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THE ENCYCLOPEDIA OF SOUTHERN APPALACHIAN FOREST ECOSYSTEMS: A PROTOTYPE OF AN ONLINE SCIENTIFIC KNOWLEDGE MANAGEMENT SYSTEM

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Summary: The Encyclopedia of Southern Appalachian Forest Ecosystems (ESAFE), a hyperdocument-based encyclopedia system available on the Internet, provides an organized synthesis of existing research on the management and ecology of Southern Appalachian forests ecosystems. The encyclopedia is dynamic, so that new or revised content can be submitted directly through the Internet, continually updating, expanding, and improving the knowledge base. Unlike most Internet-based hyperdocuments, quality control of the encyclopedia is ensured through a complete peer review process similar to traditional scientific journals. The encyclopedia has been evaluated by a diverse group of land managers, the general public and ecosystem scientists. The current version, available for viewing at "www.forestencyclopedia.net", represents the first 2 years of a 3-year project funded by the USDA National Research Initiative Program.

1. Introduction

There is an overwhelming body of research available on the ecology and management of Southern Appalachian forests. For example, the Coweeta Hydrologic Laboratory, a center of forestry research in the region, has produced over 900 publications (Stickney et al. 1994). Scientists at the USDA Forest Service, Southern Research Station's Bent Creek Experimental Forest, have produced 287 publications. Nodvin et al. (1993) published a list of some 2,500 publications associated with the Great Smoky Mountains National Park. The Southern Appalachian Assessment (SAA) generated nearly 3 gigabytes of information about the status of resources in the southern Appalachians (Hermann 1996; http://sunsite.utk.edu/samab/data/SAA_data.html).

Despite the accumulation of this large body of research knowledge, a gap exists between what scientists know and what the management community is able to apply on the ground. Most of this research knowledge is neither easily accessible nor readily useable because it has not been synthesized and integrated into a coherent, meaningful knowledge structure. This knowledge base mostly retains the fragmented nature of the many separate publications that compose it. What should emerge as an integrated and coherent body of knowledge appears instead to managers as disconnected, often contradictory, pieces of the "whole" that they need for applied problem solving. Because land managers deal with forest resources in aggregate, they need knowledge in a form that captures the integrative nature of ecosystems and management.

To address this need for more accessible, understandable, condensed, and synthesized research knowledge, we developed the Encyclopedia of Southern Appalachian Forest Ecosystems (ESAFE) -- a hyperdocument-based encyclopedia system available on the Internet. This project aims to synthesize what we know scientifically about the management and ecology of Southern Appalachian forest ecosystems, organize it logically, and make it universally available at no cost to users. The encyclopedia is designed to be dynamic, so that new or revised content can be submitted directly through the Internet, continually updating, expanding, and improving the knowledge base. Unlike most Internet-based hyperdocuments, quality control of the encyclopedia is ensured through a complete peer review process similar to traditional scientific journals.

The main objectives of the encyclopedia are to:

1. organize research knowledge about southern Appalachian forest ecosystems;
2. present scientific information on the Internet in a form that is accessible to a wide variety of users; and,
3. provide research information in a form that is easy to apply to the daily work of forest managers, landowners, and researchers.

In this paper, we briefly discuss the advantages of using hyperdocument technology for managing knowledge, introduce ESAFE, and explain its development, evaluation process, peer review, and modification.

2. Knowledge Management and Hyperdocuments

Professional resource managers, consultants, and researchers must deal with vast amounts of information to do their jobs. Part of this information overload is due to our traditional focus on knowledge creation instead of knowledge management. Knowledge management is defined as "a set of organizational practices that combine the information processing capacity of information technology with the creative and innovative capacity of people to create, capture, organize, store and retrieve, diffuse, present, and maintain knowledge" (Heinrichs et al., 2003). Despite the practical importance of access to knowledge and its role in the scientific process, the application of knowledge management to forest science is still in its infancy. Many recent reviews of the effectiveness of forest research and extension institutions still emphasize the need for reaching greater numbers of people more efficiently. A continuing complaint by end-users of scientific knowledge is "I can't find the knowledge I need, when I need it, in a form I can both understand and use to solve problems."

