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'COPAS', an Innovative Technology for Long-Term Studies of Tropical Rain Forest Canopies

By

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With 5 Figures

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Summary

GOTTSBERGER G. & DÖRING J. 1995. 'COPAS', an innovative technology for long-term studies of tropical rain forest canopies. – Phyton (Horn, Austria) 35 (1): 165–173, 5 figures.- English with German summary.

A new three-dimensional technique for investigating the tropical rain forest canopy is introduced. Its advantages comprise, but are not limited to, coverage of a large area, non-intrusive observation, safe and comfortable access as well as minimal topographical requirements. It is intended to realize the project as soon as possible.

Zusammenfassung

GOTTSBERGER G. & DÖRING J. 1995. ‚COPAS', eine neue technische Möglichkeit für Langzeitstudien der Baumkronen tropischer Regenwälder. – Phyton (Horn, Austria) 35 (1): 165–173, 5 Abbildungen. – Englisch mit deutscher Zusammenfassung.

Ein neues dreidimensionales Gondelsystem zur Erforschung der Baumkronen tropischer Wälder wird vorgestellt. Damit sollen sichere, möglichst wenig in die Waldstruktur eingreifende Langzeituntersuchungen im Kronenbereich möglich werden. Schwierige oder steile Geländeverhältnisse können durch unterschiedliche Mastlängen ausgeglichen werden. Es bestehen Bestrebungen, das Projekt möglichst rasch umzusetzen.

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Why Rainforest Canopy Research?

Tropical forests cover only 3% of the total earth's surface, yet they contain more than half, or, if we agree with the newest estimations, even up to 80% of all recent plant and animal species. Tropical forests also contribute one third of global primary production, i.e., the incorporation of carbon dioxide from the atmosphere into organic, carbon-containing compounds (STORK 1988, WILSON 1988, REICHHOLF 1991). In spite of their enormous importance, the destruction of rain forests by man seems to be an inevitable process. More than 40% of the world's original rain forests already have been destroyed by deforestation (JANZEN 1988, MYERS 1991). Burning of tropical rain forests causes enormous amounts of carbon dioxide to be released into the atmosphere (DETWILER & al. 1985, ROTHMANS & SWART 1991, SETZER & PEREIRA 1991). This has negative effects on the world's climate and contributes to the so-called 'global change' (PETERS 1988, Enquete Commission 'Protecting the Earth's Atmosphere' 1992, TANS & al. 1990, ESSER 1992).

The understanding of ecological relationships in the tropics is closely associated with the investigation of tropical tree crowns. The forest canopy houses an extremely high biodiversity (ERWIN 1988, RIEDE 1990, BENZING 1990). The structure of trees and their crowns in space and time forms the matrix for diversity and dynamics of the whole system. Only a thorough knowledge of this matrix enables an understanding of the factors and processes necessary for sustainable use of primary and secondary forests. As interface between biosphere and atmosphere, the canopy occupies a central function for buffering 'global change'. On the other hand, scientific knowledge of tropical tree crowns, their biology and their importance for atmospheric changes and for life on earth is poor. This gap is recognized at present and there are strong efforts to improve our knowledge of this 'last unknown continent', as documented by the 1st International Canopy Conference in Sarrasota, Florida, USA 1994.

The success of tropical rain forest canopy studies, and thus, the indispensable improvement of our knowledge about their importance for biological processes and global change, will depend largely on the accessibility of tree crowns and possibilities to perform intensive long-term studies.

Methods of Access to the Canopy

The general inaccessibility of tree crowns of tropical forests strongly limits the possibilities of broad investigations (MITCHELL 1982, DIETERLEN & NILL 1993). Simple methods consist in making observations from a distance using binoculars, picking up plant pieces or animals fallen from the crowns, investigating cut or fallen trees, obtaining samples by shooting off branches of trees, or, in case of insects, by 'fogging' (ERWIN 1983, ADIS & al. 1995). Although considerable knowledge about the diversity of tropical rain forests has been obtained by these methods, they are largely unsuitable for long-term ecological investigations.

Quite successful are alpine climbing methods, so-called single rope techniques, supplemented by platforms established within tree crowns (PERRY 1978, PERRY & WILLIAMS 1981, DIETERLEN & NILL 1993). These methods were popularized by PERRY 1986 and subsequently used and improved by several researchers (NADKARNI 1988, WOLF 1993 a-c, FREIBERG 1989, 1994). Such methods at least need well-trained sportsmen and -women which feel safe climbing in the canopy, limiting their applicability to a small group of persons. Moreover, because of reasons of stability, only certain tree species can be climbed and the periphery of the crowns is principally inaccessible even for this pioneer technique.

