functionally very diverse. Phytology (botany) deals with the former, zoology with the latter. The green plants are autotrophic and constructive , the colourless as well as the animal organisms heterotrophic and transforming or decomposing. Heterotrophic are also the fungi, which today is considered as a separate group of organisms and with which the mycology deals.

The ecological factors act at different levels of complexity, naturally also at the molecular level (◘ Table 1). They cause certain effects and interactions. At the level of individuals, adaptation takes place via modifications, mutations and selection. This is, among other things, the topic of auto-ecology. At the ecosystem level, these adaptations and constantly changing population structures mean ever-changing dynamics, for example for material cycles and energy flows (flux). Populations are recorded by demecology, synecology examines biotic communities and their composition (static view), ecosystem biology investigates the dynamics in biotic communities and thus also the properties that determine energy flows (flux) and material cycles.

The highest living units are the communities of plant and animal organisms, each composed of populations that, together with the abiotic environmental factors (climate and soil), form ecosystems characterized by a constant circulation of substances and energy. The study of these ecosystems from the smallest to the global - the **biosphere** - is the task of ecology in the broadest sense.

This book provides a brief, accessible introduction to this global ecology.

Heinrich Walter, the founder of this textbook (Breckle 2002a), expressed the connections between humans and the biosphere as follows:

"The biosphere comprises the natural world into which man has been placed and which, thanks to his mentalcapacities (good sense and reasoning)-, he is able to regard objectively - thusraising himself above it. On the one hand, he is a child of this external, apparent world, and dependent upon nature, but on the other hand through the world within himself, has access to the divine.

Only an awareness of both sides of his nature enables man develop into a wise and harmonious being with the hope of divine fulfilment upon death. It is not the sole calling oif man to use nature to his own ends. He also bearsto the responsibility for maintaining the earth’s ecological balance, of tending and preserving it, to the best of his ability."

Table 1 The different levels of complexity and examples of impacts

|  |  |
| --- | --- |
| Complexity level | Examples of reactions and possible effects (e.g., salt exposure) |
| Interactions and effects in biomes, in the biosphere (large scale ecosystems) | Salt and other material cycles, material balances, energy fluxes, sedimentation, accumulation in erosion basins, geomorphological long-term processes |
| Interactions and effects in ecosystems | Salt and mineral cycles, mass balance, accumulations, mass balances, energy yield, species composition (frequency and dominance) |
| Effects on populations | Reproduction, age distribution, competitive ability, selection |
| Interactions with intact whole plants, individuals | Mineral metabolism, vitality, water balance, adjustments of growth, developmental stages, hormonal balance |
| Interactions with tissues | Formative effects, defect formation, osmotic stress, ion effects |
| Interactions with cells | Formative effects, altered differentiation, premature senescence. |
|  |  |
| Effects on cell organelles | Respiration, photosynthesis, biosynthesis of secondary plant compounds |
| Effects on bio-membranes | Permeability, potential changes |
| Bioeffects on macromolecules | Gene regulation, enzyme activities, DNA changes |

In order to fulfil this task and not to engage in overexploitation, which ultimately calls his own existence into question, man must recognise the ecological laws of nature and take them into account, even if there are still and again and again people who believe that they can abolish nature and rely entirely on technology, or vice versa, people who follow dogmatic or fundamentalist currents completely uncritically and in a frightening manner.

We will deal primarily with natural ecological systems and conditions, as it would go beyond the scope of this abridged version to also deal in detail with all the secondary ecosystems created by humans and the various stages of degradation, especially since the ecological laws of nature are best discernible in natural ecosystems, which are therefore in a dynamic equilibrium. Natural ecosystems are the models and the reference point for sustainability. They have developed and optimized over millions of years of evolution.

