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EUROPEAN SCIENCE FOUNDATION—RESULTS OF A SURVEY OF EUROPEAN CANOPY RESEARCH IN THE TROPICS

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INTRODUCTION

The European Science Foundation (ESF) has launched a scientific programme in Tropical Canopy Research that will cover a period of five years from 1994–1998. This programme, supported by funds from research councils from Germany, Italy, Netherlands, Denmark and Austria, will provide a greater understanding of the tropical forest ecosystem and explore the significance of biodiversity in the canopy. The canopy of tropical forests has been termed the 'last biotic frontier' because of the enormous richness in all kinds of living organisms found there and because of its important role in the carbon and water cycles. We need to gain a much better understanding of the complex interactions between organisms that form canopy communities and the interaction between the canopy and those environments below and above it if we are to preserve this valuable resource.

The main focus of the proposal for the ESF Tropical Canopy Research Programme is the complex interactions between canopy organisms and their biotic and abiotic environment. The fundamental problems of canopy research have been addressed in the proposal. These include the taxonomic component of research, the roles of 'chance events' versus 'regular or predictable events' in the structuring of canopy communities, the causes and consequences of species loss due to the effects of, e.g., habitat diminution and fragmentation and investigations into the changes that occur in biological diversity along natural and man-made gradients. Further studies will focus on the complex and variable architecture of tree canopies.

In preparation for the Workshop on the Tropical Canopy Research Programme that was held in Vienna on 1–3 July 1994, the European Science Foundation commissioned Dr. N. Stork of the Natural History Museum in London from 16 May 1994 to carry out a survey of those European institutes and researchers working in the field of tropical canopy research. The purpose of this survey was to compile a working document which would provide a clearer picture of canopy research in Europe.

Important objectives of the ESF programme are to 1) focus research on a few well equipped and suitable field stations in the tropics and thereby coordinate different research ideas and methods, 2) standardise the different techniques used in tropical canopy research, perhaps sharing of expensive equipment and thus ensuring increased collaboration by researchers, and 3) sharing of standardised data sets.

The survey was carried out by contacting many different researchers and institutes in the European community and asking them a set of questions to determine their main interests and ongoing projects. In order to get a rapid response from researchers sufficient to allow the compilation of this document and its circulation prior to the Workshop, the questionnaire was limited to the following questions:

- Which fields of tropical canopy research are you particularly interested in?
- How many people are involved in your research group and what kind of grants do you hold?
- Where do you carry out your research? What would be the advantages of this site(s) for further co-ordinated research?
- What do you think are the most important questions to be answered or hypotheses to be tested in canopy research?
- What roles do you think that the ESF network should provide?

This questionnaire was circulated to those researchers whose names were on an existing ESF database for tropical research, to those on the North American canopy e-mail network, and to a few additional researchers. An excellent response was received from this survey (70 replies as of 29 June 1994) and the results are summarised below.

1. RESEARCH INTERESTS

There is a diverse range of interests in the field of canopy research and the results of the survey are of course strongly influenced by the initial list of those questioned. For example, few researchers appear to be interested in the relationship between the canopy and physical parame-

ters. And yet the considerable correspondence in this subject area in the last few months on the North American e-mail canopy network would indicate that we may not have contacted many European scientists interested in such areas. Given the immense interest in global climate change, there are almost certainly many European physical scientists who would be interested in the ESF Tropical Canopy Programme.

Most respondents appear to be interested in the diversity of organisms in the canopy and the complex interactions between these organisms. Table 1 summarises the main areas of interest.

Researchers studying arthropod diversity often concentrate on one family or one order. It was found that five scientists concentrate on Orthoptera (grasshoppers and crickets), six on Coleoptera (beetles), two on Diptera (flies) and two on Spiders. The functional roles of mites in canopies is being studied by looking at the symbiotic relationship between mites and plants, and mite-insect associations. The trophic interactions between canopy arthropods are also studied along with host plant specificity.

Canopy diversity is often looked at along the lines of epiphyte ecology and insect diversity. Life-cycles, pollination ecology, reproductive biology, growth of understory tree species and plant-insect interactions are all generally linked in many research areas. The physical processes mentioned above refer to gas exchange, phosphorous cycling and water relations in the canopy. A few researchers are interested in the exchange of gases between the rain forest and the atmosphere.

Fragmentation and species loss are of course very important areas of study since as yet the numbers of species lost from habitat destruction, extinction and anthropogenic disturbance is unknown. Just a few decades ago tropical rain forests covered 14% of the earth's land surface, today it is less than 6%. Researchers are looking at the effects of environmental change by concentrating on deforestation, logging and forest regeneration.

Many botanical institutes (e.g., Royal Botanical Gardens Kew, UK) are not directly involved in canopy research but, by the very nature of working on the systematics of plants, are extremely interested in our ESF Tropical Canopy Research Programme.