This situation is exacerbated by the "publish-or-perish" reality most researchers operate within. Researchers primarily write for peer-reviewed scholarly journals that are usually narrow in scope and highly technical in nature. As a result, it continues to be very difficult and costly for forest management professionals to assemble relevant pieces of research knowledge, draw useful conclusions, and translate them into a management solution, particularly within the short time frame most managers have available. Efforts to publish technology transfer bulletins and notes in paper text format have been frustrated because they go out of date rapidly, are either too general or too narrow, and are expensive to reprint in updated form every few years. Problems addressed by managers are often unique and require *ad hoc* synthesis and integration.

The emergence of the Internet has been the key technological development and enabling tool for knowledge management over the last decade. Internet infrastructure, combined with increasingly sophisticated hyperdocument authoring systems, make web-based scientific knowledge management a practical and affordable option (Simard 2000).

Anyone who has accessed the Internet has been exposed to hypertext (or, hyperdocuments)—a highly nonlinear and interactive mixture of text, graphics, images, video, and audio. Abstractly, a hyperdocument consists of a network of chunks (organized collections of information that are each internally self-contained and independently understandable) connected by links (an electronic cross-reference used to connect logically related chunks). Links simulate the mental association between chunks in the mind of the author. The *structure* of a hyperdocument refers to the organization of chunks. Structure commonly takes the form of tables of contents, outlines of chunks, graphical diagrams of chunk relationships, indices, or link organization. The *content* of a hyperdocument refers to the domain-specific material that makes up the subject matter.

Hypertext offers many advantages over paper text that make it more suited for managing scientific knowledge: it can be easily accessed, it occupies little physical space, and it can be published cheaply and rapidly. Unlike linear print media that is static and assumes a single, fixed skill level by the intended audience, hyperdocuments can be readily updated and manipulated to appeal to a variety of users. These characteristics allow hypertext technology to improve the speed and accuracy of data, information, and knowledge management.

As with any media-form, hypertext does have several disadvantages. The single greatest difficulty of hypertext users is navigating to find desired information without getting disoriented. "Getting lost in hyperspace" commonly happens when (1) users follow a chain of links and become distracted from their primary objective, and (2) users find themselves unable to return to chunks that are of particular interest. The fundamental cause of the navigation problem is the disparity between the author's organizational structure and the user's conceptualization of the knowledge space. The greater the difference between those two views, the more likely the user will get lost in hyperspace. The danger is particularly great for users who are entirely new to the subject matter and have formed no mental maps of their own before using the hyperdocument. This navigation problem can be alleviated if hypertext authors pay careful attention to good global and local navigation devices. Global navigation aids allow readers to (a) determine their present location, (b) identify the location's relation to other materials, (c) return to their starting point, and (d) explore related pages not directly linked to the current page. Local navigation aids provide the user with access to pages that have some logical relationship with the current page.

A second hypertext issue is how to communicate to the user exactly what is covered by the hypertext and what is not covered. People are used to picking up books or articles that give direct sensory clues as to their size, where they begin, and where they end. The traditional linear authoring style allows rapid browsing for content. A hypertext system provides users few of these clues, and few good design or technical solutions exist for solving this problem. Therefore, hypertext authors must communicate as much of this information as possible where users are likely to begin. Ideally, the homepage of the hypertext system tells users what the system is about, how large it is, what it contains, and, just as importantly, what it does not contain.

A third hypertext issue is how to enable the user to search for specific topics as quickly and accurately as possible. Very powerful and flexible search engines have been developed -- almost every hypertext system provides an excellent one. These search engines are modules that are readily available for any hypertext author to use without further need to refine them.

An increasing number of knowledge management Internet sites are being developed with some form of natural resource management focus. In an attempt to bring some order into this proliferation of sites, the United States National Web-based Learning Center for Natural Resource Management (Jackson et al., in press) is working to develop a classification of these web sites. For example, there are sites with a very strong educational objective offering structure coursework in numerous topics related to natural resources. One of the best examples of on-line coursework is found at the site "www.cnr.vt.edu/forestupdate". Other sites specialize in Frequently-Asked-Questions (FAQ) management. A good example of such a site is "www.answerlink.info". Still other sites specialize in some form of scientific reference management. For example, the Southern Research Station has over 6,000 research publications in their reference management system at "www.srs.fs.fed.us" each of which is available in full text, free of charge from the web site. Many sites exist that offer index-like listings of numerous other sites with natural resource management content. The southern regional forestry office maintains a site at "forestryindex.net" that organizes other sites, allows searches across these sites for specific information, and allows developers of natural resource sites to add their own site to this index. Still other sites exist that organize natural resource data by geographic location, see for example "climchange.cr.usgs.gov/data/atlas/little". Many sites provide voluminous and very detailed data about trees, insects, diseases, etc., for example, " fhpr8.srs.fs.fed.us/idotis/insects.htmll". Sites that organize simulation models for downloading are also available in abundance. A good example of this type of site is found at " www.fs.fed.us/fmsc/fvs/software/varfiles.php" which allows users to download the Forest Vegetation Simulator. However, few if any currently available sites are specifically focused on the internet-based management of scientific knowledge that is peer-reviewed and continually updated.