2 **Importance of systematics and taxonomy for biology**

The destruction of tropical ecosystems not only increases degraded areas and renders them completely infertile through erosion, but much more serious is the loss of biodiversity (Boerboom & Wiersum 1983, Mutke & Barthlott 2008, Barthlott et al. 2014, Barthlott & Rafiqpoor 2016). This destruction results in a disproportionately large loss of terrestrial plant and animal species and correspondingly coordinated communities. Species loss due to primeval forest die-offs is occurring many times more rapidly than, say, dinosaur extinctions or changes during glacial periods. Worldwide ecological field research is still urgently needed (Breckle et al. 2004).

Currently, about 1.8 million animal and plant species have been described, i.e. scientifically documented. However, as one must assume today, this is only a fraction of the species occurring on the globe. The diversity of certain areas and the comparison of different recording methods can be estimated by extrapolation, resulting in figures of five to ten million species. Other approaches, such as fractal geometry, yield species numbers of up to 30 million. The real numbers are very uncertain to estimate, but each new expedition material from the tropics always yields a wealth of new species. Scientific processing of the material often lags years behind. The number of specialists for many animal groups is so small that they cannot keep up with the processing of the material, and most of it remains unprocessed. The systematic affiliation, the taxonomic-nomenclatural correct naming, or even more the phylogenetic relationships are in many animal groups only very roughly or not yet known. In the case of higher plants, the state of knowledge is much better, due to the smaller number of species. But already in the case of algae and even more so in the case of fungi, so many unknown new species are still to be expected that it would be urgently necessary not only to considerably accelerate teaching, i.e. teaching and research, in systematics at universities and research centres, but at least to reintroduce it at all. Actually, almost all biologists work with organisms - but some biochemists, physiologists, geneticists often seem to no longer know which organisms they actually work with.

Helmut Gams: "*All the findings of the various sub-disciplines of biology, i.e. as far as possible all the characteristics, should ultimately be used to achieve a constant improvement in the natural system of organisms*" (oral comm.).

Systematics is the biological science of the future; it organizes diversity, biodiversity, the conservation of which is now recognized as a fundamental problem (Breckle 1999).

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| --- |
| Box 1 The tasks of systematics and taxonomy |
| Systematics and taxonomy are essential foundations for understanding between the biological disciplines. Systematics brings order into diversity. On the one hand, it must conservatively serve the understanding by a fixed framework, on the other hand, it must progressively by a flexible framework express the advances in knowledge of phylogenetics also in the nomenclature. Without well-founded methods in systematics and taxonomy, not only ecology but also the whole of biology hangs in the air and has no point reference. |

|  |
| --- |
| Box 2 The documentation |
| In addition to the task of presenting scientific facts, processes and structures to the public in exhibitions, museums also have the important task of scientific documentation. |

3 **Importance of scientific documentation (e.g., in museums)**

In the systematic-taxonomic treatment of species diversity, documentation is of decisive importance. Type material, on the basis of which the species diagnoses are described, must be stored safely for the future in museums or in the large herbaria as the essential documentation centres.

With the help of the new possibilities of information exchange, catalogues and taxonomic overviews, identification keys, range maps can be deposited on the Internet and thus made accessible to all users online. But even for this, there is a lack of sufficient numbers of capable young biologists, and certainly not of the political insight to set the right priorities for the future.

There are still many amateur scientists who spend their free time studying a particular group of organisms, not to mention the many ornithologists. This has been shown in the floristic mapping of Central Europe. Many of these private collectors have special knowledge and possess valuable small collections. The museums must be enabled to acquire such material as a donation or as an estate, or even by purchase. Today this often fails due to lack of insight and financial, human or spatial resources and valuable, perhaps irretrievable material ends up in the trash.

4 **Importance of excursions for young scientists**

Students can only find their way around organismic biology if they are offered opportunities to get to know organisms in their environment in the field. In recent years, for example, universities have reduced their mandatory program of beginner field trips from a meager five afternoons to an irresponsible three. Some no longer require field trips at all. Grants for field trips lasting several days have been drastically cut.

