# BIODIVERSITY RESEARCH IN COLOMBIA: WHAT WE KNOW AND WHAT WE NEED TO KNOW

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## 1. INTRODUCTION

Colombia is one of the countries with the highest biological diversity in the world. With a land surface of 1,1400,000 $km^2$ (approximately 0.7% of the continental surface area of the globe), it is home to more than 40,000 plant species, over 1800 bird species, and over 580 amphibian species, close to 15% of the world's species for these groups.

This enormous richness can be attributed to the geological history and geographical location of the country. Colombia's location near the Equator, as a land bridge between North and South America, has allowed the migration of species between the continents. Many northern species have distributions that reach as far south as Colombia. Oaks of the genus *Quercus,* widespread in North America, are found in higher elevation forests throughout Central America, and in some forests in the Andes of Colombia as far south as the border with Ecuador. The geological history of Colombia has also played a significant role in speciation and diversification. The oldest rock formations in Colombia are parts of the Guyana shield, and are found as giants standing over the plains of the Orinoco and parts of the Amazonian region of Colombia. The Andes is more recent, and is split into three separate ranges, with the Eastern range stretching as far north as Venezuela. The Pacific coast of Colombia, known as the *Chocó,* is one of the places with the highest rainfall world-wide, with some locations getting more than 12,000 mm of rain annually.

Biodiversity research in Colombia dates back to the late $18^{th}$ century, when the journeys of Alexander von Humboldt through the Orinoco and the Andes and the Botanical Expedition of the Kingdom of Nueva Granada led by the Spanish scientist, José Celestino Mutis, took place. These early explorations revealed many new species and recorded the traditional uses of plants. Some of these groups were extensively used for treating ailments, as in the case of quinine. Since that time, scientists have continued to work on documenting the biodiversity of the Neotropics. Nevertheless, we are still far from understanding what there is, how it functions, and how to use it in a sustainable way.

One of the points that I have been asked to address during this talk is how to translate the results of research into policy and contribute to the decision-making process. In order to answer this, I would like to provide you with a brief description of the institutional structure of the environmental sector in Colombia, and will later continue to describe research priorities.

## 2. THE ENVIRONMENTAL SECTOR IN COLOMBIA

The environmental sector in Colombia was restructured as a response to the commitments of the Convention on Biological Diversity, signed in Rio de Janeiro and ratified by Colombia in 1994. The result is a series of institutions and organisations that are collectively known as the National Environmental System. The highest ranking body is the National Environmental Council, with representatives from different ministries and government agencies, as well as representatives from the

private sector, universities, and the civil society. This body is in charge of establishing general policy guidelines and facilitating cross-sectoral coordination. The restructuring also led to the creation of the Ministry of the Environment, as a small ministry in charge of supervising environmental policy and representing Colombian positions in international conventions and treaties relating to the environment. Environmental control and management are completely decentralised in the new system, and are in charge of regional autonomous corporations for sustainable development, with a board that includes the state and municipalities, and other representatives.

Last but not least, and most important for the purpose of this meeting, are the research institutes that are in charge of providing the scientific and technical support to the environmental system. This includes five research institutes with specific mandates, such as meteorology, biodiversity, marine research, and two with a regional focus on the Amazon and the Chocó. The Institute in charge of biodiversity research is named after Alexander von Humboldt, and was established in 1995 as a joint venture between 24 partners, including the Colombian Ministry of the Environment, the Colombian Science Foundation, universities, institutes, and non-government organisations. The Institute's mission is to promote, coordinate, and conduct research that contributes to the conservation and sustainable use of biological diversity in Colombia. In order to carry out this mandate, three strategic research programs have been identified: biological inventories, conservation biology, and use and valuation of biodiversity, as well as three cross-cutting programmes on policy and legislation, training, and communications and information.

## 3. CONCEPTUAL FRAMEWORK

The development of a biodiversity research strategy for Colombia requires a conceptual framework. We have adapted the scheme developed by Noss (1990) to examine the trends in biodiversity research in Colombia. The framework recognises the levels of organisation of biodiversity (genetic, species, and ecosystem diversity), and three attributes that can be discerned (composition, structure, and function). The result is a two-dimensional matrix, allowing for any combination of attributes at any level of organisation. A third dimension can be added to include the impacts of human intervention, from 'intact' ecosystems, through managed ecosystems, to degraded ones where restoration programs need to be implemented.