TABLE 1. Summary from Appendix I (data as of replies received by 29 June 1994).

Research topics	No. of groups
Scientific topics	
Systematics	13
Diversity	40
Ecology	39
Fragmentation/species loss	19
Physical processes	5
Canopy access	5
Organisms	
Arthropods	39
Other invertebrates	2
Trees	25
Epiphytes	17
Fungi	3
Birds	6
Other vertebrates	4

2. RESEARCH SITES

It is clear that there are an enormous number of tropical sites utilised by European canopy researchers and these are summarised in Table 2. Those involved in the ESF Tropical Canopy Research Programme need to examine carefully the particular merits of sites for collaborative field research. Below we highlight some of the relevant information about these field sites where it has been provided by those questioned during the survey.

South and Central America

Six scientists are interested in sites in French Guyana. In particular Saül has been utilised by the Opération Canopée team where they carried out their Tree-top Raft research project. Saül was one of the thirteen sites mentioned in the working meeting "Inventorying and Monitoring Biodiversity under the Diversitas Programme" as a good location for a research station working on the biodiversity of moist tropics. Recently an interest group for forestry research was set up which makes it possible to structure research. The Tropenbos Foundation carries out a number of research projects in French Guyana and other institutes that are working at this site including ORSTOM, INRA, CIRAD, ENGREF and ONF can further help to bring about co-ordinated research.

Another major field station in French Guyana is Les Nouragues. This site is open to all European teams who would like to start research here and is particularly favoured by the Opération Canopée research project. It has very good facilities in the midst of several thousand km^2 of uninhabited and protected natural forest. The area has high biological diversity. Access to the canopy is provided by four consecutive suspension bridges (110 m long) and twelve platforms in the canopy trees. The camp can accommodate

12–15 people and there is a laboratory, kitchen, microscopes and water supply.

Ecuador has a research station in Rio Tiputini in Yasuni National Park, the Yasuni Scientific Research Station. There is good access to the forest, which is 26,000 hectares of pristine lowland tropical rain forest, and to the site which has housing and laboratory space. There is collaboration with the Catholic University of Quito and the host country collaboration is excellent as a Danish team has been working there for many years.

Araracuara is a very well developed site in the Colombian Amazon. Here there are two semi-permanent canopy walkways which are installed in the flooded varzea forest and in a terrace forest and a cable device has been planned for tierra firme forest. The site has comfortable housing and tree climbing equipment is available. The Tropenbos Foundation conducts a wide range of studies regarding biodiversity at this site.

The study site utilised by Professor Morawetz and his research group in S. Venezuela is at the upper Orinoco River next to La Esmeralda. The advantages of this site are the excellent possibilities for host country collaboration, rich and undisturbed forest, well organised field station and a broad range of different vegetation types around the site.

Costa Rica is well known for its many good facilities and research areas. Here there is collaboration with two universities and they have a well developed system of cataloguing biodiversity at INBio. A formal relationship is being established for research in the Bosques programme at the La Selva station.

Africa

Opération Canopée also works in Gabon at the Makokou research station. This station was built by the CNRS in 1968 and has scientific records covering twenty years. Its facilities include accommodation and working areas for 25 researchers, laboratories, library, herbarium, maintenance and surface staff. Not much work has been carried out on the canopy here but there is a lot of potential as Gabon is one of the most stable countries in Central Africa and the authorities approve the development of research. Six other researchers work in Uganda where there is collaboration with local universities. In Kenya the contacts with government and academic authorities are very good and there is a well established infrastructure for field research.

Ghana, Ivory Coast (Taï National Park) and Togo are favoured by three groups including the Tropenbos Foundation for sustainable canopy research as they are sites with good facilities and host country collaboration. This area is one of the world's "hot spots"—a place with exceptional high endemism and exceptional degrees of threat. Tanzania is also an area of tropical "hot spots" but unfortunately the bureaucracy is problematic and the facilities are not too good.

South East Asia and Australia

The Malesian area that comprises Malaya, Singapore, Indonesia, Brunei, Philippines and Papua New Guinea has numerous good facilities and these are used by those involved in the Floral Malesian Network project (some 130 participants from 30 countries) which is run by Dr. Marc Roos.

There is a suitable network of local co-operating bodies in Polynesia where there are facilities from the MNHN field station in Moorea.

Sabah (E. Malaysia) is a well studied area and there is a very well maintained research centre in Danum Valley. In Sabah there are existing canopy walkways (900 m) at other sites in lower montane dipterocarp forest. In Peninsular Malaysia at the Forest Research Centre (FRC) at Kepong and Pasoh there is already a very well developed infrastructure and host country collaboration.

