A DATA MANAGEMENT SYSTEM FOR MONITORING FOREST DYNAMICS

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COMISKEY, J. A., AYZANOA, G. E. & DALLMEIER, F. 1995. A data management system for monitoring forest dynamics. Efficient data management is essential to the success of long-term biodiversity monitoring programmes, such as research in forest areas carried out by the Smithsonian Institution/Man and the Biosphere Biodiversity Program (SI/MAB). Over the past several years, SI/MAB has developed a user-friendly Biological Monitoring Database that allows programme personnel and other researchers to record and analyze large amounts of comparable data in attempts to understand changes in forest ecosystems. The system is being used extensively for research and education. The system's field module is designed for on-site data entry, interpretation and verification. The office module combines data from all SI/MAB research sites and produces user's and field guides and other reports for widespread distribution. SI/MAB continues to refine the system for greater ease of use and additional applications.

Key words: Forest dynamics - monitoring - neotropics - data management - education

COMISKEY, J. A., AYZANOA, G. E. & DALLMEIER, F. 1995. Satu sistem pengurusan data untuk mengawasi dinamik hutan. Pengurusan data yang efisien penting untuk mencapai kejayaan dalam program pengawasan kepelbagaian bio yang berjangka masa panjang seperti penyelidikan dalam kawasan-kawasan hutan yang dijalankan oleh Smithsonian Institution/Man and the Biosphere Biodiversity Program (SI/MAB). Sejak beberapa tahun yang lalu, SI/MAB telah membangunkan satu pangkalan data Pengawasan Biologi yang mesra pengguna yang membolehkan personel program dan penyelidik-penyelidik lain untuk merekod dan menganalisis jumlah besar data yang sama dalam percubaan-percubaan untuk memahami perubahan-perubahan di dalam ekosistem hutan. Sistem ini sedang digunakan secara meluas untuk penyelidikan dan pendidikan. Modul sistem lapangan ini direka untuk catatan di tapak, interpretasi dan penentusahan. Modul pejabat mengumpul data dari semua SI/MAB tapak-tapak penyelidikan dan menerbitkan panduan pengguna dan panduan lapangan serta laporan lain untuk edaran yang luas. SI/MAB terus memperbaiki sistem tersebut untuk memudahkan penggunaannya serta penerapan-penerapan tambahan.

Introduction

In 1987, The Smithsonian Institution/Man and the Biosphere Biodiversity Program (SI/MAB) began the systematic process of monitoring biodiversity and forest dynamics in temperate and tropical forests. The objective is to gather and analyze information about species and ecological communities so that we can better understand changes in forest ecosystems (SI/MAB Biodiversity News 1991, 1992). Increased knowledge of such changes enhances our opportunities to maintain ecosystem integrity, restore degraded landscapes and assist forest dependent human societies shape more stable futures.

To achieve that objective, SI/MAB has to date established permanent research plots in Bolivia, Peru, Guyana, Puerto Rico, U.S. Virgin Islands and the Great Smoky Mountains National Park, Tennessee, USA. We prepare and disseminate guidelines for setting up monitoring projects throughout an expanding network of research sites, and conduct training courses in all phases of the monitoring process for in-country scientists, researchers, students, land managers, and others.

From the outset, SI/MAB has been developing and refining the Biological Monitoring Database (BioMon) for data gathering, entry, analysis, interpretation, and storage. On-the-ground experience at our research sites shows that efficient data management is key to successful monitoring. BioMon addresses the need for a flexible, accurate methodology capable of providing a speedy turn-around between the physical census and publication of useful materials.

