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Arvydas Lietuvninkas

# The Sustainable Role of the Tree in Environmental Protection Technologies

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Edita Baltrėnaitė
Department of Environmental Protect
Vilnius Gediminas Technical University
Vilnius, Lithuania

Pranas Baltrėnas
Vilnius Gediminas Technical University
Vilnius, Lithuania

Arvydas Lietuvninkas
Vilnius Gediminas Technical University
Vilnius, Lithuania

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*For Lithuania and its people*

# Preface

Changes in Earth's biosphere as civilization has developed, its increased technogenic load, and reduced overall resources of resistant stability spur the natural and technological sciences to properly concentrate on the possibilities of interaction between sustainable human activity and natural ecosystems. Trees are a primary focus. Natural tree ecosystems (forests), in terms of the overall mass of the biosphere, have been devastated, in the majority of cases by human activity. Humans also have intensively utilized the energetic, biological, and recreational resources of trees throughout their life cycles. The involvement of industrial society in large-scale applications of fossil fuels along with the rapid development of industry has resulted in the urgent current issue of widespread pollution of the ecosphere and the threat of global warming.

The use of trees in ecological technologies is based on their unquestioned importance in maintaining stability in the biosphere as well as on their presence in a number of Earth's biomes and its ecosystems, particularly those of Scots pine growing in urbanized territories and zones affected by pollution sources. This aspect in particular creates favorable conditions for using trees as bioindicators for establishing the properties and levels of contamination and, in some cases, as a measure for reducing pollution. Because the consequences of negative changes occurring in nature can only be minimized once their essential character is understood, this book focuses mainly on trees as biogeochemical objects and discusses a mechanism by which heavy metals enter into trees, the impact of biotic stressors as determinants of entry, the specificity of metal accumulation in certain species of trees and their parts, the biophilicity of heavy metals, and other aspects of biogeochemistry.

Considering the extent of the life cycle of the tree and with respect to wood as an industrial material and an agent for the sequestration of atmospheric carbon dioxide, investigations into thermally treated wood products and the efficiency of their application in the field of environmental protection engineering are presented. Greater focus is shifted to the properties of biochar and to defining its advantages as a packing material of the filters.

Exhaustive treatment of the versatile role of trees in environmental protection technologies is hardly possible without specifically applied research methods. Thus, investigation into heavy metal concentrations and their distribution in tree rings has assisted in advancing technology for wood sampling and evaluating their representiveness. To assess the eco-technological aspect of using trees in environmental protection technologies, a method of dynamic factors that maximizes the elimination of the impact of local environmental geochemical features on the element uptake evaluation has been developed. As an effective method for examining various ecological aspects, a mathematical simulation of the processes of contaminant transport in the environment, including the original models developed by the authors of the book, has been applied.

The novelty of the book is its explication of the sustainable role of the tree in environmental protection technologies, and the book includes reviews, research, and an evaluation of the use of trees.

This publication is dedicated to scientists and experts in the field of environmental protection. Would-be scientists – Ph.D. and M.A. students – may refer to the study as a source of scientific knowledge in the field of environmental protection technologies.

Reviewers
Prof. Dr. Habil Irena Eitminavičiūtė, Vilnius, Lithuania.
Dr. Arūnas Draugelis, Chicago, United Stated of America.
Prof. Dr. Habil Petras Vaitiekūnas, Vilnius, Lithuania.

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Edita Baltrėnaitė
Pranas Baltrėnas
Arvydas Lietuvninkas

# Introduction

It is quite natural that the tree is treated in this book as an important part of nature and the environment in which humans live. With respect to form and functions, trees are sacral objects for people. It should be noted that, though the main functions of trees have not changed, different ways of perceiving them through our senses have developed in humans. The cult of the Tree of Life as a worldwide symbol developed in tribal systems based on using such wooden cult objects as totems and considering a tree as an abode of ghosts. The mythological World Tree was the key artifact promoting the formation of a mythological space concept. According to this concept, the World Tree grows in the center of the universe and forms the axis connecting the sky, Earth, and the underground kingdom. The top of the World Tree supports the sky, its branches embrace the whole world, and its roots reach Earth's depths.

