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The International Canopy Network: A Pathway for Interdisciplinary Exchange of Scientific Information on Forest Canopies

Abstract

Forest canopy communities are important in maintaining the diversity, resilience, and functioning of the ecosystems they inhabit. With the increasing interest in and amounts of data on forest canopies resulting from new access techniques, ecologists require tools to manage and analyze their data and to compare data from disparate studies. Canopy ecologists need to deal with new types of data, a great deal more data, and the need to share data among researchers who have separate research questions. With the support of the National Science Foundation, we established an organization to bring together forest canopy researchers, quantitative scientists, and computer scientists to develop methods to collect, store, display, analyze, and interpret three-dimensional spatial data relating to tree crowns and forest canopies. Our activities include compiling the array of research questions and needs from canopy scientists via a survey, examining potentially applicable information models and software tools that are in use in allied fields, and developing conceptual models for the types and format of information and analyses to answer research questions posed by forest canopy researchers. We are also building an interdisciplinary and international communication network (electronic and conventional), organizing the published canopy literature, and serving as a repository for canopy information accessible to scientists, forest managers, and the public.

Introduction

Forest canopy communities are important in maintaining the diversity, resilience, and functioning of the ecosystems they inhabit. In 1993, we created the International Canopy Network (ICAN) to develop methods to visualize, analyze, and understand the complex three-dimensional structure of tree crowns and forest canopies. Our goal in this paper is to explain the impetus for this project and describe our progress toward increasing participation from the forest researcher, manager, and arborist communities.

The forest canopy, which is generally defined as "the aggregate of all crowns in a stand of vegetation, which is the combination of all foliage, twigs, fine branches, epiphytes, as well as the air in a forest" is important for four major reasons. First, the biodiversity within the canopy is exceedingly large, estimated at over 50% of certain ecosystems (Erwin 1983, Gentry and Dodson 1987). Second, the biomass, nutrient and carbon pools, and surface area created by canopy components is large, which can enhance the interception, storage, and circulation of atmospheric nutrients (Carroll 1980). Third, canopy plants provide resources for birds, mammals, and invertebrates within forests (Nadkarni and Matelson 1989). Finally, abiotic characteristics such as windspeed, light intensity, and concentrations of gases within and above a forest are strongly modified by the canopy (e.g., Oke 1987, Fitzjarrald and Moore 1990). Understanding of these organisms and processes would be enhanced by optimizing tools to sample, visualize, and analyze the elements of canopy structure in a statistically rigorous manner.

Historically, canopy studies have been dominated by people seeking the thrill of climbing and following the lure of the discovery of new arboreal species. Recently, the innovation of high-strength and low-cost canopy access equipment has made more detailed canopy study an option for scientific research. With the development of effective technological climbing methods such as the "canopy raft" (Hallé 1990), the canopy crane (Parker et al. 1992), and of ground-based methods such as fogging (Erwin 1983), researchers can now spend less time fretting over how to get into in the treetops and more time analyzing and interpreting canopy data.

Within the last decade, scientific interest in the canopy has burgeoned remarkably (Russell et al. 1989, Lowman and Nadkarni 1996). The number of scientific publications on canopy structure has grown at a disproportionately rapid pace relative to the general field of biology (Fig. 1).

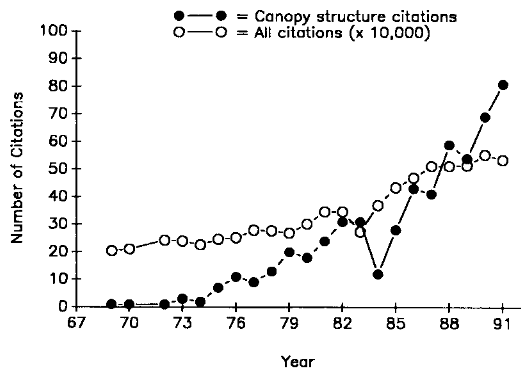

Figure 1. The rate of scientific literature published on canopy structure compared to the rate of literature published in the general biological literature. Data points are the number of citations with keywords related to canopy structure tallied in a bibliographic search of the database BIOSIS (closed circles) and the total number of all citations indexed in BIOSIS for that year (x 10,000) (open circles). Note that the rate of publications about canopy structure greatly exceeds the rate of all citations after 1984, indicating the explosion of interest and study of forest canopy structure in recent years.