Papua New Guinea has three different areas for research. Laing Island in Madang was favoured by three groups and has good transport and laboratory facilities. The Christensen Research Institute, also situated in Madang, is used by three research groups as it has excellent facilities including air conditioned lab facilities, 24-hour electric power, computers, microscopes, a number of vehicles and a library. It is 4 km away from primary lowland forest which is a mixture of deciduous and nondeciduous tree species. The third site is the Wau Ecology Institute in Tabubil where there is good collaboration with the University and with tribal landowners.

The Kuala Belalong Field Station in Brunei is very well equipped and in excellent natural forest. This site has been used by many research scientists involved in the Royal Geographical Society/Universiti Brunei Darussalam expedition and Operation Raleigh expedition.

3. Main Questions to be Answered or Hypotheses to be Tested

In this section we have selected particular phrases used by researchers in their answers to our survey. In some cases the English has been corrected, hopefully without altering the points being made.

3.1 General biodiversity

- What are the local processes that maintain local biodiversity?
- Marked variation in community structure (e.g., species richness and rank-ordered species abundance curves) indicate large regional differences which may be related to historical processes of diversification/extinction.
- How is diversity distributed at the local and regional level?
- What is the contribution of canopy diversity to local and regional biodiversity? How much is this influenced by biogeographic considerations?
- How does canopy diversity relate to habitat and organism strategy?
- Tropical forest canopies are important in the maintenance of biodiversity and the mitigation of climate change.
- What are the threshold values of environmental parameters that should be utilised to maintain predetermined degrees of biodiversity?
- How does canopy diversity operate in different (bio)geographic settings, ecological habitats and along altitudinal gradients?

3.2 Canopy ecology and structure

- Is the three dimensional nature of the canopy the reason for the high diversity of associated species assemblage?
- We must test and develop the hypothesis of the double nature of forests, in particular the folded forest model (Professor Oldeman), in which the size of the "folds" of exchange surfaces decrease both stepwise and as a continuum from whole tree crowns to one bacterium.
- Is there a close link between architecture and both ecological and physiological functions?
- Is it possible to approach the problems of canopy complexity and biodiversity using models integrating functional groups at various scale levels (e.g., the forest model of Professor Oldeman)?
- What are the factors influencing different types of canopy in each forest and/or continent?
- Community level responses to habitat heterogeneity and within canopy stratification are areas that have not yet been fully addressed.
- Can we define canopy more precisely?
- How is tree architecture connected to plant diversity? What are the important trends in forest successional sequences?

3.3 Canopy flora (epiphytes and trees)

- The systematics of many taxa of canopy trees and epiphytes is hardly known.
- A rapid assessment of the biodiversity of trees by photo-interpretation and/or videography, spatial distribution and typology of species crown should be related to botanical collection in the canopy.
- Why do epiphytes form such a major component in tropical biodiversity, what proportion of the biodiversity is represented by synusiae?
- Inventory of fungi in the canopy is essential as very little is known about this group.
- Is dioecy associated with the climbing habit in angiosperms?
- What is the spectrum of pollination and dispersal of seeds at canopy level per forest ecosystem type?
- Is the canopy an archipelago of food plant/habitat "islands"?
- Is epiphytic life form a crucial agent in the generation of biological diversity and is the biotic origin of the epiphytic habitat responsible for patchiness of the canopy (from the point of view of epiphytes) and hence the particular richness of vascular epiphytes?
- In which way does structural and substrate diversity determine epiphyte species richness?
- We need to evaluate the uneven distribution of secondary metabolites throughout the forest.
- Is the biochemical activity of trees and lianas higher at canopy level?

3.4 Canopy fauna

3.4.1 General

- A better insight in the quantitative and qualitative diversity of canopy faunas should be obtained through an alpha taxonomic approach.
- Cataloguing the diversity, systematics, phenology and natural history of the canopy fauna and roles of convergence and homology are important in conserving phenology in the New and Old World.
- Is the canopy fauna a model for comparative evolutionary biology?
- How can we explain the striking differences between canopy faunas of different continents?
- What are the peculiarities/idiosyncrasies of canopy life-forms?
- How is canopy (especially insect) diversity

correlated with floristic/architectural/micrometeorological parameters?
- Which tropical life-forms are missing in subtropical regions? Is this due to the annual disturbance regime?
- What is the influence of the canopy on soil fauna conservation?
- Is vertical variation in leaf properties associated with the palatability to different rain forest fauna thereby influencing their distribution vertically in canopies?

3.4.2 Arthropods

- How much does one canopy differ from another? What proportion of arthropods are extinction-prone; what "parts" of the canopy are important to arthropods?
- How can insect diversity be predicted by knowing the forest structure?
- How much canopy is needed to maintain stable communities of arthropods?
- Is the grasshopper's foodplant an important proximal factor that indirectly determines phenotype? Why is such a high proportion of the canopy fauna of this group oligophagous?
- To what extent are insect communities associated with particular tree species?
- Are tropical herbivorous insects more or less specific to their host plants than their temperate counterparts?
- How does host specificity level vary with size and food type of herbivorous insects and with characteristics of the host plant?
- Information on habitat patch requirements is lacking for most invertebrates.
- To what extent does the canopy moth community differ from that at ground level and does the loss of canopy through logging change the status of a large component of the moth fauna from 'residents' to 'tramps'?

