Chapter 1

Introductory Chapter: Global Aspects and Scientific Importance of Desert Ecological Research

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1. Introduction

If ecologists or environmental scientists are talking about desert ecological research, then almost everyone is thinking about specific desert flora [1–5], fauna [6, 7], or desertification itself as a consequence of climate change [8, 9], or sand dunes-triggered disasters [10]. In fact, the importance of ecological research in deserts is far more general and wider. For deeper understanding of this importance need to overview the definition of deserts from different viewpoints, the real areas of deserts, and some basic production biological data.

2. Definition of deserts, semi-deserts, and habitats prone to desertification

Efficient functioning of the Earth's ecosystems is based on the autotrophic plant life, which can make use of the radiation energy of the Sun directly. This plant life needs, besides the light of the Sun, simultaneous availability of minerals in the lithosphere, carbon dioxide in the atmosphere, and liquid water in the hydrosphere. Thus, biosphere appears on the interface of these three spheres. Where these four factors are available in the most efficiently usable form, tropical rainforests can be found. Every other habitat is more or less a "struggle zone" for plants because some of the four above mentioned factors limit the biosphere. Based on the degree of environmental limitations, ecosystems can be arranged along a scale. Desert ecosystems can be found on the opposite endpoint of this scale compared to tropical rainforests. Semi-deserts can be found near deserts on this imaginary line, just a little bit nearer the other endpoint of the scale.

3. Vegetation approach

If this most general definition of deserts is accepted, several habitats, which are not referred to as deserts in the habitual language use must be considered to be deserts. In order to quantify the scale, we can use biomass per area as a static indicator as well as net primary production per area per time as a dynamic indicator. Biomass of tropical rainforests is characterized by 2200 g/m^2/year net primary production (NPP) and 45,000 g/m^2 biomass, this is currently the "ideal existence status" of the biosphere. In the case of deserts, NPP is between 0 and 3 g/m^2/year and biomass is between 0 and 20 g/m^2. In the case of semi-deserts, NPP amounts to 3–150 g/m^2/year and biomass amount to 20–700 g/m^2.

Desert or semi-desert conditions can be caused by:

1. Lack of liquid water usable for plants (arid areas without precipitation)
   - areas without precipitation (orographical, e.g., Gobi, Tibet, or cool, dry deserts, e.g., Namib, Atacama)
   - areas with much larger evapotranspiration than precipitation due to the heat (southern and central part of Sahara)
   - permanently frozen areas (Greenland, Antarctica, and peaks of high-altitude mountains)
   - sheer, unweathered rock surfaces where water runs off (barren, rocky areas in mountains)
2. Lack of access to minerals in the lithosphere
   - Photic zone of open oceans (where biomass has a desert value of only 3 g/m^2, which is even less than that in the Sahara, however, NPP has a semi-desert value of 125 g/m^2/year)
3. Lack of light
   - Abyssal water of open oceans, caves (special ecosystem with low productivity)
4. Lack of air and light
   - Inner part of the rock masses of the Earth (where microbial life may often exist)
5. Continuous physical disturbance, which prevents plants from settling in
   - Coastal tidal zone
   - Fast-running reaches of rivers
   - Shifting sand areas

- Volcanic areas exposed to regular lava flow or tuff eruption
- Areas exposed to anthropogenic transformation and disturbance (urban concrete surfaces, airports, highways—"anthropogenic deserts")
- Areas exposed to extreme environmental pollution (e.g., mazut lakes)
- Certain agricultural areas with low productivity (not irrigated, plowed areas with regular disturbance, lying fallow most of the year, semi-desert category in annual average)

At the borders of the semi-desert category, there are tundra, open grasslands (e.g., rocky, saline, and mountain) and several other habitat types besides classic tropical and temperate semi-deserts.

4. Climatic approach

Vegetation is normally able to evapotranspirate water equivalent to 20 mm of precipitation at a temperature of 10°C. A month is considered to be climatically arid if its monthly average temperature exceeds double the monthly amount of precipitation. If each of the 12 months of the year is arid in multi-year average, the area is considered to be a desert from a climatic point of view. If less than 2 months of the year are not arid, we speak about semi-desert climate. Similarly, if the multi-year average of the monthly average temperatures is below 0°C for 12 months, we speak about ice desert from a climatic point of view; if the period with an average temperature above 0°C lasts up to 2 months, the climate is tundra. However, the climatic approach may be misleading because the typical vegetation type of a certain area does not depend on the climate only.