Several examples of hypertext scientific knowledge management systems in forestry have been previously published, including the Encyclopedia of AI Applications to Forest Science (Rauscher 1991), the Ecology and Management of Aspen (Rauscher and others 1995a), the Northeast Decision Model Design Document (Rauscher and others 1995b), A Hypermedia Reference System to the Forest Ecosystem Management Assessment Team Report (Reynolds and others 1995), Oak Regeneration: A Knowledge Synthesis (Rauscher and others 1997), and Forestry Compendium "http://www.cabi.org/compendia/fc/index.asp."

3. The Encyclopedia of Southern Appalachian Forest Ecosystems

We began developing the prototype Encyclopedia of Southern Appalachian Forest Ecosystems (ESAFE, http://www.forestencyclopedia.net) in July 2000. It is composed of summaries of hundreds of topic areas compiled from over 5,000 literature sources by over 15 authors. The encyclopedia's infrastructure allows this content to be constantly expanded, improved, and updated with peer-reviewed material. As of this writing (late February 2003), ESAFE has 1008 pages of content that includes over 129 tables, 105 figures, 3,000 internal hyperlinks, and 900 external hyperlinks. Many features of ESAFE are familiar to Internet users. These include drop-down menus, collapsible menus, simple and advanced search engines, user help, user comment forms, and a table of contents (site map). Unlike most websites, the encyclopedia is built upon a dynamic content management system that creates a mechanism for updating the site with peer-review content. The peer review process will make ESAFE an attractive technology transfer outlet for scientists.

3.1 Scope of ESAFE

As explained clearly by its name, ESAFE focuses on the forest ecosystems of the Southern Appalachians. Although traditional forestry topics, such as oak silviculture, are covered in more detail, we have included a

variety of other forest-related topics. These include soils, geology, classification of natural communities, environmental history, wildlife ecology and management, management of aquatic resources, non-timber forest products, old-growth forests, biodiversity, aesthetics, disturbance, biogeochemical cycling, air quality, insects and diseases, exotic species, decision support, recreation, sociology, and economics. The dynamic content management system (see 3.4, below) will allow these topics to be expanded as pages are created, peer-reviewed, and accepted. Users can get an up-to-date overview of the completeness of these topics by accessing a link from the encyclopedia's homepage.

The main audiences targeted by the encyclopedia are natural resource professionals and land managers/land owners. However, one of the advantages of using a hypertext format is that audiences with differing levels of experience can be targeted. Therefore, we also expect that researchers, local and regional policy makers, students, and the general public will find particular sections of the encyclopedia useful.

3.2 Content development

ESAFE content is designed to provide a concise state-of-the-knowledge synthesis of Southern Appalachian research. We developed this content using four different sources: original syntheses written by the principal investigators or other experts; the previously published hyperdocument, Oak Regeneration: A Knowledge Synthesis (Rauscher and others 1997); and content excerpted from sources in the public domain. We began by composing an outline of the proposed content that was later translated into a hierarchical hyperdocument structure. The hierarchical structure of ESAFE made it possible to divide content into sections that were assigned to individual authors, who developed and expanded the outline to complete their section. Authors used their own approaches to synthesizing content, ranging from writing original literature reviews of primary literature to summarizing existing literature reviews. Authors referenced primary and secondary (review) literature using the name and year format familiar to scientists. In the encyclopedia, these citations become direct links to bibliographic information, and eventually to on-line full-text documents.