Composition refers to the identification of the components of biological diversity, as reflected by, for example, species lists. Structure refers to the characterisation of these components, including their relative abundance (e.g. the types of ecosystems in a given area). By function, we mean the study of the dynamic nature of biodiversity in space and time (e.g. the monitoring of allele frequency in a population over time, or the effects of management practices on demography).

Not surprisingly, the analysis of biodiversity research in Colombia over the past two decades shows that most work has been done on the composition at the species level, and very little work has been done on the function at the genetic and ecosystem levels. Therefore the strategic plan for research in biodiversity is designed to address this conceptual framework as a whole, to identify gaps and weaknesses, and to design actions to overcome them. These focus on six main areas: biological inventories, conservation biology, use and valuation of biodiversity, policy and legislation research, training, and information.

## 4. BIODIVERSITY INVENTORIES

Despite the fact that biological inventories have been carried out over the past two centuries, we still have little data on what is found where. Most of the collections have focused on vascular plants and vertebrates, especially birds and mammals. Groups like invertebrates, fungi, and bacteria have received little attention. Overall, we estimate that we probably know less than 10% of the species found in Colombia, and over half of the information on geographical distribution is housed in collections outside Colombia and is unavailable to researchers. Research relating to characterisation at the genetic level is scarce, except for certain species of importance to agriculture and health. However, the decreasing cost and increasing speed of molecular techniques are making these increasingly available to researchers world-wide.

The Institute has completed an exercise to determine the priority geographical areas for biodiversity inventories nation-wide, through a series of workshops involving leading scientists. The criteria to evaluate geographical priorities include species inventories, endemism, current state of knowledge, and degree of threat, including variables such as extent of original habitat left, degree of fragmentation, rate of change, and existence of protected areas. This has led to the identification of areas which are of top priority and which are, in general terms, areas of high diversity and endemism, poor knowledge, and high degree of threat. The resulting maps are used to establish a map that is used by institutions nation-wide for biodiversity inventories.

*What we know:*
- Species inventories for over 80% of the vascular plants and vertebrates;
- Characterisation of most ecosystem types;
- Variation in plant species occurrence in recent historical times;
- Geographical distributions of most ecosystems and some species;
- Genetic characterisation of a number of species of importance for agriculture and forestry;
- Taxonomic and geographical priorities for species inventories.

*What we need to know:*
- Species inventories for most invertebrates, fungi, and micro-organisms;
- Spatial and temporal dynamics of biodiversity;
- Phylogenetic relationships of selected taxa;
- Genetic characterisation of selected taxa.

*What we can do in the short term:*
- Computerise biological collections and repatriating information to the country of origin for biogeographic analysis;
- Complete collections in geographical areas that have high species richness and levels of endemism, are poorly known, and are threatened;
- Complete biodiversity inventories in some areas as a basis for other research;
- Strengthen inventories on taxa that are of economic potential, are threatened, or can be used as indicators;
- Establish DNA banks to facilitate genetic studies.

## 5. CONSERVATION BIOLOGY

A second major line of work relates to research that directly contributes to the conservation of biological diversity at all levels. Whereas *ex situ* conservation techniques are useful to conserve genetic diversity, ecosystem level diversity can only be preserved under *in situ* conditions. Furthermore, *in situ* conservation is generally favoured in the absence of a complete understanding of diversity and interactions.

Research relating to conservation should focus on a better understanding of the current status, on monitoring, and on trends of biological diversity, with special emphasis on endangered or threatened taxa or habitats. Preliminary results of this work have provided a complete list of threatened plants of Colombia, including some 600 species to date, following the criteria used by IUCN. We find that a major group of threatened plants are species with restricted geographical distributions and those that are commonly used. By far the largest percentage of these species are orchids (29%), as a result of over-exploitation for ornamental purposes and the transformation of habitats. Some plant families that are used for timber are also threatened or endangered.