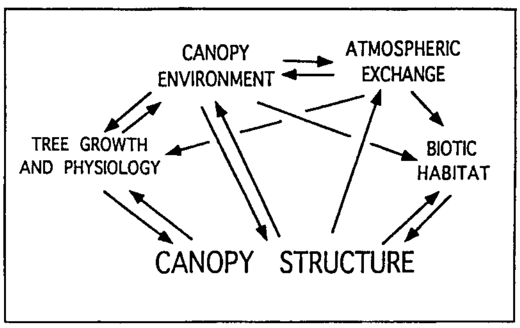

Figure 2. The complex interrelationships of canopy structure among different areas of canopy science.

Aspects of the canopy have been the focus of many recent symposia, scientific books, and popular articles and other public media. This focus is related to increasing concerns over conservation, biodiversity, global atmospheric change, and the management of rain forests.

Tree crowns and forest canopies are spatially complex, three-dimensional structures that are temporally dynamic. Knowledge of canopy structure lends insights into the interrelated fields of biotic habitat, canopy environment and atmospheric exchange and tree growth and physiology (Fig. 2). In a sense, the idea of "structure" sits at the interface between organism and environment, and thus at the heart of ecology itself. "Forest structure" has historically been approached from many standpoints, e.g., from the standpoint of tree architecture (Hallé et al. 1978) or physiological and morphological processes (e.g., Ford 1992). It has meant the organization of the species in a community, often with a ranking by density or bulk (e.g., a histogram giving for each species its foliar biomass) (Parker et al. 1989). Others have drawn stick figures giving the shapes and positions of tree crowns and attendant organisms, using work-intensive techniques of surveying from the ground (Nychka and Nadkarni 1990). Finally, forest ecologists and managers have attempted to measure canopy structural diversity from ground measurements and using remote sensing technology (e.g., Sorrensen-Cothern et al., in press).

Both the types and amounts of canopy structure data are changing rapidly. In the past, the simplicity of rope-climbing generated studies by scientists who worked singly or in small groups and produced fairly small data sets. The ease with which recent access innovations permit multiple teams of scientists to work within the same volume of the canopy, however, results in complex and expensive data sets that must be used jointly. For example, although projects on the canopy crane in Panama started out as largely independent, plans for an upcoming study feature a coordinated effort that involves teams working on complementary projects such as leaf nutrients, leaf allozyme activity, and insect diversity, all in relation to a common database of canopy structure (S. Mulkey, pers. comm.). Similarly, the canopy crane that was erected in the Pacific Northwest, during 1995 on the T.T. Munger Research Natural Area in Washington, will be used by a group of associated scientists who will ask questions on subjects ranging from tree architecture to the effects of air pollution on canopy lichens. These investigations will require spatial information on the underlying substrate (i.e., tree trunks, branches, and foliage), not only for its own sake, but also to relate forest canopy data to allied data sets. Thus, in the near future, canopy scientists will have to deal with new kinds of data, more data, and the need to share data.

Data collected by canopy research teams are likely to be extremely useful to other scientists such as geographers and land use managers, just as data emanating from allied fields could aid forest canopy researchers. Such "retrospective" use of data, however, requires the foresight to collect and record information that can act as a bridge to integrate separately collected data.

Having ascertained that questions involving the structure of the forest canopy are recognized as important, and that new methods of access are available for data collection, we anticipate an urgent need to deal with the new information on forest canopies that will be forthcoming in the next few years. To date, no one has worked out quantifiable and cost-effective methods to characterize tree crowns and forest canopies. Field ecologists are notorious for their independent (at times idiosyncratic) ways of taking, storing, and analyzing data. In many ways, the current situation is analogous to what planetary scientists faced when anticipating data from space probes: large quantities of new types of data that must be shared by a variety of scientists asking different questions. With the increasing interest in and amounts of data on forest canopies, ecologists require tools to plan for developing the means to collect, process, store, analyze, portray visually, interpret, and distribute these types of data.