BioMon allows consistent documentation - in users' and field guides and special reports - of up-to-date, detailed biological information gleaned from the permanent plots, (Dallmeier *et al.* 1991a, b, c, d, Dallmeier *et al.* 1992, Dallmeier 1993, Dallmeier *et al.* 1993 a, b, c, d). One purpose of BioMon and the guides is to transfer timely results into the hands of other researchers, managers, and support personnel so that they can conduct more effective studies, training, and biodiversity monitoring projects. Our efforts during the past seven years have yielded nearly 100 000 independent observations, sufficient to produce the guides, and begin in-depth analysis of forest diversity, dynamics, and regeneration. This has served as a baseline for other researchers using the permanent plots in their own work. Biomon has proved indispensable as an educational tool at SI/MAB workshops.

Research methodology

The description of BioMon requires some background in the type of data collected at the SI/MAB research sites (for more see Dallmeier 1992, Dallmeier

& Comiskey, in press). At all permanent plots, researchers are responsible for dividing each one-hectare plot into smaller quadrats. Trees with a minimum diameter of 10 cm at breast height (dbh) are then located, measured, tagged, identified and numbered. (At our Virgin Islands site, the minimum dbh is 4 cm). Other features are also recorded, such as the degree of coppicing (for trees that are regenerating after Hurricane Hugo in Luquillo, Puerto Rico), crown condition and the current status of each tree (Table 1).

Table 1. Status codes for tree condition

Status	Standing	Leaning	Fallen	Broken	Not Located
Alive	AS	AL	AF	AB	NL
Dead	DS	DL	DF	DB	NL

The data - along with the researchers' names, dates of census, and notes - are made available in the guides. They are accompanied by maps of the plots that locate each tree and show its relative size and its current status. This level of detail is essential in meeting the objectives of the monitoring programme. With several years of data, determinations of growth, mortality, and regeneration of the forest are possible.

The SI/MAB biological monitoring database

As SI/MAB's biodiversity monitoring programme matured and gained in geographic scope and the amount of information collected, the need for comparable data that could be shared with a variety of researchers became ever more apparent. Thus, we programmed BioMon according to the principles of modularity, ease of use, and compatibility. We incorporated off-the-shelf software and created portable links that, along with documentation, are made available to other researchers attending SI/MAB workshops. BioMon has been designed as an integral part of the field work thus ensuring a consistent approach.

BioMon is menu driven (Figure 1), allowing the user to access the system with a minimal amount of prior training. This has proven particularly helpful during the SI/MAB methodology courses and workshops, where participants may handle up to 20 000 individual values per hectare. The ability to concentrate on data entry accuracy, without the concern of prior database management experience, is very important.

The system has two main components, similar in their structure but with different intents and capabilities (Figure 2). The Field Module manages information for a specific site. The Office Module manages and analyzes data for all sites, leading to the production of diverse publications.