3.5 Fragmentation, species loss and environmental change

- If floral and faunal inventory of the rain forest were more complete for the canopy would the actual loss in biodiversity by habitat reduction be more obvious? How would this translate to actual losses?
- What is the impact of man on the canopy fauna?
- To establish how vulnerable an ecosystem is to fragmentation, atmospheric pollution (acid rain) and exploitation by concentrating on the effects of increased solar radiation (UV) and future ozone layer problems we must look at trophic relationships, energy flows and genetics.
- The difference of communities to withstand disturbance must be taken into account to link processes that may generate and maintain species richness when faced with habitat diminution and fragmentation.
- A better picture of habitat destruction and fragmentation is needed. Therefore we must increase our knowledge of food web ecology.
- How does plant diversity at canopy level recover in natural and man-made induced forest succession?
- Did insect diversity of the present canopy originate in true pluvial forest or is it derived from another type of vegetation? Therefore what is to be protected?
- In the context of forest disturbance: What effects does the opening up on the canopy have on the physiological stress and survival of particular species?

3.6 Physical processes

- We need to investigate the exchange of climatic relevant gases between the rain forest and the atmosphere.

3.7 Communication and research

- There should be a method of describing detailed canopy form that is both three-dimensional and temporal, taking into account the dynamic nature of canopy growth, so that canopy researchers can communicate and compare observational details using a common terminology.
- It is primarily important to gain as many field observations as possible about any interaction between organisms in this habitat.
- Theoretical and practical problems of sampling and scaling appear to represent formidable limiting factors in research. Therefore efforts should be directed to establish a sound sampling design.
- The major problem with nearly all canopy research to date is the lack of spatial replication in sampling. Therefore hypotheses must account for spacial variation and meet statistical requirements.

4. Roles for the ESF Tropical Canopy Programme

The scientists who were contacted during this study voiced their opinions on the role of the European Science Foundation in tropical canopy research.

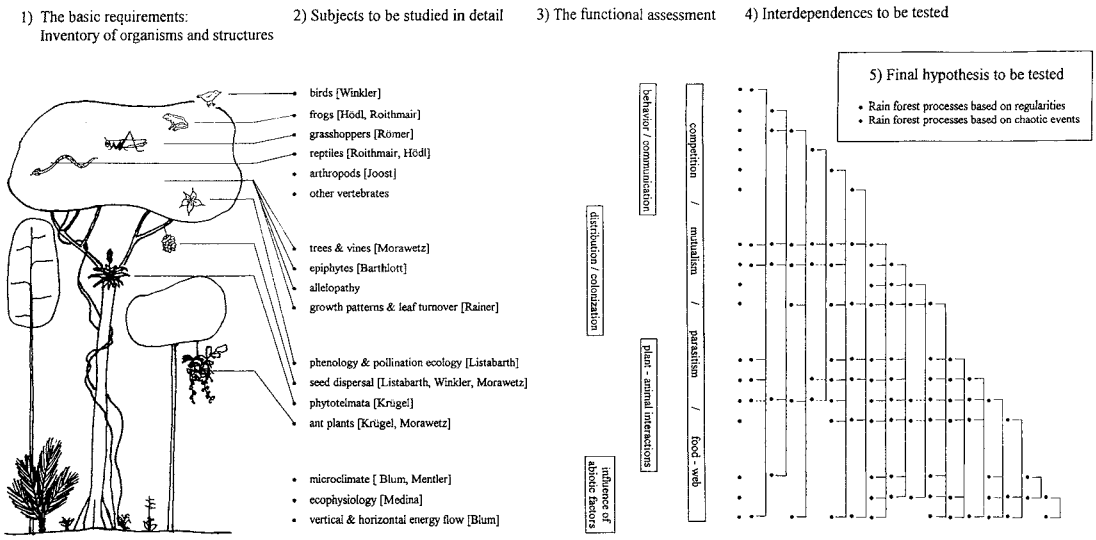

FIGURE 1. Schematic drawing of the basic requirements, the investigation topics, the interdisciplinary connections, and hypothetical concept.

It was thought that the ESF programme should motivate research and stimulate collaboration.

The formation of an e-mail network of canopy scientists which would provide a way of quickly passing research information to each participant seems to be a good idea, although it must be managed well and monitored frequently to ensure the smooth passage of information.