With the support of a two-year planning grant of the Database Activities Program of the National Science Foundation, we established an organization to bring together forest canopy researchers, quantitative scientists, and computer scientists to establish methods to collect, store, display, analyze, and interpret three-dimensional spatial data relating to tree crowns and forest canopies. We call this organization the International Canopy Network (ICAN). The interdisciplinary nature of this project requires the interweaving of expertise from three types of participants: "domain scientists," scientists working directly with research related to tree and forest biology such as tree physiologists and ecosystem ecologists; "structural information specialists," scientists who have developed the capability to analyze 3-D structural data in allied and non-allied fields (e.g., hydrologists, astronomers, medical doctors); and "computer scientists," scientists working with questions about information management, storage, and analysis.

Project Activities and Products

Activities for the first two years of the ICAN include five steps (Fig. 3): define ecological questions and needs about canopy structure by canvassing domain scientists; compile lists of existing conceptual and applied approaches, databases, and tools from structural information specialists; develop a preliminary conceptual information model and recommendations for data analyses with input from computer scientists; "test" the feasibility of the preliminary information model and recommendations with a set of pilot field data collected by domain scientists, and if necessary, modify the model and recommendations; and

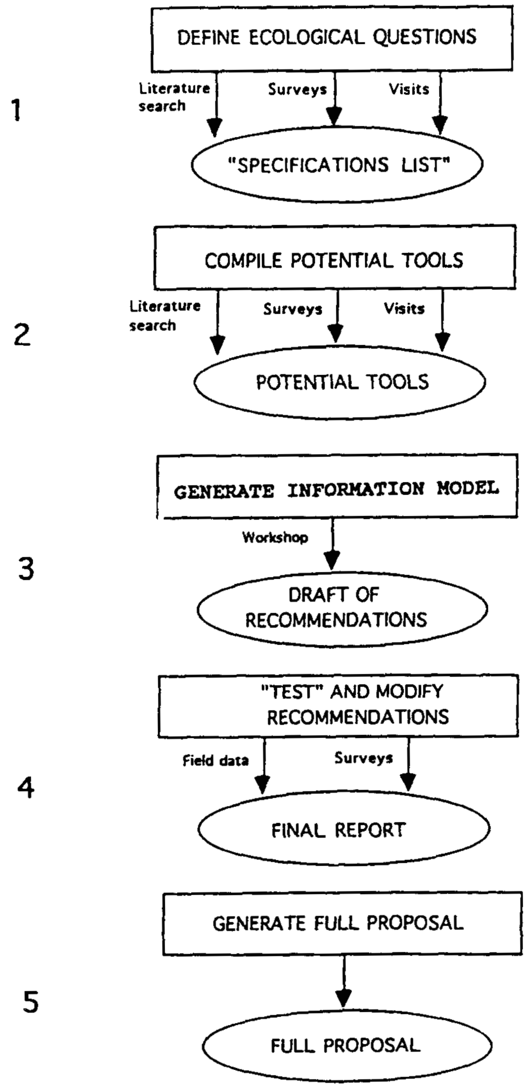

Figure 3. Five research activities and products of the International Canopy Network.

communicate the model and recommendations to the science community and plan for implementing the results of this planning project.

Our first step is to define the questions and needs on canopy structure by canvassing domain scientists. We are surveying the diverse community of canopy scientists to understand the scientific issues that are now believed to require information on canopy structure; the specific attributes of canopy structure for which information is required, and the manipulations and displays now being used. This process consists of three activities: a literature search and summary of books, journals, and existing software; surveys and interviews via telephone, conventional mail, and electronic mail (which have been developed with the help of a consultant sociologist experienced in developing such surveys); and organization of communications pathways among canopy scientists by establishing an electronic mail bulletin board (called "CANOPY"), which is currently administered by the Long-Term Ecological Research (LTER) network office at the University of Washington.