In discussing the modern forms of perceiving the functions of the tree, some well-known feature films are worth mentioning. Thus, in the movie Avatar, directed by James Cameron in 2009, the so-called soul (also native or sound) tree plays the lead and most mystical role and is vitally important for the native people of the fantastic planet Pandora. The 3-D version of Star Wars features Endor, a mystical moon covered with gigantic trees, while the Lord of the Rings features a race of creatures similar to trees called Ents.

In our own day, when the problem of sustainability of various processes and objects is under extensive discussion and debate, the sustainability of trees and their functions has become much more important if we consider their life cycle in areas receiving technogenic pollutant loads. The deterioration of the state of Earth's ecosystemss, the growing concentration of greenhouse gases in the atmosphere, and predictions of climate change are also cause for concern. The sustainability of trees in the context of long-term development is primarily associated with maintaining the geochemical status of the carbon cycle and such dangerous products of technogenesis as metals found in the biosphere, which are strongly affected by human activities.

The life of trees and usage of their products are actually closely connected with their life cycle stages, while their functions confirm the sustainability of trees with respect to their use in environmental protection technologies, which can be attributed to their long life and long-term effects.

Two main areas of environmental protection, where the role of trees is particularly important, are associated with the stage of their life and the stage involving the use of their products. In the first stage, the functions of trees are based on their use in ecotechnologies, while the second stage is closely connected with their use in environmental protection engineering. These two stages are related by the use of trees in environmental protection technologies both as animate and inanimate objects. The major stages of a tree's life cycle include the extraction of nutrient materials from the environment (resources) as raw materials and energy (***Stage A***), the processing of resources (***Stage B***), the manufacture of products (***Stage C***), the use of those products (***Stage D***), and waste utilization (***Stage E***) (Fig. 1).

At ***Stage A***, resource materials are considered to be inorganic environmental resources used by trees to support their vital functions. Trees use inorganic materials, assimilating $CO_2$ from the atmosphere and nutrient materials from soil for synthesizing biomass and developing their compartments while taking an active part in the biogeochemical cycle (Chap. 1). In polluted territories, these processes