The ESF should also link up with other ongoing canopy networks such as the Canopy Research Network, USA run by Drs. Nalini Nadkarni and Geoffrey Parker, and the European Tropical Forest Research Network, Germany run by Dr. Horst Freiberg.

The ESF Programme could also provide methodological guidelines and protocols to facilitate data exchange.

Workshops would make it possible for different scientists to meet and discuss projects. Practical workshops for small topics, like tree climbing techniques, would be useful and good for young researchers and students. Some scientists believed that visits to the tropical countries were much more worthwhile than workshops.

Most scientists contacted agreed that fellowships, grants or other kinds of funding are extremely important in research programmes. Funds should be made available for European scientists, and especially young researchers, to visit tropical countries. Funds should also be made available for tropical scientists to enable them to work with their European counterparts. The ESF could co-ordinate and distribute information on the financing possibilities for tropical scientists. Fellowships provided by the ESF would help to stimulate and co-ordinate canopy research efforts. The ESF should also try and increase the possibilities for fund-raising (e.g., National Science Foundations).

5. LARGE RESEARCH GROUPS

It was clear from our survey that although many individuals were involved in canopy research a few large research groups were very obvious. Without detracting from the significant contributions that individuals made, we felt it was important to summarise the scope of the large research groups. This section was put together on the information provided and will almost certainly have to be expanded further as other collaborative research groups become apparent.

Professor Wilfried Morawetz is co-ordinating the "Austrian Canopy Research" programme: "Towards an understanding of the structure and function of a neotropical rain forest ecosystem with special reference to its canopy." This programme plans to co-ordinate a broad range of scientific fields that all concern tropical forest ecology with all the scientists working on specific projects while providing important links between each. This programme is expected to run for a period of five years with regular meetings and workshops to discuss progress and interactive, interdisciplinary studies.

Professor Morawetz and his group have proposed the building of an observation crane at a research station in S. Venezuela at the upper Orinoco River next to La Esmeralda. This crane will allow long term, repeatable, studies in the canopy without disturbing the ecosystem. This project is supported by the Austrian Academy of Sciences so the cost of the crane will be covered by the "Research Centre for Biosystematics and Ecology." Financial support will also provide facilities for meetings, material, payment for scientists and administrative help.

The basic structure of the project can be seen in Figure 1.

The main fields of research will be basic structure of trees, epiphytes, flowers and fruits; studies on birds, frogs and reptiles, grasshoppers and other arthropods; special interactive systems such as pollination ecology, seed dispersal, ant plants and phytotelmata and the study of abiotic factors which will concentrate on climate and microclimate, soils and nutrient cycles. A computer simulation model "RAFOM" ("rain forest manager") will be used to predict and test ecological questions.

Dr. Antoine M. Cleef is the Head of the Tropical Ecology research group at Amsterdam University. This group has a wide range of interests in the forest canopy. Much research has been conducted on plant diversity and epiphyte sociology in relation to habitat properties in mature and secondary rain forests. Further studies have been on animal-plant relationships with regard to pollination and seed dispersal.

The canopy research group consists of Dr. Hans F. M. Vester, Dr. Arthur van Dulmen, Dr. Guido B. A. van Reenen and Dr. Astrid T. Groot. Collaborative research includes Dr. M. J. A. Werger (Utrecht University) working on water and nutrient relations of epiphytic growth, Professor R. A. A. Oldeman (Wageningen Agricultural University) on tree architectural analysis and canopy development of secondary rain forests, and in Costa Rica Dr. Maarten Kappelle is collaborating with Dr. Nalini Nadkarni from the American Canopy Research Network at the Le Selva research station.

A number of research sites are utilised in the Colombian Andes, Costa Rican Talamanca Cordillera and Chiapas in Mexico for neotropical mature and secondary montane forests and Araracuara in the Colombian Amazon for permanent plots of mature and secondary moist lowland forest. Comparative studies are planned for wet lowland (Bahia Solano) and lower montane rain forest (Tambito) in the Choco Pacific coast forests, Colombia.

Colombia is very suitable for canopy research as a number of institutes have been involved with the sites for up to 25 years and host country collaboration has been assured by written bilateral agreements. Costa Rica and Mexico also have formal agreements for research in these areas. Previous canopy studies have taken place in these sites and they are the reference sites for a number of studies on community ecology, system ecology, paleoecology and plant and animal diversity. The best facilities are at the Araracuara site. There are two semi-permanent walkways and a cable device will be installed which enables excellent access to the secondary forest.

Professor Francis Hallé and Dr. Olivier Pascal are co-ordinators of the French Opération Canopée project. The main operation of "OpCAN" is the invention of a tree-top raft system. This raft is placed in the canopy by a small airship. The raft consists of kevlar netting stretched between inflatable neoprene tubing and is twice the size of a tennis court, providing superb access to the canopy. A tree-top "skimmer" or "sled" is also used. This device is trailed at tree-top level enabling rapid collection operations covering a large area. The tree-top raft missions have brought together researchers with varied backgrounds (physicists, botanists, physiologists, zoologists and biochemists).