In October 1993, we sent out a four-page survey to 430 domain scientists, compiled from participants in canopy symposia, authors of current papers about canopy structure, and other professional contacts. We are currently summarizing the results of the survey, to which 220 scientists responded. Results will be synthesized into a publication and circulated on the canopy electronic bulletin board. The end product of these steps will be a "specifications list" which will identify issues and questions of concern to forest ecologists, a roster of currently available ways to collect and analyze canopy data, and a list of suggestions for potentially useful models and tools to overcome the perceived obstacles to canopy science.

Second, we will compile the existing approaches and tools from structural information specialists in other fields. We wish to discover if appropriate approaches and tools such as software and statistical tests for working with canopy structure already exist in other fields and need not be re-invented. We are currently identifying existing methods for working with spatial information from researchers in allied and non-allied fields who deal with large amounts of three-dimensional spatial data of tree-like forms. Examples of fields we are investigating include oceanography, electrical engineering, astronomy, hydrology, and medicine (especially tomographic and vascular systems research). We will pursue this process through literature surveys, interviews, and resource visits. We have also placed announcements in scientific journals; 230 announcements were sent to a wide variety of journals, and more than 40 are publishing them.

Third, we wish to develop a preliminary conceptual information model with input from database and computer scientists. This model will be adaptable to multiple applications and implementation must be affordable. Our method will be to invite a panel of database and computer scientists (8-10 individuals) to work with us. Participants will be identified through contacts we make during our surveys. Individuals on this panel will be sent the specifications list from domain scientists and the "potential tools" list from structural information specialists (Fig. 3). At their home institutions, they will individually work on creative solutions.

At the beginning of the second year (1995), we will convene a three-day workshop at The Evergreen State College to facilitate discussions. At the beginning of the workshop, the research to date will be reviewed. Particular software and other "products" will be demonstrated. This will be followed by brainstorming sessions. After the workshop, participants will submit a written report of their ideas, which will be included in the draft report of recommendations. Using information modeling methodology, we will develop an information model that integrates data and data analysis requirements.

Our fourth step is to examine the feasibility of the recommendations with a set of pilot field data collected by domain scientists. To learn whether the types and amounts of data called for in the recommendations are realistic, we will collect a set of pilot data at a field site where the canopy is accessible. This stage functions as a feasibility study, to determine whether the types and size of data required by potential models are practical, i.e., whether field researchers can collect the required data within a realistic schedule and financial budget. Depending on our progress, we may also be able to use these data to try out candidate analytical database packages, i.e., to create a visualization of a real forest canopy. With the actual measurements, we will know what degree of accuracy, repeatability, intensity of effort, and cost the various data management strategies will require.

We anticipate that a set of pilot data will be collected at the field site of the canopy crane in the Pacific Northwest. For example, the heights and angles to a series of points on branches recorded from a central benchmark might be useful to construct a three-dimensional map of the canopy. Maneuvering the mobile boom of the canopy crane would allow these data to be taken safely and relatively easily. If necessary, the recommendations will be modified, based on the field experience and feedback from participants.

The fifth step is to generate a strategy for implementing our recommendations for this planning project, which may include a major proposal to the National Science Foundation and other agencies. Our objective for this final stage is to ensure that the information model developed can be implemented and made available for use to forest canopy and spatial information specialists.

Future Directions

Although we recognize that forming a scientific communication network cannot replace independent scientific projects as the true "stepping stones" of academic inquiry about canopies—these complex and important pieces of our landscape, we believe that facilitating communications, forging avenues for multidisciplinary exchange of ideas, and putting people, equipment, approaches, and databanks together in innovative and creative ways can enhance our understanding of forest canopies. As with other established scientific networks (e.g., the LTER, supported by the National Science Foundation), productive intersite and interdisciplinary insights can be expected from these activities.

Our major hope is that this process will result in free-flowing exchange of information and concepts among those addressing canopy questions from various approaches. For example, quantifying canopy structure will allow those studying canopy-atmosphere interaction to better relate their data to those viewing the canopy as habitat for biota, and for those studying tree crown growth and physiology (Fig. 2). We hope for strong and active participation from other forest scientists, resource managers, and computer specialists. We are excited at the interdisciplinary nature of the task, and at the communications pathways we are forging both within the field of forest ecology and outside our disciplines. Most important, we are enthusiastic about taking steps that will provide greater ease and more understanding about the complex structure of forest canopies.

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