Plants and animals have been able to adapt to areas with different environmental (among them climatic) conditions better and better during the evolution (on a historic time scale). In the second part of the Cambrian period (approx. 542–488 million years ago), hot tropical conditions were dominating most of the Earth, however, 100% of land could be considered a desert, only traces of some coastal invertebrates indicate terrestrial life. Also, during the Ordovician (488–443 million years ago), the climate was hot in several areas, the first plants (liver mosses and hyphae) appeared on land, however, this type of vegetation could have reached rather desert than semi-desert level. The first vascular terrestrial plants appeared in the Silurian (443–416 million years ago), however, they began to form vegetation mainly on the waterside, the continents' interior kept being a desert for the most part from a vegetation point of view. During the evolution of terrestrial life, more and more various adaptation modes have appeared in response to the various climatic conditions, and this process is still going on. At the same time, climatic regulation capacity and generally self-regulation capacity, biodiversity, total biomass, and productivity of the biosphere have also shown an increasing tendency (excluding fall-backs caused by climatic variation).

	Therophytes	Cryptophytes	Hemi-cryptophytes	Chamaephytes	Phanerophytes	Epiphytes
Tropical rainforests	—	—	—	10–20%	60–80%	10–20%
Tropical and temperate desert and semi-desert	40–50%	5–10%	10–20%	10–20%	5–10%	—
Ice and tundra	1–5%	1–5%	60–70%	20–30%	—	—

Table 1. Comparison of frequency distribution of plant life-forms (based on [11]).

Vegetation types have reached various levels regarding adaptation to the abiotic conditions of the given habitat, which is also shown by the distribution of plant life-forms. Long-living K-strategists and phanerophyte life-form are dominating where vegetation has been able to adapt efficiently to existing conditions. However, where the habitat is rather a "struggle zone", shorter-living r-strategists, herbaceous annual, or rosette plants are dominant (see **Table 1**).

Thus, deserts and semi-deserts are "front lines" of the expansion of biosphere, and therefore, their research (similarly to tropical rainforests) is highly important regarding life and future of mankind.

5. Importance of deserts and semi-deserts regarding the whole biosphere and human society

Global ecological importance of deserts and semi-deserts in the broader sense can be estimated according to their area and indicators of their vegetation. Tropical rainforest can be a reference base as a counterpoint, however, when speaking about deserts and semi-deserts in the broader sense, tundra and artificial deserts (human-transformed areas) must be considered as well besides tropical and temperate deserts and semi-deserts in the narrower sense. Land takes up approximately 150 million km^2 on Earth from which approximately 15 million km^2 are covered with ice, mainly in Antarctica and Greenland. **Table 2** shows potential and current values of tropical rainforests as well as areas considered as desert and semi-desert in the broader sense, excluding the before mentioned ice fields. **Table 3** shows the sources of data. Comparison of habitat types can be based on carbon stock in the biomass (t/ha), yearly carbon sequestration by primary production (t/ha/year), and biodiversity of the habitat type (species number per 10,000 km^2). These data can be found in **Table 4** and their sources in **Table 5**.

These habitats offer a wide range of ecosystem services, among others due to the climate regulation role of the assimilated and retained carbon stock. Monetary value of these is shown in **Table 6**, based on a price of $11 per ton (Interagency Working Group, 2013).

	Africa km²	South America km²	North America km²	Asia km²	Europe km²	Pacific km²	Total km²
Lowland rainforest	4.0177×10^6–8.7000×10^5	7.0721×10^6–4.5400×10^6	0	3.4907×10^6–1.7700×10^6	0	0	1.4581×10^7–7.8000×10^6
Deserts	1.7022×10^6–1.0932×10^6	2.7405×10^6–8.7276×10^5	2.2211×10^6–5.8855×10^5	1.3390×10^7–6.7763×10^6	0	3.9828×10^6–3.6949×10^6	3.9357×10^7–2.2865×10^7
Tundra	0	0	1.8922×10^6–1.8922×10^6	1.8922×10^6–1.8922×10^6	2.6542×10^5–2.6542×10^5	0	4.0497×10^6–4.0497×10^6
Human areas	1.4140×10^3–4.1679×10^4	7.0490×10^3–1.4854×10^5	2.5700×10^2–1.8185×10^5	$4.3900 \times 10^2 - 3.8400 \times 10^4$	$4.4390 \times 10^3 - 1.1406 \times 10^5$	$4.9000 \times 10^1 - 1.3871 \times 10^4$	$1.3647 \times 10^4 - 5.3840 \times 10^5$

In the case of natural ecosystems, the first number shows the area before human interference, whereas the second one shows the remnant at the turn of the millennium. In the case of human areas, the first value refers to the 1700s, whereas the second one refers to the turn of the millennium.

Table 2. Potential and current areas.