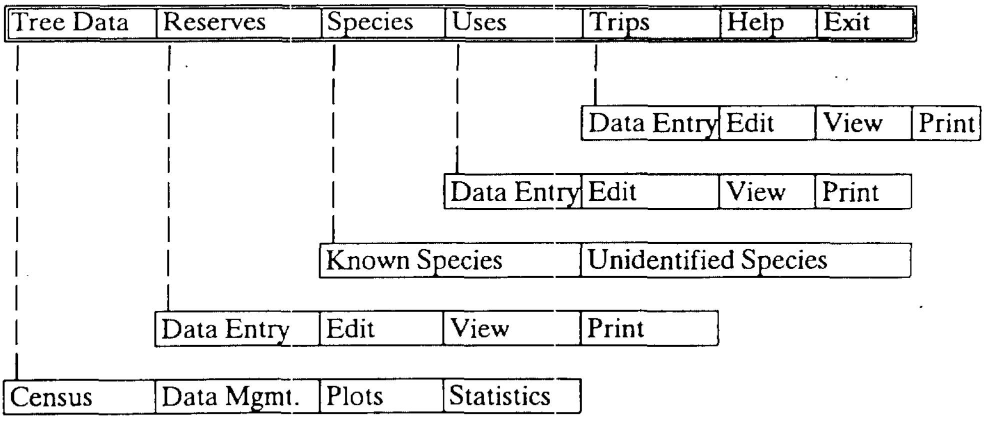

Figure 1. Main menu structure

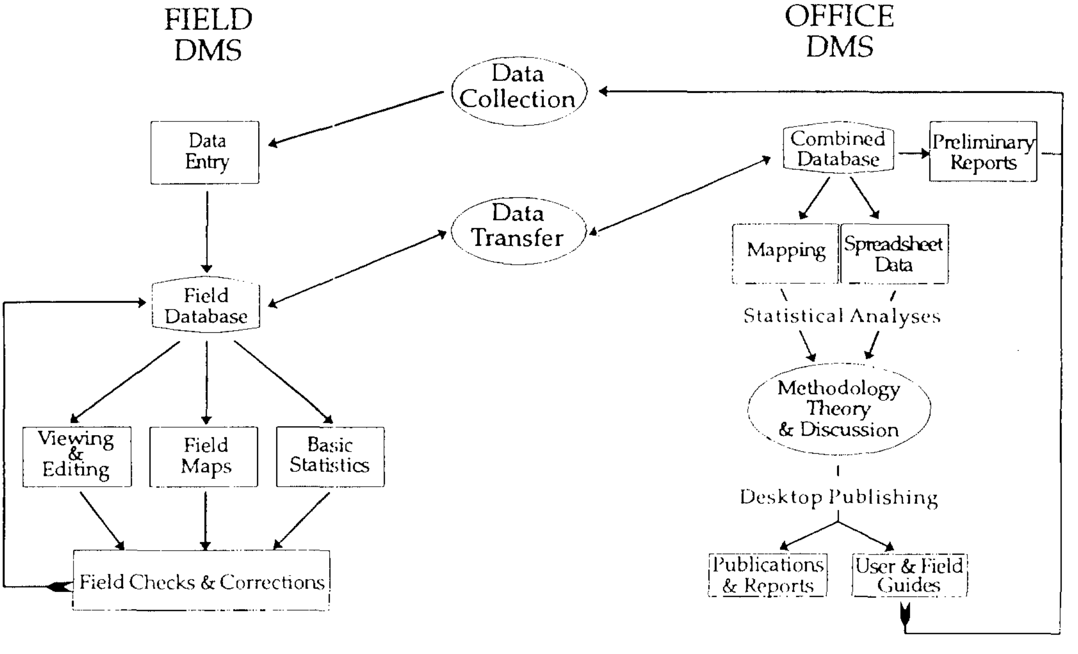

Figure 2. SI/MAB data management system

Structure of the database

The data base is composed of a collection of linked tables, whose information is made available through a series of on-screen forms. The columns within each table contain the different data parameters collected (shown in parentheses in Figure 3); the rows represent each individual record.