"OpCAN" has a file of participants and candidates for their missions (about 100 researchers) and the association's funding is mainly from private sources. "OpCAN" is presently looking for funding and the group is ready to use their new technology in any site chosen by the ESF programme.

The Tree-top Raft missions have been carried out in French Guyana (1986, 1989) and in Cameroon (1991). The merits of French Guyana include its political stability. The same is also true of the Makokou research station in Gabon, Africa, a possible future site for the "OpCAN" operations.

There are two main lines of research that "OpCAN" would like to develop. These are rapid assessment of biodiversity and research into the canopy structure. A method of identifying trees is hoped to be developed by videography and/or photo-interpretation and studies of the spacial distribution of species and the drawing up of a typology of species crown. This could be performed directly with botanical collection operations using the Tree-top Skimmer. Research into the relationships between structural complexity and biodiversity will be studied and the search for suitable levels of perception (small branch, crown etc.) will contribute to develop the assessment of biodiversity. Research into genetic heterogeneity within tree crowns and biotic interaction of the canopy will also be carried out.

Dr. Roelof A. A. Oldeman is Chairman of the

Board of the "Stichting Het Kronendak" (Foundation the Canopy) in The Netherlands. This program co-finances research into canopy architecture and dynamics, life communities in the canopy, and the phyllosphere particularly as a nitrogen-cycling compartment. "Foundation the Canopy" is in regular contact with "OpCAN" and Professor Hallé and has scientific advisors from many different groups. The foundation financed some operational costs for Dr. Bongers at the forestry department of the Agricultural University of Wageningen. One fellowship was given to the Araracuara site in Colombia under the supervision of Dr. A. M. Cleef. Their third scientific advisor is Dr. Pierre Charles-Dominique (Brunoy, France) who works in the Les Nouragues site in French Guyana. Also working in French Guyana is Dr. Koop (Wageningen) who is a specialist on architectural simulation models. In association with the foundation Dr. Charles-Dominique and Dr. Cleef are preparing a programme on the phyllosphere which will study epiphyte communities.

The principal researchers on canopy arthropods at the Natural History Museum, London are Nigel Stork and Peter Hammond. Their research group, over the last 15 years, has looked at the diversity and community structure of arthropods in the canopy. Collaborators include Professor J. Lawton and Dr. T. Blackburn (Imperial college, University of London), Professor R. Kitching (Griffith University, Australia), Dr. J. Adis (Max-Planck Institute), Professor W. Paarmann (Göttingen), Dr. A. Watt (ITE, Edinburgh), Dr. A. Russell-Smith (NRI, Chatham) and other colleagues in the Museum (Dr. K. Gaston, Dr. P. Eggleton, Dr. C. Lyal and several Ph.D. students).

The Museum's entomological canopy research foci are:

(i) Describing and explaining patterns of community structure in temperate and tropical forests.
(ii) Using this information to examine questions of local and global species richness patterns.
(iii) Evaluating and testing standardised sampling methods for comparative studies.
(iv) Studies of forest loss, fragmentation and regeneration.

The main sampling method is knockdown insecticide sampling but other methods include light and pitfall trapping, malaise and flight interception trapping.

Current research is being carried out in Manaus, Brazil at the well equipped Reserva Ducke site, Mbalmayo; forest reserve in Yaoundé in Cameroon and the Kuala Belalong Field Centre in Brunei. All three sites are well equipped and suitable for collaborative research programmes.

TABLE 2. Tropical Forest research sites and number of groups utilizing them.

Research sites	No. of groups
S. & C. America	
Brazil	4
Bolivia	1
Colombia	4
Costa Rica	6
Ecuador	7
French Guyana	6
Mexico	2
Panama	2
Venezuela	7
Africa	
Cameroon	4
Ethiopia	2
Gabon	3
Ghana	3
Kenya	2
Tanzania	3
Uganda	7
S. E. Asia	
Brunei	2
Papua New Guinea	6
Sabah, E. Malaysia	5
W. Malaysia	7
Thailand	1
Vietnam	3

A collaborative grant proposal with Prof. Hallé and his research group and with PRONATURA has been submitted to the CEC DGXII.

Dr. Pierre Charles-Dominique (Museum National d'Histoire Naturelle, Brunoy, France) heads a large research group that is interested in many different areas of tropical canopy research. Dr. Charles-Dominique is also in close collaboration with Dr. Oldeman and Dr. Cleef (see above).

