Reprinted from BULLETIN OF THE ECOLOGICAL SOCIETY OF AMERICA
Vol. 82, No. 3, July 2001
Made in United States of America

Lasers in the Jungle: the Forest Canopy Database Project

The forest canopy is of critical importance for a variety of life processes in our biosphere. Defined as "the combination of all leaves, twigs, and small branches in a stand of vegetation, including the air and interstices of the foliage," elements of the forest canopy house the photosynthetic machinery of the forest, influence the exchange of energy and matter with the atmosphere, control the microclimate at various scales, and maintain habitat for wildlife (Parker 1995). Forest canopy studies bear directly upon three of the most pressing environmental issues of the new millennium: the maintenance of biodiversity, the stability of world climate, and the sustainability of forests.

Studies from multiple scientific disciplines constitute the field of canopy research, e.g., forest ecology, meteorology, zoology, geography, and conservation biology. Recent technological applications for access to the canopy, such as the "canopy raft" and the canopy crane (Parker et al. 1992), have allowed researchers to record and interpret larger amounts of meaningful canopy data. In the last decade, a burgeoning of scientific interest in the canopy has occurred (Lowman and Wittman 1998). Interdisciplinary research groups are now coalescing to approach canopy questions from new and different spatial scales. Heightened public interest in biodiversity, global climate change, and tropical deforestation has generated books, symposia, popular articles, and films about the canopy (Lowman and Nadkarni 1995).

Both the types and amounts of canopy structure data are changing rapidly. In the past, scientists working alone with simple rope-climbing techniques generated studies that produced fairly small data sets. However, recent access innovations permit multiple teams of scientists to work within the same volume of canopy. Canopy scientists have to deal with more data, new kinds of data, and the need to share data. Data collected by canopy research teams will be useful to other scientists (e.g., geographers, land use managers), just as data emanating from allied fields could aid forest canopy researchers.

Historically, canopy scientists have been notorious for independent ways of taking, storing, and analyzing data. In 1993, our team of forest canopy ecologists and computer scientists received a planning grant from the National Science Foundation's (NSF) Database Activities Program. The project brought together forest canopy researchers, quantitative scientists, and computer scientists to work toward establishing methods to collect, store, display, analyze, and interpret three-dimensional (3-D) spatial data relating to tree crowns and forest canopies. We created a self-sustaining nonprofit organization, the International Canopy Network (ICAN), to assure that network activity would continue beyond the life of the NSF grant (Nadkarni et al. 1995). Over 750 forest canopy researchers from 62 countries now subscribe to the e-mail bulletin board and quarterly newsletter. Regional, national, and international meetings, workshops, and symposia on canopy topics are regularly organized.

We also conducted a survey of more than 350 canopy researchers and evaluated potentially applicable information models and software tools used in allied fields (Nadkarni and Parker 1994). We organized a multidisciplinary workshop for canopy scientists and database/computer scientists. These activities: (1) identified important questions under study in the emerging field of canopy research; (2) formulated a number of key forest structure–function relationships that are currently poorly understood due to lack of database tools; and (3) generated common ground for joint research by canopy researchers and database scientists.

The conclusion of both the survey and the workshop was that understanding forest canopy biota and processes was not limited by canopy access (as we had anticipated), but rather by two characteristics of canopy data: (1) lack of quantitative tools that allow canopy researchers to analyze the complex, three-dimensional spatial data associated with forest canopy studies, and (2) lack of harmonized data sets. Forest canopy researchers have tended to collect data in noncomparable formats. Although canopy data sets are increasing in number and variety, they tend to be anecdotal and descriptive, and are not readily combined with others to expose general patterns or rules. Much of this is because canopy researchers heretofore have been preoccupied with detailed descriptions of a particular environment, stand, process, and study objective. Few projects have common methodologies or data formats, so their resulting observations are not easily shared and compared.

At the brink of the new millennium, then, the study of the canopy of forest ecosystems is being held back by the lack of data management tools. The relative youth of this field—with its lack of entrenched methods, legacy data sets, and conflicting camps of competing groups—provides a unique opportunity for integrating data management and analysis tools into the research process. The sociology of the discipline is conducive to sharing data; researchers appear openly communicative and supportive of each others' work. Thus, the forest canopy studies serve as an excellent arena to generate database tools that could also serve other fields of ecology and science.

In this Commentary, we describe one fundamental part of the development of the field canopy studies, the Forest Canopy Database Project. In 1998, we were awarded a grant from NSF's Database Activities Program to develop a database and database tools to enhance the ability of researchers in one emerging and interdisciplinary field, forest canopy studies, to collect, analyze, link, and archive data. This capability will speed the development of the field to more efficiently address both intellectually stimulating and environmentally pressing questions of interest to academics, policymakers, and the general public. We anticipate that the database and tools

can serve as an exemplar for other interdisciplinary and emerging fields of science.

To date, the computer database has taken two pathways. The first piece is our web-based centralized "Big Canopy Database." This database holds information, field data, and images of use to canopy researchers, educators, and conservationists, including lists of researcher contacts, research projects, study area descriptions, images, canopy-dwelling taxa, visualization and analysis programs, meetings, training programs, equipment and safety descriptions, and scientific and popular citations. A prototype is available for viewing at <www.evergreen.edu/canopydb>

The second piece is a web-based program called "Emerald," which will allow canopy researchers to search for and download field data submitted by other researchers, design field databases and download them for their own use, and to document and archive their own databases. The system thus builds new databases from database components that "fit" canopy data. We term these components "templates."

"Emerald" currently contains data sets from six different canopy projects. To submit data to the database, a researcher from each study works directly with a database technician to provide metadata and to structure his/her data to fit one or more existing field data templates, or to generate a new template for novel data types. We anticipate that after some number of studies are entered, a finite number of data templates will be available, and researchers joining the database will find what they need within the program, obviating the need for an intermediary. The current Emerald prototype is implemented in SQLServer, Microsoft's Active Server Pages (ASP) and HTML. We are currently enhancing that prototype, using SQL Serve, but with Java rather than ASP.

Our efforts to create a database for the canopy research community will help push forward this emerging field of science. We also believe that our efforts could be viewed as a model for other emerging areas of ecology, where data-linking and data-sharing can be effective in integrating results from different studies. We seek input from researchers in the field of canopy studies to contribute to the database, and from those outside the field who may have insights into making this process efficient and productive.

Literature cited

Lowman, M. D., and N. M. Nadkarni. 1995. Forest canopies. Academic Press, San Diego, California, USA.

Lowman, M. D., and P. K. Wittman. 1996. Forest canopies: methods, hypotheses, and future directions. Annual Review of Ecology and Systematics **27**:55–81.

Nadkarni, N. M., and G. G. Parker. 1994. A profile of forest canopy science and scientists—who we are, what we want to know, and obstacles we face: results of an international survey. Selbyana **15**: 38–50.

Nadkarni, N., G. G. Parker, E. D. Ford, J. B. Cushing, and C. Stallman. 1996. The International Canopy Network: a pathway for interdisciplinary exchange of scientific information on forest canopies. Northwest Science **70**:104–108.

Parker, G. G. 1995. Structure and microclimate of forest canopies. Pages 73–106 *in* M. Lowman and N. Nadkarni, editors. Forest canopies. Academic Press, San Diego, California, USA.

Parker, G. G., A. P. Smith, and K. P. Hogan. 1992. Access to the upper forest canopy with a large tower crane. BioScience **42**:664–670.

Nalini M. Nadkarni
and
Judy B. Cushing
The Evergreen State College
Olympia, Washington 98505 USA