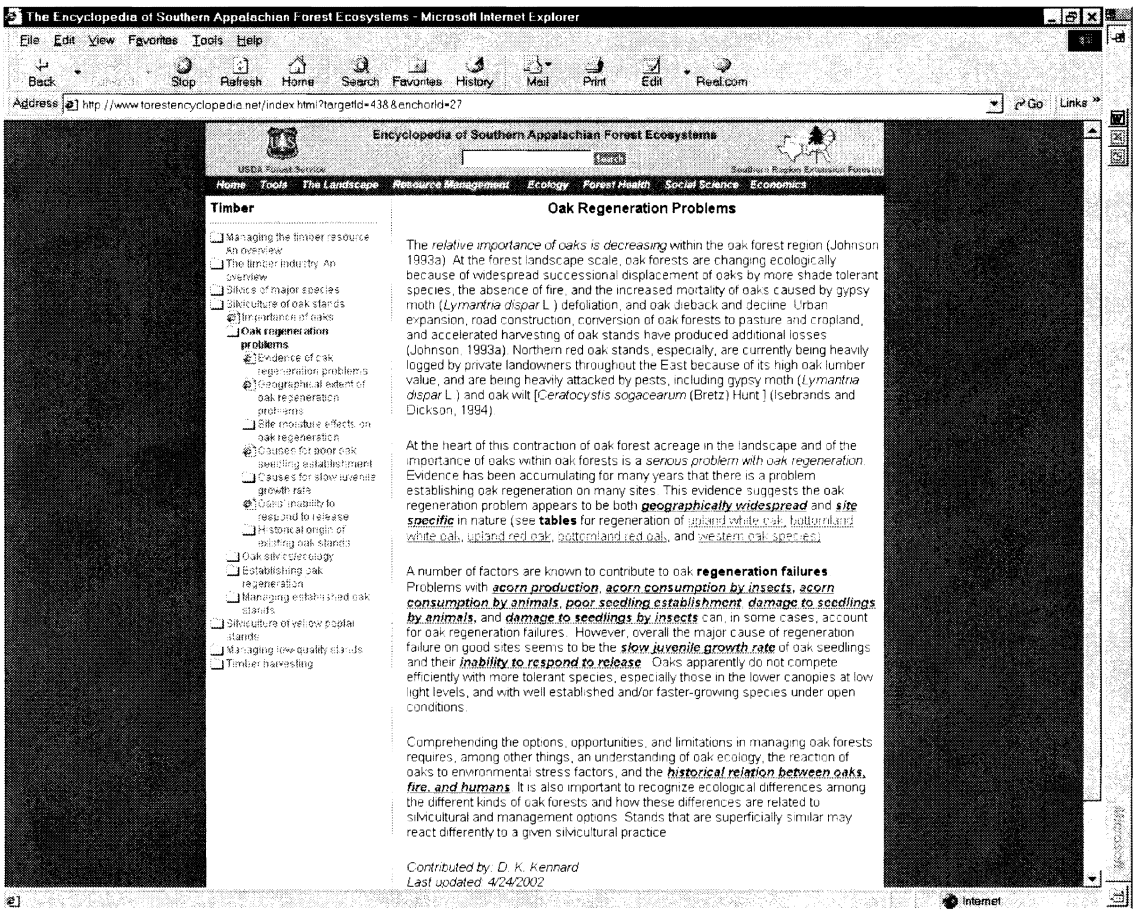
Because multiple authors produced content, it was important that all content conformed to a set of guidelines to ensure a consistent look and feel. These authoring guidelines help ensure readers can comprehend content pages quickly and easily. For example, no more than 3-4 screens (900-1200 words), preferably fewer, of information are contained in a single page; longer pages are split along logical lines into two or more detailed pages. Since hypertext should be more visual than paper text, key terms are bolded; key concepts italicized; and bulleted lists, charts, tables, graphs, figures, photographs, or pictographs are used to clarify, streamline, and condense the text. Hyperlinks provide an additional visual cue that is also familiar to users.

One of the most important authoring rules was that each page be independently understandable and self-contained. Authors cannot rely on sequential reading to present material since readers arrive at a particular page by linking from many different directions (hypertext pages or chunks). Also, unlike paper text documents, where much verbiage is used for transition and contextual placement of facts or concepts, hypertext pages contain only pertinent facts and concepts – if something must be explained more fully, the author simply creates a new page and a link.

3.3 Structure and Navigation

Topics in ESAFE are organized into six major sections: The Landscape, Resource Management, Ecology, Forest Health, Social Science, and Economics. These six sections are represented in a drop-down menu that is visible to users at all times (Figure 1).