The research group is interested in fruit consumption by vertebrates (bats, monkeys and birds) and their seed dispersal roles in the ecosystem. Forest dynamics is also another area of research. The group is very interested in forest regeneration and structure. Projects have been developed on canopy density, forest gaps and species composition. Researchers in this group also study bird canopy displays and breeding systems, 'ant-gardens' on canopy epiphytes, the effects of light intensity and quality to determine the percentage seed germination. The research group consists of 11 researchers and 9 post-doctoral and Ph.D. students.

Most of the work is carried out in the Les Nouragues biological station in French Guyana.

This site is extremely good for canopy research. There is good access to the site by helicopter and boat and the area has a very high level of biological diversity. There are very good facilities at the site such as a fresh water supply and accommodation for 12–15 people. Access to the canopy is enhanced by two square kilometres of paths at every 100 m, and four consecutive suspension bridges (110 m long), and 12 platforms in canopy trees from 15 to 45 m high. French Guyana itself is advantageous as it is a French Department with high political stability and has support from several important national research institutions and ministries in Paris.

Many German scientists are involved in the German Science Foundation (DFG)-funded Schwerpunktprogramm ('theme programme') on tropical biodiversity. This programme, led by Prof. Eduard Linsenmair, has as its main theme "Mechanisms of the maintenance of tropical biodiversity" in which research is carried out in the areas of ecology by trying to understand the mechanisms of tropical communities and the questions of biotic interactions. The role of chance versus deterministic factors in the maintenance of biodiversity is also a key idea in the programme.

The most important topics within the Schwerpunktprogramm are primary production and resource distribution, the structure of tropical communities, saprophages and animal-plant interactions.

The theme of this programme is therefore strongly linked to that of the ESF Programme and the original proposal. Scientists in this group are working at many field sites around the world; these include Manaus in Brazil, Borneo, Costa Rica, Sabah in Malaysia and Ecuador. At present the programme is made up of about 30 research groups with collaboration from many different scientists in Germany including Professor Paarmann (Göttingen), Professor Göttsberger (Ulm) and Dr. Riede (Freiburg).

The Tropenbos Foundation, of which Mr. Erik M. Lammerts van Bueren is the Director, was set up in 1988 to contribute to the conservation and the use of tropical rain forests by co-ordinating available scientific expertise in the Netherlands and therefore generating knowledge and methodologies. The foundation organises, formulates and finances "objected-orientated" research programmes and they are in close collaboration with governments and research institutions in the Netherlands and in the Tropics.

A number of main sites have been focused on; these are Araracuara research station in Colombia, Taï National Park in the Ivory Coast, Mabura Hill district in Guyana, Cameroon and Wanariset research station in Indonesia. The research areas that are focused on are impacts of harvest intensities on biological diversity, nutrient and water cycling, animal ecology, canopy studies and vegetation dynamics.

The foundation organises workshops to discuss the main research priorities and an integral part of the foundation is to increase training and education. This is mediated by holding meetings, courses and seminars. There are also links and collaboration with other tropical rainforest research projects and institutions such as the European Tropical Forest Research Network (ETFRN) and the Centre for International Forest Research (CIFOR).

Dr. Henrik Balslev is the research co-ordinator in a joint collaborative project between Denmark and Ecuador, the ENRECA programme. The programme which focuses on Natural Resources for Development is jointly run by the Botanical Institute at Aarhus University, Denmark and Herbarium QCA at the Pontificia Universidad Católica del Ecuador. The project (that has been running since 1990) will run until 1995 and also involves Universidad Nacional de Loja in southern Ecuador and some research students from Bolivia and Colombia.

One of the important aims of the project is to improve the contact of Ecuadorian research students with the international research community. This has been achieved as more than 70 foreign scientists have visited Herbarium QCA due to the presence of the well organised botanical collections. This has meant that scientists are working together and exchanging ideas and experience. The scientists involved in this project pursue their own research interests but they are also involved in teaching in the department.

6. Other Networks

Nalini M. Nadkarni and Geoffrey Parker in the USA have formed the Canopy Research Network. With the support of the National Science Foundation they have established this organisation to bring together forest canopy researchers and have used a survey to compile an array of questions and needs faced by canopy scientists. The aim is to produce an international communication network, organise published canopy literature and serve as a global information source for all researchers.

The European Tropical Forest Research Network (ETFRN) run by Dr. Horst Freiberg was initiated by the Commission of the European Union (EU) and was established to mediate between those who need scientific information and those who are producing this information. The main aims of the ETFRN is to increase co-

operation between research institutes, governments and industries of European and Tropical countries to preserve tropical forests. The ETFRN produces a newsletter that serves to unite its members in their various fields of research. Dr. Freiberg is interested in the use of GIS/GMS for canopy architecture and fragmentation analysis.