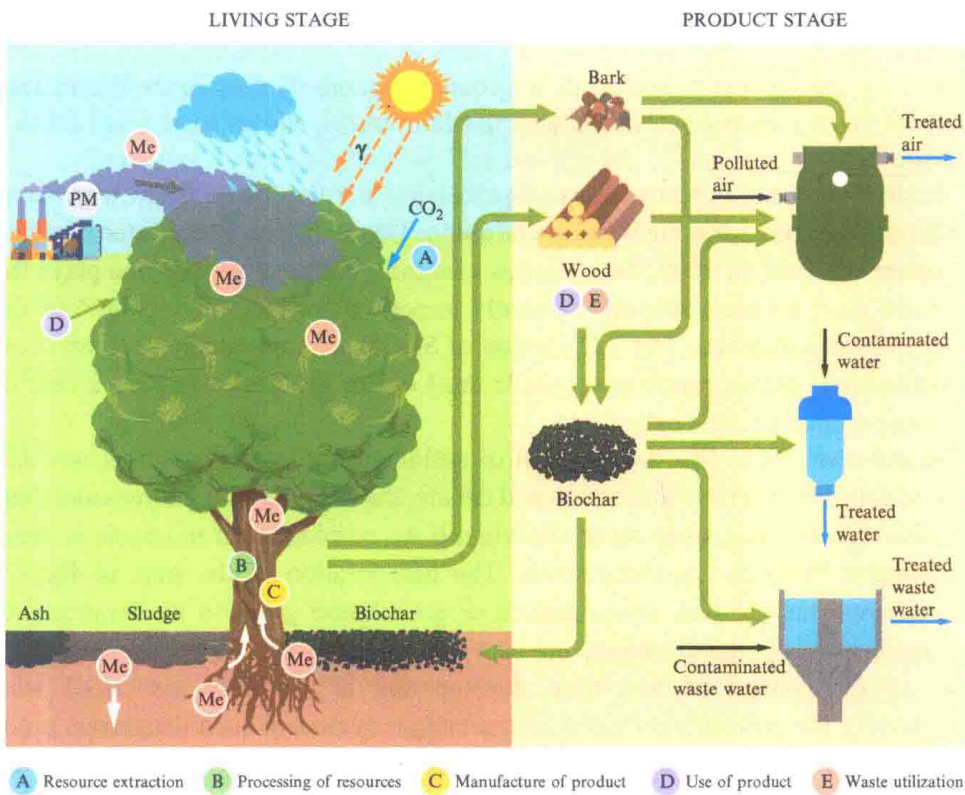


**Fig. 1** Major stages of a tree's life cycle

of ecosystems related to trees depend on the type of pollution (Chap. 2) and the transport of pollutants to them. The role of trees as sustainable functional units in areas covered by forests has become particularly important owing to their active participation in biogeochemical carbon circulation in the biosphere. Trees assimilate carbon dioxide from the atmosphere, thereby reducing its concentration as a causal factor of the greenhouse effect. The sustainability of trees is also associated with their role in removing such pollutants as metals from the surroundings and accumulating them in their systems, thereby limiting their mobility and possible negative effects on ecosystems for a long time.

The function of trees associated with stabilizing metals is discussed in Chap. 3, which also partially describes ***Stage B*** of the tree life cycle (resource processing), dealing with the transport of metals and their transformation and accumulation in trees, though in these cases, processes can be strongly affected by biotic factors.

***Stage C*** is associated with the manufacture of the product of biomass synthesis and its increase in the tree's life cycle. In a technogenic environment, a growing tree is subjected to aerogenic and edaphic pollution, causing both quantitative and qualitative changes in biomass properties. The biogeochemical properties of trees are associated with qualitative changes, while functional characteristics determine their qualitative changes (Chap. 4).

At ***Stage D***, relating to the use of the product, a wider range of application of trees besides biomass their use is discussed. In ecotechnologies, these are the functions of bioindication and phytoremediation, involving relatively cheap and effective innovative technologies, which take advantage of the environment's capacity to reduce pollution and risks over the long term (which represents the main sustainable development principles). In environmental protection engineering, the natural and processed products of trees are used. Mathematical models of these processes have become tools that are extensively used in practice (Chaps. 5–7).

At ***Stage E***, the waste materials of trees, including both natural (e.g., bark, wood shavings) and processed (e.g., ashes, biochar, wood fibers) products, which can be practically used, are categorized with waste products. In most cases, these products meet the needs of a specific application and satisfy technical requirements. Their market is being expanded, which helps to avoid negative impacts on the environment and human health. Thus, natural resources are managed in a sustainable way, and materials recovered from trees are used more efficiently (Chaps. 6 and 7).

This monograph aims to demonstrate the links between trees' functions and sustainable development at each stage of the tree's life cycle. The use of trees in environmental protection technologies confirms the ability of humans to expand their knowledge of nature, to have respect for it, and to better understand the role of trees in their lives. Besides the well-known ecological significance of trees, we would like to mention that the role of trees has increased through extensive use of environmental protection technologies. The areas of practical application of trees are as follows: (1) the use of trees and their products in ecotechnologies and the development of predictive models of processes and (2) the evaluation of practical applications of wood products in environmental engineering systems.

The description of the environmental protection role of trees at various stages of their life cycle presented in this book aims to emphasize their ability to improve the state of the environment from both ecological and environmental protection engineering perspectives. Trees can reveal changes taking place in the environment, stabilize the spread of pollution, and protect the environment. When a tree completes the stage of its existence as a living organism, the period of its indirect participation in engineering environmental protection solutions follows.

The present work links nature and technology, ecology and engineering, principles for knowing the world and the application of knowledge, and discusses implications and benefits because, in nature as in life, everything makes sense, while, according to Barry Commoner, everything is connected to everything else.