	Africa	Asia	North America	South America	Europe	Pacific
Lowland rainforest	FRA ([12])	FRA ([12])	See at South America	FRA ([12])	—	See at Asia
Deserts	Hannah et al. ([13])	Hannah et al. ([13])	Hannah et al. ([13])	Hannah et al. ([13])	—	Hannah et al. ([13])
Tundra	—	Brink ([14]); Tchebakova et al. ([15]); Golubyatnikov et al. ([16])	Brink ([14]); Tchebakova et al. ([15]); Golubyatnikov et al. ([16])	—	Brink ([14]); Tchebakova et al. ([15]); Golubyatnikov et al. ([16])	—
Human areas	Goldewijk et al. ([17])	Goldewijk et al. ([17])	Goldewijk et al. ([17])	Goldewijk et al. ([17])	Goldewijk et al. ([17])	Goldewijk et al. ([17])

Table 3. Sources of data shown in **Table 2**

	Carbon stock C t/ha	Carbon sequestration C t/ha/year	Species number/10,000 km^2
Lowland rainforest	210	13–17	2750
Deserts	3	1.15–2.69	457
Tundra	2.5	1.94	227
Human areas	5	2.2	1684

Table 4. Carbon stock, carbon sequestration and species number per unit area.

	Carbon stock C t/ha	Carbon sequestration C t/ha/year	Species number
Lowland rainforest	http://www.esd.ornl.gov	Girardin et al. ([18])	Barthlott et al. ([19])
Deserts	Melillo et al. ([20])	Ito and Oikawa ([21])	Ellis et al. ([22])
Tundra	Melillo et al. ([20])	Ito and Oikawa ([21])	Ellis et al. ([22])
Human areas	Melillo et al. ([20])	Haberl et al ([23])	Ellis et al. ([22])

Table 5. Sources of carbon stock, carbon sequestration and species number per unit area values.

	Carbon stock		Assimilated carbon	
	$ on potential area	$ on current area	$ on potential area	$ on current area
Lowland rainforest	1.23×10^{13}	3.76×10^{12}	7.64×10^{11}–9.99×10^{11}	3.76×10^{11}–4.92×10^{11}
Deserts	4.76×10^{11}	2.77×10^{11}	1.83×10^{11}–4.27×10^{11}	1.06×10^{11}–2.48×10^{11}
Tundra	4.08×10^{10}	4.08×10^{10}	3.17×10^{10}	3.17×10^{10}
Alpine vegetation	5.76×10^{10}	2.95×10^{10}	2.41×10^{10}	1.23×10^{10}
Urban area	2.75×10^{8}	1.09×10^{10}	1.21×10^{8}	4.78×10^{9}

Table 6. Monetary value of carbon dioxide in $

6. Main future tasks and problems of desert research in solving the global problems of our time

Global problems of our time are basically human ecological ones with the interplay of environmental and social factors. The most important global crisis phenomena are closely connected with each other, form a coherent system, and are associated with the anthropogenic disorders of the healthy functioning of the biosphere.

Main crisis phenomena are:

1. Global overpopulation crisis (population explosion),
2. Global climate change,
3. Global biodiversity crisis (mass extinction of species, habitat loss, the collapse of ecosystems),
4. Global social crisis (income scissors opening wider),
5. Global information crisis (insufficiency of scientific synthesis, overspecialization, publication flood), and
6. Lack of global coordination (independent influence of 195 nation states without substantive common planning and regulation).

Several of these problems are linked to the ecological research of deserts. Among the anthropogenic causes of desertification, overpopulation plays an important role; however, this