Obviously, there are more and more biologists who have never had the good fortune to participate in a good several days Field Trip and realize that this is the most intensive way of learning, of grasping not only biological, but general scientific relationships. Not just seeing something presented to you in front of the "goggle-box", the television, but looking and synthetically grasping and recognizing connections, for example, about the geological, the geomorphological situation, the natural resources as the basis for the possibilities of agriculture and forestry in the area under consideration, the flora and fauna and their interdependence, the spatio-temporal dynamics of producers, consumers and degradation processes, phenology, the historical basis of landscape formation, the possibilities of sustainable conservation, all this can be explained to students standing on a hill. But whether faculties (or ministries) today still want or are even capable of doing this? Biology without a due share of field biology is an amputated biology. On field trips, the participants are in the middle of the action. Only then can they also meet possible dangers, only then are appropriate precautions without fearful hysteria (for example, against ticks, or spiders, or snakes) a natural prevention, and only then they also learn to move in nature in accordance with nature. Today this can be supplemented very sensibly to a moderate extent and well supported by critical use of online archives and information.

Especially also for other disciplines, excursions are regarded of crucial importance today. Surprisingly and fortunately, some student councils have grasped this more quickly than some teaching staff who have been reformed several times and teach so-called modern and modulated subjects.

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| --- |
| Box 3 The importance of field trips |
| Excursions are the most intensive form of learning. Through analytical grasping and synthetic linking of contexts, one learns to look and understand correctly, using all the senses, to synthesise and understand the links and connections between the organisms and their environment from which they develop, the concepts, vision and understanding of the whole regarded ecosystems |

5 **Literature**

Barthlott, W. & Rafiqpoor, M.D. 2016: Biodiversität im Wandel – Globale Muster der Artenvielfalt. In: Lozán, J.L., Breckle, S.-W., Müller, R. & Rachor, E. (Hrsg.): Warnsignal Klima: Die Biodiversität: 44-50. In Kooperation mit GEO-Verlag. Wissenschaftliche Auswertungen. www.warnsignal-klima.de

Barthlott, W., Erdelen, W. & Rafiqpoor, M.D. 2014: Biodiversity and Technical Innovations: Biomimicry from the Macro- to the Nanoscale. In: Lanzerath, D. & M. FRIELE (eds.): Concept and Value in Biodiversity. Routledge Studies in Biodiversity Politics and Management, 2014: 300-315. ISBN 978-1-415-66057-0

Boerboom, J.H. A., & Wiersum, K.F. 1983: Human impact on tropical moist forest. In: Holzner, W., WERGER, M.J.A., & Ikusima, I. (eds.): Man’s impact on vegetation. Junk, The Hague: 83–106

Breckle, S.-W. 1999: Wie wichtig ist Systematik für Biologen und Ökologen? Cour. Forsch.-Inst. Senckenberg 215: 49–54

Breckle, S.-W. 2002a: Salinity, halophytes and salt affected natural ecosystems. In: Läuchli, A. & Lüttge, U. (eds.): Salinity: Environment – Plant – Molecules. Kluwer Acad. Publ. Dordrecht: 35-77

Breckle, S.-W. 2004: Flora, Vegetation und Ökologie der alpin-nivalen Stufe des Hindukusch (Afghanistan). In: Breckle, S.–W., Schweizer B, Fangmeier, A. (eds.): Proceed. 2nd Symposium AFW Schimper–Foundation: Results of worldwide ecological studies. Stuttgart–Hohenheim: 97–117

Mutke, J. & Barthlott, W. (2008): Biodiversität und ihre Veränderungen im Rahmen des Globalen Umweltwandels. In: Lanzerath D., Mutke, J., Barthlott, W., Baumgärtner, S., Becker, C. & Spranger, T.M. (Hrsg.): Biodiversität. [Ethik in den Biowissenschaften – Sachstandsberichte des DRZE, 5]. Freiburg i.B.: 25-74