Better and safer access for a larger group of persons is offered by suspension-bridges (compare DIETERLEN & NILL 1993) which are fastened between individual trees. The possibilities of movements on such 'canopy walkways', however, are only one-dimensional and the positioning of the walkway depends on the structure of the trees and the forest. Besides, canopy walkways persistently influence the ecosystem by creating secondary and artificial connections between tree individuals, which are then used by animals, e.g. ants, and which therefore influence the dynamics of populations. Good possibilities for long-term observations are offered by permanent towers (compare DIETERLEN & NILL 1993), however, investigation is limited to small areas and few trees only.

A spectacular method is the use of a dirigible hot air balloon carrying a working platform which is put down onto the canopy (HALLÉ & GAILLARDE 1990, HALLÉ & PASCAL 1992). Certainly, this technique will be indispensable for fast investigation of species diversity in larger areas. Long-term ecological studies in one place, however, are difficult or impossible, because, in putting down the platform, the periphery of tree crowns is altered by breaking branches and twigs. Animal life is also permanently disturbed. Furthermore, access to sites underneath the platform needs additional single rope techniques and allows only punctual observations. For the reconnaissance of the canopy by air photography also ultralight airplains have been used (VOOREN & OFFERMANS 1985), which, however, need experienced pilots and corresponding starting and landing places.

Lately (since ca. 1990 in Panama by the Smithsonian Institution), construction cranes are used, which are either firmly installed in one place or are moving along rails, carrying a working gondola on the beam. Although this is a promising possibility, its disadvantages lie in a relatively high energy requirement and in the necessity to cut a strip of forest in the central part of the investigation area. Furthermore, a moving crane on rails (MORAWETZ, pers. comm.), requires a completely flat area, a rare condition in tropical forests even in the Amazon region.

Three-dimensional Access to the Canopy by COPAS (Canopy Operation Permanent Access System)

Based on the experience with the above mentioned methods, a new Canopy Operation Permanent Access System (COPAS) featuring gondolas moveable in a threedimensional way has been developed (Fig. 1). The topography of a region is not a limiting factor as the system can be installed in flat areas as well as on steep slopes.

The COPAS technique was conceptualized at the University of Giessen about 5 years ago in the working group of G. GOTTSBERGER by his collaborator J. DÖRING. After the move of G. GOTTSBERGER to the University of Ulm it is now continued as joint project of the universities of Ulm and Giessen.

Fig. 1. At the moment the Canopy Operation Permanent Access System (COPAS) is still a vision – but we are working hard creating the technical base for tropical canopy research (collage by H. GRAMBIHLER).

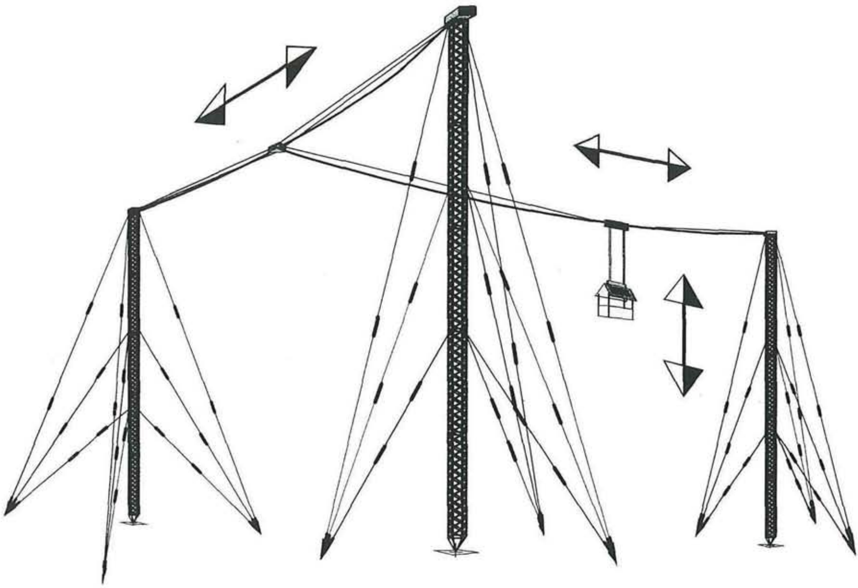

Fig. 2. The COPAS gondola system carried by three masts drawn in perspective. The arrows indicate the possibilities of movements in all three dimensions.