Earthwatch Europe is the funding organisation of the Centre for Field Research (CFR) who encourage field studies by scientists. Andrew Mitchell, the Deputy Director of Earthwatch Europe, is interested in providing repeatable access to the maximum volume of tropical rain forest from the outer fringes of the canopy to the forest floor. He is developing a project called "Biotopia" which will examine the role of the canopy in global climate change and investigate ecology and biodiversity. The project will bring together existing methods of accessing the canopy (i.e., Professor Hallé's "Tree-top Raft" project) and provide a wide range of benefits for canopy researchers.

Margaret Lowman and Francis Hallé are co-chairing a major international symposium, Forest Canopies: Ecology, Biodiversity and Conservation. This event will no doubt facilitate networking amongst researchers of many countries.

APPENDIX I. The main research interests.

Name	Scientific topics						Organisms						
	Systematics	Diversity	Ecology	Fragmentation species loss	Physical processes	Canopy access	Arthropods	Other invertebrates	Trees	Epiphytes	Fungi	Birds	Other vertebrates
Dr. Christiano Amedognato	x	x	x				x		x	x			
Dr. Henrik Balslev	x	x							x				
Professor Wilhelm Barthlott		x	x							x			
Dr. Yves Basset			x	x			x						
Dr. Adrian Bell			x						x	x			
Dr. Antonio Bellow Pérez		x					x						
Professor Silvano Benvenuti			x									x	
Dr. P. Charles-Dominique			x	x	x		x			x		x	
Dr. Antoine Cleef		x							x	x			
Professor F. Ehrendorfer		x	x				x			x		x	x
Professor Enrico Feoli			x						x				
Professor Franco Ferrara	x							x					
Dr. Brigitte Fiala		x	x	x			x		x				
Mr. Jon Fjeldsã			x						x			x	x
Dr. Horst Freiberg				x					x				
Professor Wolfgang Frey			x							x			
Dr. Patrick Grootaer		x	x				x						
Dr. Gerhard Göttsberger	x	x	x			x	x		x	x			
Professor Francis Hallé		x				x							
Mr. Peter Hammond	x	x	x	x			x		x		x		
Dr. Hubert Höfer		x					x						
Professor Bert Hölldobler			x				x						
Dr. Manfred Kaib		x	x				x						
Dr. Elisabeth Kalko			x										x
Dr. Juergen Kesselmeier					x				x				
Professor Timo Koponen		x	x							x			
Dr. Erik M. Lammerts van Bueren		x	x				x		x				
Dr. Pekka T. Lehtinen		x		x			x						
Professor K. E. Linsenmair		x	x	x			x		x				
Dr. W. Los		x					x						
Dr. Michel Louette	x	x					x						
Dr. Jon Lovett			x						x				
Professor Ulrich Lüttgo			x							x			
Dr. Christopher Martius		x	x				x						
Professor Ulrich Maschwitz		x	x				x						
Dr. Nick Mawdsley	x	x	x	x			x		x				

APPENDIX I. Continued.

Name	Scientific topics						Organisms						
	System-atics	Diversity	Ecology	Fragmen-tation species loss	Physical processes	Canopy access	Arthro-pods	Other inverte-brates	Trees	Epiphytes	Fungi	Birds	Other verte-brates
Professor Patrizia Messeri				x									
Professor Alessandro Minelli				x									
Dr. Andrew Mitchell						x			x				
Professor Wilfried Morawetz		x		x			x						
Dr. D. M. Newberry					x				x				
Dr. Matti Nummelin		x					x						
Professor Franz Oberwinkler		x	x								x		
Professor R. A. A. Oldeman			x						x	x			
Professor Guiseppe Onolla		x					x						
Dr. Claire Ozanne		x		x			x						
Dr. J. Parnell	x		x							x			
Dr. Olivier Pascal			x			x			x				
Professor Jacques M. Pasteels		x		x			x		x				
Dr. Susanne Renner	x		x							x			
Dr. Klaus Riede		x	x				x		x				
Dr. John Roberts			x						x				
Dr. M. C. Roos		x								x			
Professor Hugh Rowell	x	x					x						
Professor Leif Ryvarden	x										x		
Professor Valerio Sbordoni		x		x			x						
Professor Ole Anton Saether	x						x						
Dr. Michael Schmitt	x	x					x						
Dr. M. R. Speight			x	x			x		x				
Dr. Karel Spitzer		x					x						
Dr. Nigel Stork	x	x	x	x			x		x				
Dr. Stephen L. Sutton		x			x	x	x						
Dr. Marc Théry			x	x	x		x			x		x	
Dr. Jean-Marc Thiollay		x		x								x	
Dr. Bjoern Aage Toemmoraas		x					x						
Dr. M. Van Gils		x	x						x				
Dr. Jackie Van Goethem		x						x					
Professor L. Van der Maeson			x						x	x			
Hern Manfred Verhaagh		x					x						
Dr. Fritz Vollrath			x				x						
Professor Dr. Otto von Helverson			x										x
Professor Lutz Wasserthal			x				x			x			