Figure 1. Sample Organizational Page in ESAFE



Content within each of these major sections is organized in a hierarchical structure, where each page has one parent page and one or more child pages below it. This tree-like structure is represented as a linked collapsible menu in the left frame of Figure 1. These menus change accordingly as users browse between the six major sections. This collapsible menu and the drop-down menu serve as the encyclopedia's main global navigation aids. Other examples of global navigation aids used in the encyclopedia are the table of contents, figure and table indices, and full text search tools.

Local navigation is provided by hyperlinks anchored within encyclopedia pages. These links can be used to move sequentially within a subject area, to move laterally within the encyclopedia to related topics, or to link to web pages outside ESAFE. Organizational pages are used to simplify local navigation. These pages, which organize links to child pages (subtopics), provide a roadmap to users, helping them understand the structure of subsections and giving them enough information to decide if they want to read further by accessing links. Content pages, generally at the lowest level of the outline hierarchy, cover an individual topic to some depth and may contain links to other related pages. When accessing local navigation links move the user within ESAFE, the new location is represented in the linked collapsible menu. If users browse among the six major sections of the encyclopedia, their location is also highlighted in the main drop-down menu. When a link reaches outside ESAFE, the different frame of the host site signals the move.

3.4 Content Management Infrastructure

The initial structure for ESAFE was created using static HTML publishing methodology, using the PHP scripting language (Ratschiller, 2000) in combination with the MySQL® relational database software to

create and manipulate the hierarchical structure. Authors created content using the Microsoft® FrontPage HTML editor. Completed content was then delivered electronically by individual authors to the project content manager, who then integrated these pieces into a master structure. This master structure was then used to update the online PHP system.

This PHP infrastructure quickly proved to be inadequate for planned expansion of the initial ESAFE system. Numerous authors providing a continuous stream of content required a complete content management system that was dynamic, easy to update, and easy to maintain. After examining many competing approaches, we chose the Zope web application framework (Spicklemire et al., 2001) to develop our second-generation encyclopedia infrastructure. Using Zope, we designed a content management system (CMS) that would: (1) allow authors to create, edit, and submit multiple types of content inside the system; and (2) allow a complete peer review and publishing cycle to occur inside the system. In a companion paper, Jordin et al. (in press) provide technical details of how Zope was used to create this CMS. Here, we highlight how the CMS works.

3.6 Peer Reviewing, Publishing, and Updating Content

The Zope CMS uses custom workflows as the foundation for the peer-review and publishing process. A workflow defines rules for each type of content that can be created inside the encyclopedia. Here, for example, we explain the workflow for an encyclopedia page (Figure 2). Authors begin the publishing process when they submit a page and its supporting content (child pages).