One aspect that has received little attention in tropical forests is the impact of alien species and living modified organisms on biodiversity. Research in other countries has shown that introduced species can make up an important fraction of the local biodiversity, and in extreme cases, such as the islands of Hawaii, the total number of plants has doubled over the past two centuries. Some of these species can be aggressive and be more tolerant to environmental change, and can therefore out-compete native species. The effect of these is especially severe on islands and in freshwater ecosystems. Research should address the direct causes of extinction, namely habitat transformation, over-exploitation, competition with alien species, pollution, and climate change.

*What we know:*
- Ecosystems represented in protected areas;
- Lists of potentially vulnerable and threatened taxa of plants and vertebrates;
- Alien species present in Colombia;
- Underlying causes of habitat transformation.

*What we need to know:*
- Long-term viability of biodiversity in protected areas;
- Trends in populations of endangered and vulnerable taxa;
- Ecological impact of alien species on native biodiversity;
- Impacts of global climate change on species and ecosystems;
- Resilience of ecosystems to natural and man-made disturbances;
- Ways to accelerate natural regeneration as a tool for restoration.

*What we can do in the short term:*
- Define priorities for new protected areas using biodiversity criteria;
- Evaluate and monitor populations of endangered taxa;
- Strengthen the role of *ex situ* facilities such as botanical and zoological gardens for conservation of endangered taxa;
- Establish long-term plots for long-term monitoring of biodiversity;
- Begin research programs for the restoration of critically degraded ecosystems.

## 6. USE AND VALUATION OF BIODIVERSITY

Biodiversity has played, and continues to play, a major role in the structuring of past, present, and future human populations. This can be clearly seen through the impact of crop and livestock exchange between continents in recent history and their effect on modern cultures. Our livelihood ultimately depends on the direct benefits we derive from biological diversity (e.g. food) and ecosystem services (e.g. watershed regulation, air quality control).

The Convention on Biological Diversity is to some extent addressing one of greatest paradoxes of all: the countries with the highest diversity are the ones with the least economic development. These countries have legitimate interests in using the biological diversity for their development in the 21st century, although the expectation of economic benefits in the short term is often over-estimated. It is therefore important to provide a research basis for this, recognising the roles of traditional and scientific knowledge. Preliminary results of our work indicate that the total value of goods and services derived from biodiversity in Colombia can be in the order of 300 billion dollars annually, five times the GNP.

*What we know:*
- Traditional and modern uses of some species in local and global markets;
- The importance of biodiversity for human history;
- Ways to cultivate and manage some of these species (agriculture, forestry);
- Ecological role of some species (pollinators, fungi, and biological control agents) in production systems;
- Markets for a number of species of local or global importance.

*What we need to know:*
- The role of traditional communities in biodiversity conservation;
- The role of biodiversity in the lives and well-being of traditional communities;
- The relationship between ecosystem services and biodiversity;
- The impact of human activities on ecosystem services and ways to mitigate them (e.g. sustainable forestry);
- The economic value of goods and services provided by biodiversity;
- New uses for biodiversity and their markets.

*What we can do in the short term:*
- Document the uses of biodiversity by traditional communities;
- Evaluate the ecological, economic, and social sustainability of production systems;
- Develop mechanisms to measure the value of goods and services derived from biodiversity;
- Design ways to add value to biodiversity at the local level and ways and means to promote an equitable sharing of benefits;
- Identify new markets for biodiversity products and services;
- Identify new uses for biodiversity, including bioprospection.

In addition to the three research programs outlined above, additional actions have to be implemented to strengthen research and allow a better impact on policy, leading ultimately to the conservation and sustainable use of biodiversity.

## 7. POLICY AND LEGISLATION

One of the major weaknesses of biodiversity research is that it seldom translates into policy decisions. Often the work carried out by researchers does not contribute in any significant way to the decision-making process, because the research priorities are not relevant or we have problems communicating them to stakeholders in a timely and understandable way. On the other hand, policies can have a significant impact (positive and negative) on research. Positive incentives need to be strengthened and negative incentives (or disincentives) need to be identified and removed.

The conservation and sustainable use of biodiversity depends on cross-sectoral policies, since often policies can lead to rapid degradation. A specific case in Colombia were the policies related to agrarian reform during the 1960s, in which a land owner had to prove the use of forests through deforestation in order to claim and maintain property. This led to massive deforestation in many areas of the country. Another example is related to infrastructure development such as roads and highways, which can facilitate access to remote areas that would otherwise be inaccessible.