# About the Authors

**Edita Baltrėnaitė** Doctor of Sciences in the scientific field of environmental engineering and landscape management, Associate Professor, acting professor at Vilnius Gediminas Technical University, Department of Environmental Protection, obtained diploma of Bachelor and International (in English) Master of Sciences at Vilnius Gediminas Technical University. In 2007, she defended her thesis titled *Investigation and Evaluation of the Transfer of Heavy Metals from Soil to the Tree*. Since 2007, Edita has been a scientific secretary of the international *Journal of Environmental Engineering and Ecological Science*, a member of the editorial board of a journal published by Romanian Academy of Science, *Annals—Series on Chemistry Sciences*, a member of the Environmental Institute of Scientific Networks (EISN-Institute), and a representative for Lithuania in the EU research programs COST859: *Phytotechnologies to Promote Sustainable Land Use Management and Improve Food Chain Safety*, COST FA0905: *Mineral-Improved Crop Production for Healthy Food and Feed*, and COST TD1107: *Biochar as an Option for Sustainable Resource Management*.

Areas of interest: application of biogeochemical processes to environmental protection technologies, evaluation of metal transport in the ecosphere and thermal processing, and the application of lignocellulosic products in environmental protection engineering.

E. Baltrėnaitė gives lectures to master's students about environmental protection technologies, anthropogenic impacts on the environment, waste utilization, soil recovery technologies, clean technologies, and soil remediation technologies and supervises doctoral students. She is also a member of the Committee for the Research Area of Environmental Engineering and a chair or member of committees for seven defended theses.

E. Baltrėnaitė was a supervisor of studies of 24 bachelor's and 12 master's degree students as well as Erasmus trainees from Finland, Italy, and Latvia. She also lectures at Helsinki University (Finland), Valencia Polytechnic University

(Spain), Aalto University (Finland), and Southern Denmark University. She has made research visits to the Norwegian University of Life Sciences, the Jozef Stefan Institute in Slovenia, and the Latvian State Wood Chemistry Institute. She maintains close ties and with high schools in Europe and other countries around the world, such as State Montclair University (USA), Swiss Federal Technological Institute in Zurich, Illinois Institute of Technology (USA), Helsinki University (Finland), Tomsk State University (Russia), Barcelona University (Spain), and Ancona University (Italy).

Major publications: author or coauthor of 92 papers (27 of which are published in Web of Science refereed journals with citation index), the author of the textbook *Manufacturing Industries and Environmental Impact*, chapters in the books *Phytoremediation: Management of Environmental Contaminants*; *Plants, Pollutants and Remediation* published by Springer, and *Plant Production Technologies* published by Elsevier.

She is a reviewer of papers for international journals, such as the *Journal of Environmental Management*, *Environmental Science and Pollution Research*, *Environmental and Experimental Botany*, and *Dendrochronology*.

In 2013–2014, Edita Baltrėnaitė was granted a young researcher grant for the work *The Evaluation of Heavy Metals' Stability in Biochar* and, in 2007, a prize for the work *Investigation and Evaluation of the Transfer of Heavy Metals from Soil to the Tree* by the Lithuanian Academy of Sciences.

**Pranas Baltrėnas** Professor, Dr. Habil, Director of the Environmental Protection Institute of Vilnius Gediminas Technical University (VGTU), a member of three international Academies of Sciences, chief editor of the international *Journal of Environmental Engineering and Landscape Management*, ISSN 1648-6897, a member of the editorial boards of five international journals, chief editor of the *Proceedings of the Conference for Junior Researchers* based on the material of the annual conference *Science—Future of Lithuania*, chair of the organizing committee for the *Environmental Engineering* conference, chair of the Committee of Doctoral Studies in the scientific field of environmental engineering, head of the Public Environmental Protection Commission in the Vilnius City Council, member of the Council of the Union of Lithuanian Scientists, chair of the Environmental Protection Committee No. 36 of the Lithuanian Standardization Department, member of the Noise Prevention Council at the Public Health Ministry, and project evaluation expert on the Research Council of Lithuania. His areas of research include complex theoretical and experimental studies of the technosphere, process modeling and the development of environment protection technologies, including regulation of stationary and mobile air and soil pollution sources and waste and effluents, the investigation of noise sources and electromagnetic fields, and the development of pollution-reducing technologies and equipment. He established the Department of