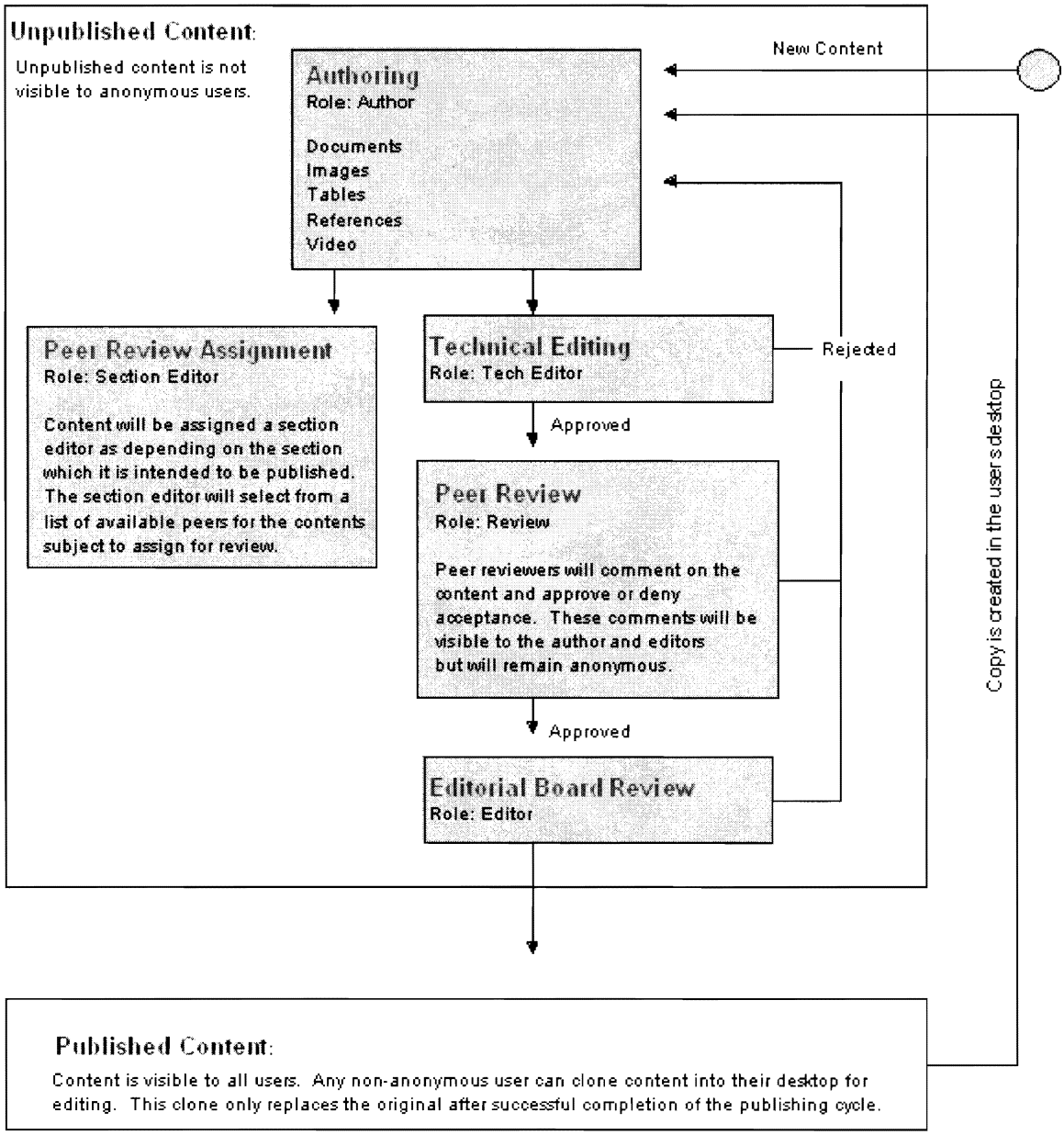
They designate the intended section in ESAFE by noting a parent page. Next, the corresponding section editor provides commentary, passes the page to another section editor, rejects the submission, or accepts it for review. After a section editor has accepted the page, he or she designates external reviewers to assess the document and supporting content for its scientific merit. After a critical number of reviewers accept the page, it progresses to the technical editor who edits the page for appropriate style and form, grammar, etc. Finally, the page is submitted to the editorial board for review and final acceptance. If at any point in the workflow a page is rejected, it must repeat the entire process to be published.

The various tasks contributors are allowed to perform within the Zope CMS are predetermined by one or more roles each is assigned: author, peer reviewer, technical editor, section editor, or editor-in-chief. For example, authors may submit content, but cannot modify any content other than their own. Authors can also check on the status of their own pages in the publishing process whenever they choose, but are restricted from certain comments in order to keep reviewers anonymous. Zope regulates access to content based on a contributor's role. Roles are identified within the Zope CMS by usernames and passwords.

Once a page is published, any contributor with approved access will be able to create a copy of the content onto their desktop area in order to make additions or changes. As with original content, these revisions to existing content must go through the appropriate channels of peer review and editing before replacing the original content in the encyclopedia structure. The original published version remains accessible by all users during the process. To prevent multiple authors from editing the same content at once, a lock is placed on the published version, indicating that it is being edited.

A unique feature that will be implemented in the new system will allow encyclopedia users to retrieve previous versions of content, if it exists, so that the change of knowledge over time can be documented. Once revised content completes the peer review cycle, the original content is converted into an archived page. When a user views any page that contains an archived version, they are notified by a hyperlink to the entire lineage of archived pages. Page archives are omitted from the catalog to make sure they are not returned in search results. By browsing this collection of archives, a user can get a sense of the direction of research and changes in what is known about the topic in question.