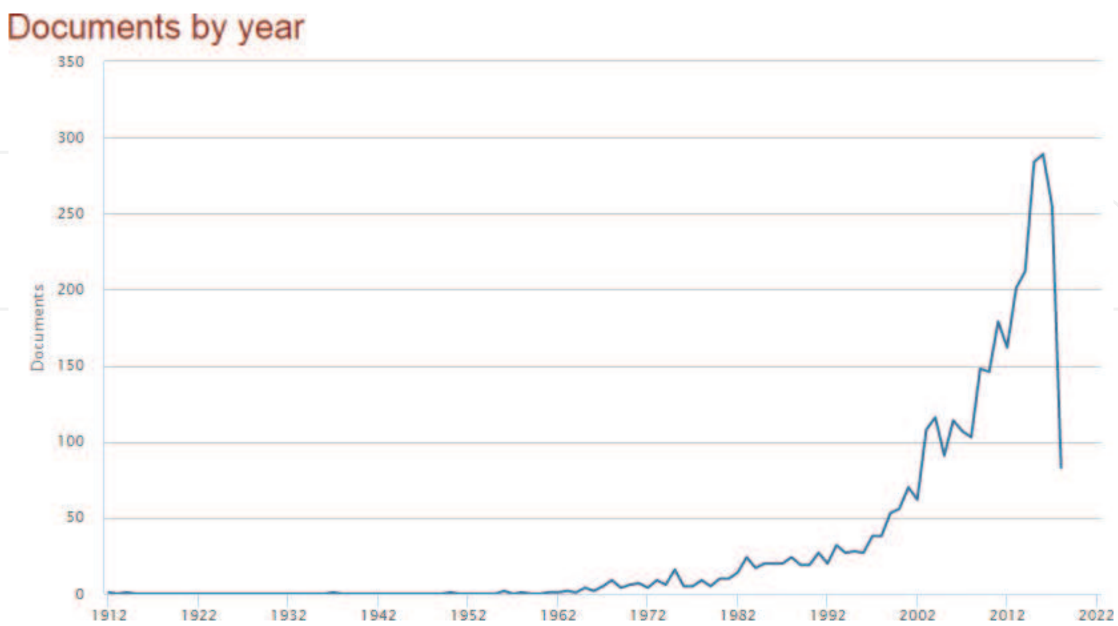

Figure 1. Number of articles with keywords desert + ecology in their abstracts in the Scopus database (downloaded on April 18, 2018).

increases the global social crisis as feedback. Global climate change is a cause and a consequence at the same time, since draught results in desertification, however, low plant production decreases carbon sequestration, which further enhances climate change. This group of phenomena is apparently closely connected with the biodiversity crisis also as a cause and an effect. Global information crisis makes itself felt in this area as well, since new data and knowledge are increasing exponentially, see **Figure 1**. It shows the yearly number of international scientific articles with keywords desert + ecology in their abstracts according to the Scopus database, for the period 1912–2018 (downloaded on April 18, 2018, thus data for 2018 are quarterly ones).

When examining the genre of these publication data (rate of document types, **Figure 2**), one can see that 90.7% of the publications are made up of primary publications (journal articles) and pre-publication (conference papers), and only 7.4% of them is synthesis (review articles, book chapters, or books). Thus, new information is produced much faster than we can organize it into a system of thought.

Solving global problems (among them desertification problems) of mankind is mainly hindered by the lack of global coordination, which would serve the protection of the common interest and align the efforts of mankind. Solving global problems needs efficient international cooperation, aligned scientific research, aligned political decision-making, legislation and economic regulation.

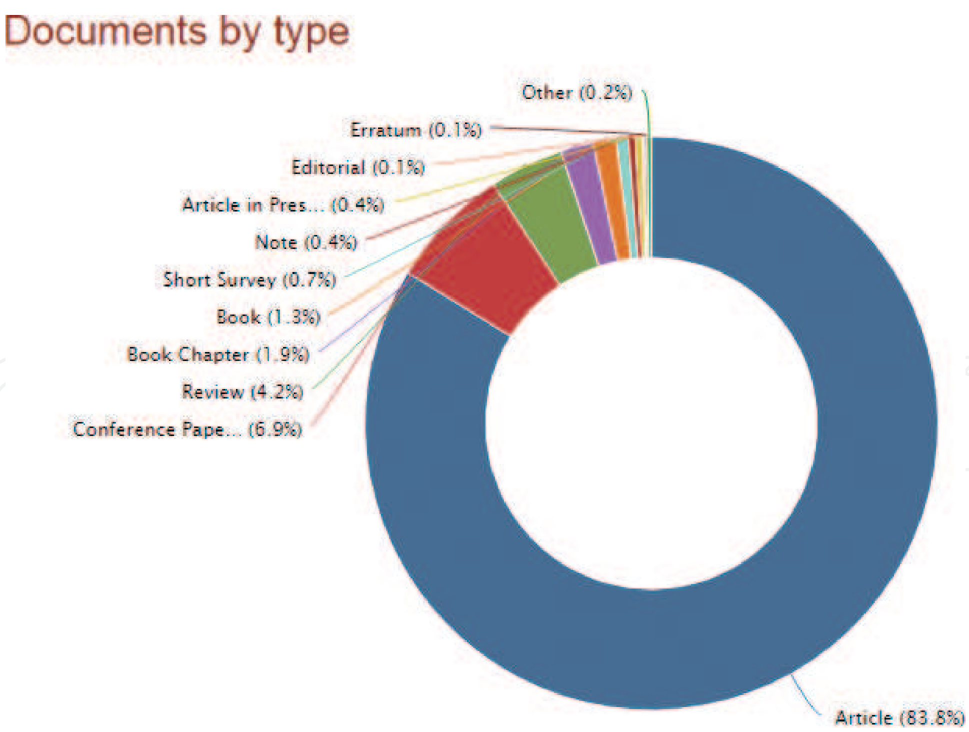

Figure 2. Distribution of articles with keywords desert + ecology in their abstracts according to a document type in the Scopus database (downloaded on April 18, 2018).

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