Environmental Protection, the Institute of Environmental Protection, and the laboratory of the Environmental Protection and Work Conditions in VGTU and pioneered the field of environmental protection engineering in Lithuania. P. Baltrėnas has conducted research visits to Weimar and Mikkeli universities and to Rostock (Germany), Dresden (Germany), Hamburg–Harburg (Germany), Lulea (Sweden), Illinois (USA), and Ancona (Italy) universities and is a Lithuanian representative (coordinator) of international programs such as COST, INTERREG, Seventh Framework, BPD, MUNDUS, and TEMPUS.

Under Prof. Baltrėnas' supervision, 19 doctoral theses have been defended. In 1994, P. Baltrėnas was the winner of the Lithuanian Republic prize for achievements in research, and in 2000, he was awarded the medal of M. Lomonosov and in 2003 awarded an honorary doctorate at the Saint Petersburg Academy of Sciences. In 2007, he was awarded the World Intellectual Property Organization (Geneva, Switzerland) Award Certificate in recognition of his outstanding achievements as an author of inventions.

Prof. Baltrėnas is the author or coauthor of 625 publications, including 15 monographs, 3 textbooks, 26 analytical and review methodological works, and 345 research papers, including 60 papers published abroad and 92 certificates and patents.

**Arvydas Lietuvninkas** Doctor of physical sciences (volcanology and petrology), professor. His life and work (1956–2006) were associated with scholarship and, later, with Tomsk State University (Russia, West Siberia). A. Lietuvninkas was born when his father, a peasant, was in exile. He completed secondary school in exile in the Krasnoyarsk region with a silver medal and graduated from Tomsk State University, Faculty of Geology and Geography, with honors. He began his career at Tomsk State as a junior researcher, then Lecturer, Assistant Professor, Vice Dean, Chair of the Department of Mineralogy and Geochemistry, and Professor.

A. Lietuvninkas published 5 monographs, 13 teaching aids and textbooks, and authored or coauthored more than 160 papers. He is also an honorary research worker in the Russian system of higher professional education and has received several medals and prizes for his achievements in research and pedagogy.

A. Lietuvninkas has been living in Lithuania since 2006. Currently retired, he collaborates with colleagues from the Department of Environmental Protection of Vilnius Gediminas Technical University in areas of his research interests. Additionally, he is a member of the editorial board of the *Journal of Environmental Engineering and Landscape Management*.

Basic research interests: metamorphism and metamorphic rock, geology of sources of minerals and geochemical methods of their exploration (1961–1988), ecological geochemistry and application of its methods to evaluating the ecological

state of ecosystems and their components, and the spread of pollutants in the environment and their accumulation in geochemical barriers.

Areas of activity: practical application of university-level methods, introduction of information technologies and ISO 9001 quality standards at Tomsk State University, application of geochemical methods to the evaluation of ecosystems and their components' ecological state, spread of pollutants and their accumulation in the air, water, and soil, theory and practice of geochemical anomalies in soil, snow cover, and biological objects, application of advanced technologies to environmental protection, and preservation of Earth's mineral wealth.

His major works include *The Stages of Postmagmatic Formation of Minerals*. Tomsk, Tomsk State University, 1977, 110 pp.; *The Stages of Hydrothermal Mineral Formation*. Tomsk, Tomsk State University, 1999, 216 pp.; *Technogenic Pollution and Children's Health*. Tomsk, Tomsk State University, 1993, 92 pp., *The Environmental Problems of the Western Industrial Tomsk Region and Ways to Their Solution*. Tomsk, Tomsk State University, 1994, 260 pp. (with co-authors); *Anthropogenic Geochemical Anomalies and the Environment* (teaching aid). Tomsk, a publishing house of scientific and technical literature, 2002, 290 pp. (2nd edition, 2005); *Geochemistry of the Environment* (textbook). Vilnius. Technika, 2012, 312 pp.

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