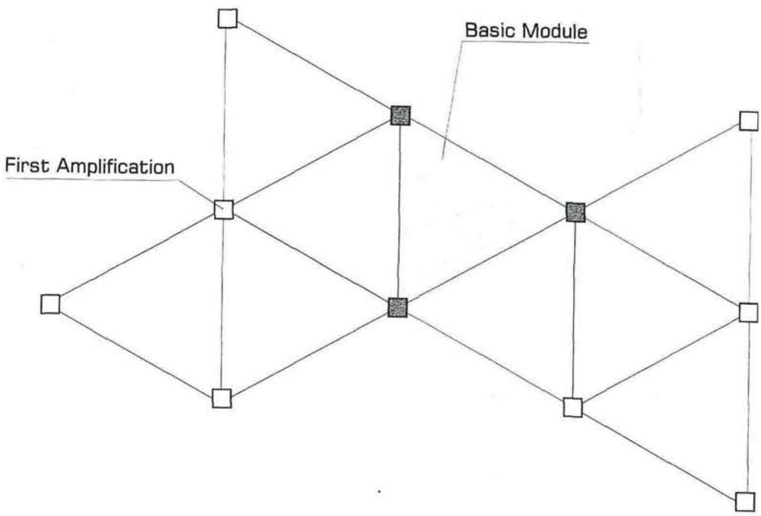

Fig. 3. The basic triangular module and possible further modules, amplifying the study area.

The planned COPAS gondola system (Fig. 2) is carried by three masts and installed within a forest. Its height will always exceed the canopy. Between two masts there is a stationary supporting-rope. A second, movable supporting-rope carries the working gondola. This rope moves with a roll and is pushed by a tow-rope along the fixed rope, its other end being held and stretched at the third mast. With the gondola it is possible to make movements in all spatial dimensions, front and back, up and down, and, by the moveable supporting rope, also to the right and left. Inside the triangle formed by the three masts the gondola reaches every point in a three-dimensional way. Access limitations caused by the density of tree crowns will be largely compensated for by the utilization of different sizes and shapes of gondolas and seats and by supplementary systems such as expositors or small platforms at the masts and in the trees.

The scheduled area spanned by the triangle of the three masts and thus, the working area of the gondola, is about 6,000 m^2 (0.6 hectares). For tropical rain forest of medium height this means access to about 200 to 400 trees with dbh (diameter at breast height) $\geq$ 10 cm, inaccessible for men from the ground. The gondola system can be amplified whenever there is necessity and demand. With a forth mast, the area is doubled (Fig. 3), the second half being accessible with a further gondola (Fig. 4). From the beginning the installation of two modules with a total number of four masts is planned, also improving the distribution of static forces.

Irregular topography or even steep slopes will not limit the establishment of the COPAS system. In this case masts of different lengths give the necessary height adjustment (Fig. 5) allowing for perfect working conditions even in mountainous rain forest regions.

The realization of the COPAS system was taken over by an association of German companies and the technical problems have been solved. Transport and construction of the system in a tropical place still to be determined will be realized by the construction company. A specific detailed tender including estimation of the costs of the system was already ordered and obtained on behalf of the Department of Special Botany at the University of Ulm. For the establishment of the system at its definite place, the collaboration of local companies is envisaged, for example, laying the fundaments for the masts.

To summarize, the 'Canopy Operation Permanent Access System' (COPAS) is a system that can be established in any region at any time, and is independent of forest height or structure. Moreover, it is integrated into the forest without using supporting trees. It will provide scientists with the basic prerequisites for safe and effective research, and promote long-term studies in the canopies of tropical lowland and upland forests.