Figure 2. Encyclopedia Page Workflow for Publishing and Peer Review



4. End-user Evaluation

We asked representatives of the target audience (forest managers, scientists, other practitioners, and laypersons) to evaluate the encyclopedia during the summer of 2002. Users were directed to an on-line evaluation and comment form from the home page, where they were asked to review the encyclopedia and comment on how well it achieved its objectives and met their needs. In addition, users were also asked to comment on several aspects of navigation and content: Is the information easy to find, easy to understand, sufficient for the user's needs, and helpful in decisionmaking? Is the information well organized and easy to navigate?

A total of 32 comments were received within 3 months of the start of the evaluation period. Comments were received from a number of different sources including USDA Forest Service (9), Other Federal (Military) (2), University (7), Private (Consulting Foresters and Forest Industry) (4), Nongovernment

Conservation Groups (1), State Forestry (2), Anonymous (5) and Unknown (2). In addition, comments were solicited from a group of managers attending a USDA Forest Service sponsored training session in the Spring of 2002.

Overall, users across all groups were impressed with the project as a whole and positive about the potential uses of the encyclopedia. Many commented on the innovative nature of the resource and its immediate use to them as scientists, managers and educators. Improvements suggested by users are summarized here.

- More research and case studies.
- More bibliographic references, links to journal articles/other resources and literature cited.
- Current level of detail was sufficient for general public but not necessarily for professional.
- Link to online SAF Dictionary if possible.
- Move to a database system rather than flat-text file system
- "Old-fashioned" index was desired
- More hypercontent rather than hypertext (graphics, video, audio, multimedia production, etc.).
- Heavier use of graphics and images.
- More content on small mammals, ecological site index, soils, policy/decision process, white pine and hemlock, pine/hardwood forests.

We contacted each respondent who supplied an email address, and mailed them the results of the evaluation. They will also be informed about any remedial actions being taken to address their concerns. Through this process, we hope to establish an ongoing community of professionals willing to provide valuable feedback to this project on a periodic basis. The electronic comment form will remain on the site to encourage new user input and review.

5. Summary and Conclusions

We developed ESAFE to demonstrate that hypertext technology is a useful way to manage scientific knowledge about ecology and management of southern Appalachian forests for a variety of users in an accessible environment. In the process of creating ESAFE, we have focused on knowledge structure as well as content. Content on a full range of forest ecology and management subjects is organized in a hierarchical structure that individual authors expand as they develop content. Author guidelines ensure that each page is independently understandable and self-contained.

Compared to other efforts (Rausher 1991, Rauscher et al. 1995a, b, Rauscher et al. 1997), this one is unique in that we have built a sufficiently complex pilot to constitute a successful proof of concept. The large number of pages (over 1000 and growing) and links is sufficient to disorient most readers. Yet, our global and local navigation tools allow users to (1) navigate the structure without getting lost; (2) learn the knowledge structure quickly so they can form a good mental map of the science; (3) search for particular pieces of knowledge quickly and efficiently; and (4) learn quickly what content is in the encyclopedia and what is not.

Furthermore, we have implemented a content management infrastructure that will support a well-designed document control workflow. The system has no foreseeable upper limits on size or scope – it is completely expandable. Adoption of the multiple author workflow (Figure 2) promises to revolutionize the way scientific knowledge is reported and delivered to users. The workflow incorporates a peer review process that parallels what is being developed for paper and electronic journals.

The end-user evaluation process, although not necessarily ideal, demonstrated that the knowledge management technology we developed is helpful for users. Some comments like the request for an "old-fashioned" index may reflect a desire by users for familiar paper text tools, which will change as they become more familiar with searching and browsing tools. By and large, though, most suggestions concerned issues of content, which will be resolved as we move from this prototype to a more complete version.

The Encyclopedia of Southern Appalachian Forest Ecosystems constitutes a framework for organizing knowledge about southern Appalachian forests and improving access to that knowledge. The encyclopedia is both dynamic, making future updates easier, and nonlinear, allowing a greater level of knowledge integration than existing print media can accommodate. Our needs for knowledge management in the southern Appalachian ecosystem are not unique, and the concepts and techniques developed in this encyclopedia project can be broadly applied to other knowledge domains. Interest in this work is gaining momentum in the region and is beginning to achieve national attention in the U.S. We recently initiated work on a Fire Science encyclopedia and plans are underway for a Central Hardwoods encyclopedia, each of which will generate unique issues for development of new knowledge management technology.

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