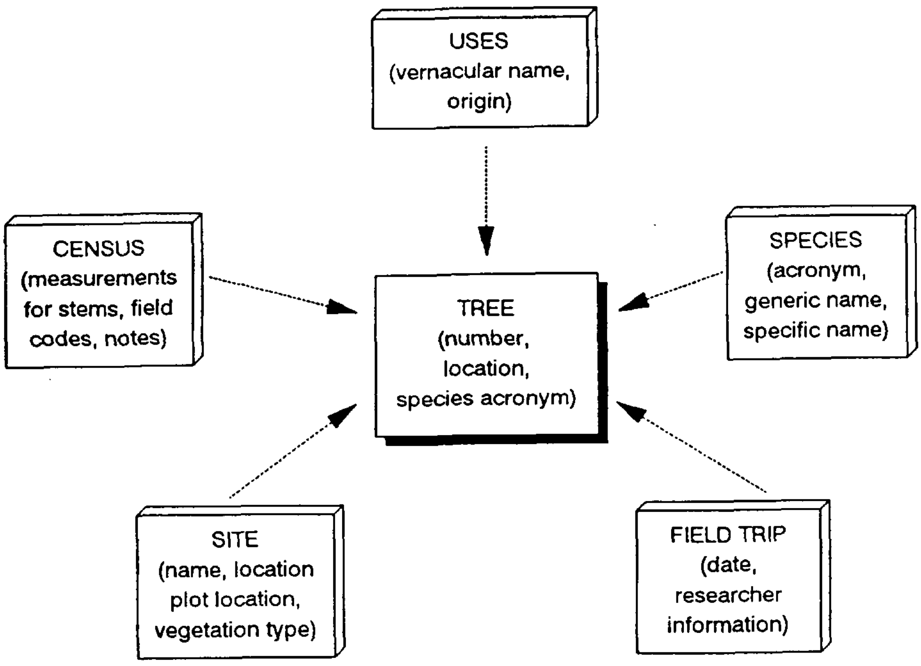

Figure 3. Database structure

The main table holds basic information for each tree, and it is to this table that all others are linked. Data from each census is stored within a separate table which contains stem measurements, field codes (Table 1) and notes. A species name table includes the full names of the species occurring at the site. It is linked to the main table by a species code, which is an acronym composed of the first three letters of both the generic and specific names. An uses table holds the vernacular names and uses of each species, along with the source for the data, whether from an indigenous community or the literature. This provides a measure of the ethnobotanical value of the forest at the research site. Additional tables contain information about the site as a whole, and information about the field trips for each census.

On a final note, designing BioMon as a relational database allows users to add new links as different types of research are conducted on site. Possibilities include faunal, hydrological and soil surveys.

Field Module

Data collected in the field are entered on pre-printed forms. This hard copy is necessary for backup and archival purposes and acts as a cross-reference for information entered into BioMon at the base camp. One form is allocated to each quadrat within the plot.

The form provides spaces to record all the measurements taken in the field - tree number and stem number for trees having more than one stem at the point of measurement; point of measurement if other than at breast height (1.3 meters); A and B location measurements, each measurement taken from a different corner of the quadrat to the position of the specified tree; a number relating to the baseline used for location measurements; the diameter of the stem; the height of the tallest branch; coded descriptions of the condition of the stem; and notes of other pertinent information.

Field data entry

Once data has been collected, it is entered into BioMon through the data entry module on portable computers. The module requests plot and quadrat numbers from the user. Those numbers are then automatically recorded on the screen form along with information concerning the name and vegetation type of the specified plot. All columns on the printed field forms are present on the screen form, as well as the columns from all linked tables.

We designed BioMon, using a database application language, so that a series of validity checks can be made during data entry and editing, thus enhancing the integrity of the recorded data. Each column, depending on the nature of the data, allows values to be entered only within certain ranges, thus minimizing errors. The programming also enables checks on existing data to prevent multiple entries and to access additional relevant information. For example, upon entering the species code, information on the specific and generic names, and any uses, is displayed on the screen. If the user has entered a non-existent code, an error message appears. All accessed data can be updated as required and are subject to validity checks.

Once the data has been entered, it is easily viewed and edited, so that more information can be added or corrections made. Sections of the data may also be printed, providing a hard copy of the database content.

One special feature of BioMon is its ability to provide a map of each quadrat in planar view. The A and B values, which locate the tree within the quadrat, are converted to X and Y coordinates and used to produce the maps. Each dot represents a tree. The size of the dots is based on the actual diameter of the tree. The number assigned to each tree also appears. The maps can be printed so that ground verification crews have hard copies to help ensure the accurate location of each tree.

On completion of data entry and verification, researchers can obtain an array of basic calculations for each site, including the number of species, and their relative density, dominance, and frequency. The programme can also produce distribution maps for selected species within the plot. This ability to provide basic analyses while still in the field is a major benefit of BioMon. Researchers can conduct further investigations on site to help in immediate interpretation of the information.