The COPAS system is unique in its flexibility and its possibilities for crown access. It will be first installed within undisturbed forest. The as-

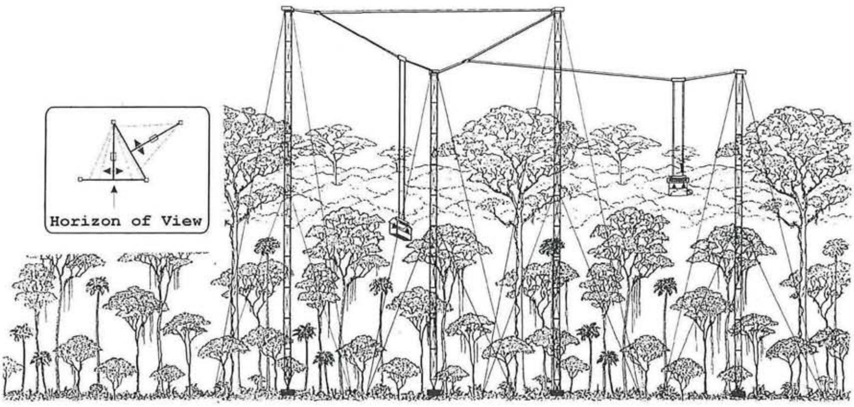

Fig. 4. Two modules with a total number of four masts and two operating gondulas installed in a forest.

sociated broad interdisciplinary research program (GOTTSBERGER & al. 1995), will hopefully contribute to the much-needed knowledge of biodiversity and function of tropical forests, and thus create a more solid base for sustainable forest management.

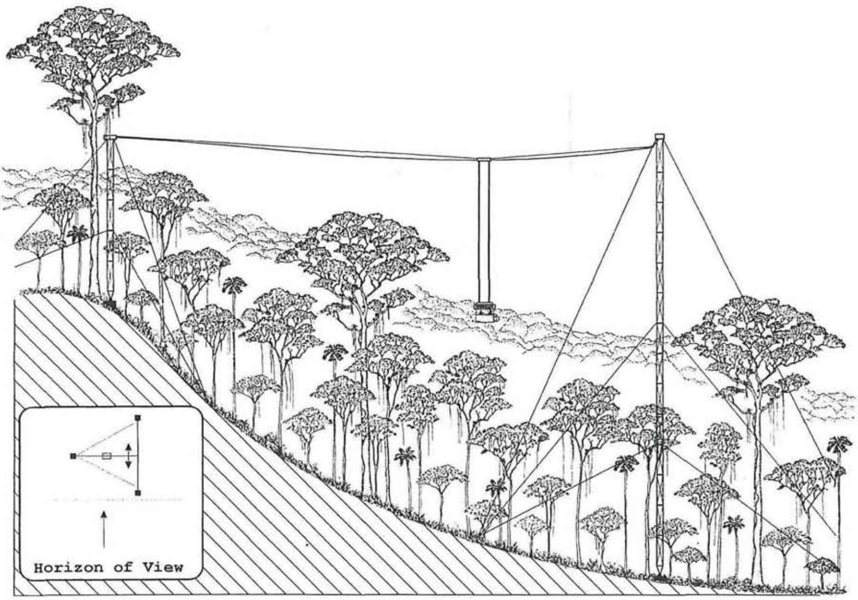

Fig. 5. Masts of different lengths providing the necessary height adjustment on a slope.

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References

ADIS J., PAARMANN W., FONSECA C. R. da & RAFAEL J. A. 1995. Knock-down efficiency of natural pyrethrum and survival rate of arthropods obtained during canopy fogging in Central Amazonia. – In: STORK N. B. & ADIS J. (eds.), Canopy arthropods. – Chapman & Hall, London (in press).

BENZING D. H. 1990. Vascular epiphytes. – Cambridge University Press, Cambridge.

DETWILER R. P., HALL C. A. S. & BOGDONOFF P. 1985. Land use change and carbon exchange in the tropics: II. Estimates for the entire region. – Environmental Management 9: 335–344.

DIETERLEN F. & NILL T. 1993. Möglichkeiten der Erforschung der Baumkronenregion des tropischen Regenwaldes. – In: BARTHLOTT W., NAUMANN C. M., SCHMIDT-LOSKE K. & SCHUCHMANN K. L. (eds.), Animal-plant interactions in tropical environments, p. 189-198. – Zoologisches Forschungsinstitut und Museum Alexander Koenig, Bonn.

Enquete Commission "Protecting the Earth's Atmosphere – Climate change – A threat to global development", 1992. – Economica Verlag, Bonn / Verlag C. F. Müller, Karlsruhe.

ERWIN T. L. 1983. Beetles and other insects of tropical forest canopies at Manaus, Brazil, sampled by insecticidal fogging. – In: SUTTON S. L., WHITMORE T. C. & CHADWICK A. C. (eds.), Tropical rain forest: Ecology and management, p. 59–75. – Blackwell, Edinburgh.

– 1988. The tropical forest canopy – the heart of biotic diversity. – In: WILSON E. O. (ed.), Biodiversity, p. 123–129. – National Academy Press, Washington, D.C.