*Some potential areas of work include:*
- Evaluating economic incentives and their impact on biodiversity;
- Identifying gaps in legislation and proposing clear priorities for action;
- Designing instruments to incorporate biodiversity into other sectors of the economy;
- Evaluating the impact on international treaties and conventions (including trade) on biodiversity.

## 8. COMMUNICATION AND INFORMATION

One element that is often not considered in designing research programmes is related to information and communication. This requires the clear identification of stakeholders/users, their information needs, and the best ways and means to deliver it to them. Potential users include decision-makers, other scientists, communications media, and the general public. Each one of these audiences differs in its interests, background, and the ways and means to best deliver information to them.

*What we can do in the short term:*
- Strengthening scientific publications (journals, field guides, monographs, textbooks)
- Consolidating databases and developing information transfer protocols;
- Supporting scientific congresses and exchange programmes;
- Preparing news bulletins and documentaries;
- Facilitating access to communication technologies such as the Internet.

## 9. TRAINING

Finally, I would like to address the issue of the human resources available for biodiversity research. It is no secret that the distribution of research capacities is hugely imbalanced geographically, and that many developing countries need to train scientists in many of the topics and areas described above.

*What we can do in the short term:*
- Strengthening graduate-level training programmes, preferably at the national and regional levels;
- Offering short specialised training courses;
- Establishing scholarship and exchange programmes.

## 10. THE WORK OF TROPENBOS IN COLOMBIA

The ideas described above are just some of the priorities for biodiversity research, although the status, needs, and opportunities will undoubtedly vary from one country to another. It is clear that scientific and technical cooperation at the international level will play a major role in the development of this research strategy, and should be clearly aimed at strengthening national capacities.

The work that the Tropenbos Foundation has been carrying out in Colombia over the past decade has been a good example of this kind of collaboration, working closely with Colombian institutions and scientists, primarily the SINCHI Institute for Research in the Amazon. Many Colombian students have received graduate-level training in the Netherlands and are now the leading scientists at several Colombian universities. The continuous support for research programmes in a focused geographical area in the Colombian Amazon (Araracuara) has resulted in a good understanding of the composition, structure, and functioning of these ecosystems. The results of these studies have been published as dissertations, scientific articles, and books, and are widely regarded as important scientific contributions internationally.

We are grateful for the continued support to these programmes by the Dutch Government and the partnership we have established with the Tropenbos Foundation, and look forward to continuing this for many years to come. We are also confident that it will lead to a stronger national capacity and to a better scientific understanding of the sustainable management of our tropical forest ecosystems.

## 11. REFERENCE

Noss, R. (1990). Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology* 4: 355-364.

**BIODIVERSITY RESEARCH IN COLOMBIA: WHAT WE KNOW AND WHAT WE NEED TO KNOW**

**Achievements**

- A well developed and broadly rooted national environmental authority is developed for Colombia, which is in charge of policy, research strategy and application of research results in policy.
- A conceptual framework for biodiversity research in Colombia was developed.

**Challenges and Problems; Information Needs**

- Knowledge of biodiversity disproportionally distributed over taxa and space within Colombia; and less than 10% of species is known.
- Biodiversity research seldom translates into policy decisions.
- Poor communication with stakeholders and users during development of research programmes.
- Lack of well-trained scientists in developing countries.

**Points for Future Research**

- Computerise biological collections and repatriate information to the country of origin.
- Complete collections in selected high priority geographical areas.
- Strengthen inventories on taxa that are of economic potential, are threatened or can be used as indicators; define priorities for protected areas based on these criteria.
- Establish DNA banks to facilitate genetic studies.
- Monitor permanent plots and populations of endangered taxa.
- Begin research programs for the restoration of critical degraded ecosystems.
- Document the uses of biodiversity by traditional communities.
- Evaluate the ecological, economic and social sustainability of production systems.
- Develop mechanisms to measure the value of goods and services derived from biodiversity.
- Design ways to add value to biodiversity at the local level and ways and means to promote equitable sharing of benefits.