It is essential for system users to maintain a backup of the data stored on the computer and ensure that it is regularly updated. The menu has such an option, exporting the data as a text file, and storing it on diskette. It is important to retain a minimum of two copies on disk, especially when working in tropical regions where humidity may cause the diskettes to fail.

Office Module

The office module is a more complex version of the field module, giving access to data from all the sites where SI/MAB is maintaining biodiversity monitoring plots. To make the data more manageable, information from each site is stored within its own directory in a series of tables. The structure of the tables is identical for each site; thus, users can make comparisons between the sites. Data collected and entered on the portable field computers can be downloaded through a network connection or from the backup diskettes. The office module, as an extension of the field module, moves from database management into statistical manipulation, map creation, and publication development.

The users' and field guides are produced from the office module. Because of the nature of the work, personnel with prior training are needed at this stage of the process. The data is exported to a desktop publishing programme, which arranges the information into the format required for publication. Format changes can be made as necessary.

Biomon as a tool for education and research

Over the last seven years, SI/MAB has held a number of biodiversity monitoring workshops in Latin America and the Caribbean. These workshops aim to present participants with an array of monitoring methods, and instruct them on the methodology used by SI/MAB in the establishment of permanent plots. BioMon has proven extremely useful not only in educating participants in the use of computers, but also in maintaining the integrity and comparability of the data collected. This has been of major benefit in situations where large amounts of data are handled by a number of different people. BioMon, on completion of data entry and verification, allows the production of summary data, furthur enhancing the educational value of the workshop. On completion of the workshop, all participants are presented with a copy of BioMon thus ensuring consistency in data collection and storage, as well as establishing a link to the central SI/MAB BioMon.

As a research tool, BioMon has been used in the analysis of the forest dynamics at the various research sites. The permanent plot, set up at Luquillo Experimental Forest in 1988, was subsequently affected by Hurricane Hugo in 1989. Further censuses in 1991 and 1992 have provided an insight into the effects of Caribbean hurricanes on the vegetation, and the resulting regeneration (Dallmeier *et al.* 1991a,b, Dallmeier *et al.* 1992). BioMon has proven extremely useful in the determination of growth, death, and regeneration rates at the site. In areas where large scale disturbances are frequent, further research will provide a clearer understanding of natural forest regeneration (Foster 1980). Application of this knowledge to restoration efforts in other Caribbean islands will aid the success of these projects. We are currently using BioMon to provide a base of information for a restoration effort in Guyana.

BioMon is fed into Conservation Data Centers in the regions where the research is carried out, thus assisting in the continuing species inventories, land management, and research (Jenkins 1988). Further links are established with herbaria in the United States, and can equally be instituted with other data centers.

Conclusion

SI/MAB's Biological Monitoring Database has proven useful in research, and education, and the maintenance of a consistent approach to managing large amounts of data. At the same time flexibility has been incorporated to allow for changes in the system, thus ensuring that changes in future monitoring may be integrated. Programming of the database, carried out by field researchers, has addressed physical constraints and ensured that the design is appropriate for on-site needs. We strongly recommended that the system be used for long-term inventory and monitoring of forest plots, especially when information is required for management purposes.

We are still working to improve applications of BioMon. Because the data is based on tree location, BioMon can be dropped into a geographic information system with limited additional programming should a plot be part of a larger management unit. Other modules or overlays (such as bibliographies or faunal analyses) can be developed and linked to the system. Finally, over the life of the programme we have removed various obstacles to data movement and sharing. We expect to continue improving BioMon, enhancing its integration capabilities and ease of use.

SI/MAB remains committed to developing a system for speedy and accurate data development, recording and analysis. Sharing of protocols and methodologies helps ensure that the data are useful to a wide audience and that data from other researchers are useful to our programme. By creating comparable data sets, we can start to answer the vital scientific and management questions that arise in attempts to staunch global deforestation.

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