ESSER G. 1992. The role of the tropics in the global carbon budget: Impacts and possible developments. – In: GOLDAMMER J. G. (ed.), Tropical forests in transition, p. 241–252. – Birkhäuser, Basel.

FREIBERG M. 1989. Standortpräferenzen von vaskulären Epiphyten in einem tropischen Regenwald von Französisch-Guiana. – Diplomarbeit, Institut für Systematische Botanik und Geobotanik, Freie Universität Berlin.

– 1994. Phänomorphologie epiphytischer Gesneriaceen in Costa Rica unter besonderer Berücksichtigung des Mikroklimas. – Dissertation, Fakultät für Naturwissenschaften, Universität Ulm.

GOTTSBERGER G., FREIBERG E., LÜCKING A., FREIBERG M., LÜCKING R., & DÖRING J. 1995. COPAS, ein dreidimensionales Zugangssystem, in Verbindung mit einem interdisziplinären Konzept zur Erforschung der Baumkronen tropischer Wälder. – 8. Jahrestagung deutsch. Ges. Tropenökologie, Februar 1995, Hamburg. – Abstracts (Poster), p. 12.

HALLÉ F. & GAILLARDE R. 1990. A raft atop the rain forest. – National geographic Magazine: 128–138.

HALLÉ F. & PASCAL O. 1992. Biologie d'une canopée de forêt équatoriale. II. – Rapport de Mission: Radeau des Cimes Octobre-Novembre 1991, Reserve de Campo, Cameroun.

JANZEN D. H. 1988. Tropical dry forests – The most endangered major tropical ecosystem. – In: WILSON E. O. (ed.), Biodiversity, p. 130–137. – National Academy Press, Washington, D.C.

MITCHELL A. W. 1982. Reaching the rain forest roof. A handbook of techniques of access and study in the canopy. – UNEP.

MYERS N. 1991. Tropical forests, present status and future outlook. – Climate Change 19: 3–32.

NADKARNI N. M. 1988. Use of a portable platform for observations of tropical forest canopy animals. – Biotropica 20 : 350-351.

PERRY D. R. 1978. A method of access into the crowns of emergent and canopy trees. – Biotropica 10: 155–157.

– 1986. Life above the jungle floor. – Don Perro Press, San José, Costa Rica.

– & WILLIAMS J. 1981. The tropical rain forest canopy: a method providing total access. – Biotropica 13 : 283–285.

PETERS R. L. II. 1988. The effect of global climatic change on natural communities. – In: WILSON E. O. (ed.), – Biodiversity, p. 450–461. – National Academy Press, Washington, D.C.

REICHHOLF J. H. 1991. Der Tropische Regenwald. – Deutscher Taschenbuch Verlag, München.

RIEDE K. 1990. Die amazonischen Regenwälder als Labor der Evolution. – Ber. naturforsch. Ges. Freiburg i. Br. 80 : 93–117.

ROTHMANS J. & SWART R. J. 1991. Modelling tropical deforestation and its consequences for global climate. – Ecological Modelling 58: 217–247.

SETZER A. W. & PEREIRA M. C. 1991. Amazonia biomass burnings in 1987 and an estimate of their tropospheric emissions. – Ambio 20 : 19–22.

STORK N. E. 1988. Insect diversity: facts, fiction, and speculation. – Biol. J. Linn. Soc. 35: 321–327.

TANS P. P., FUNG I. Y. & TAKAHASHI T. 1990. Observational constraints on the global CO_2 budget. – Science 247: 1431–1438.

VOOREN A. P. & OFFERMANNS D. M. J. 1985. An ultralight aircraft for low-cost, large-scale stereoscopic aerial photographs. – Biotropica 17: 84–88.

WILSON E. O. 1988. The current state of biodiversity. – In: WILSON E.O. (ed.), – Biodiversity, p. 1–18. – National Academy Press, Washington, D.C.

WOLF J. D. H. 1993a. Epiphyte communities of tropical rain forest in the northern Andes. I. Lower montane communities. – Phytocoenologia 22: 1–52.

– 1993b. Epiphyte communities of tropical rain forest in the northern Andes. II. Upper montane communities. – Phytocoenologia 22: 53–103.

– 1993c. Diversity patterns and biomass of epiphytic bryophytes and lichens along an altitudinal gradient in the northern Andes. – Ann. Missouri bot. Garden 80: 928–960.