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CONSERVATION ECOLOGY

Synthesis

An HTML-based Concept Model of the Dry Savanna Woodland Ecosystem for Teaching and Learning

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ABSTRACT. This article introduces a web-based conceptual model of vegetation to facilitate an easy understanding of the processes that govern the development of dry savanna woodlands. The model is based on a simple table structure that can be interpreted by most web browsers, making it easily accessible. This latter consideration is important because thetelecommunication link to most of the outlying areas in Namibia is weak. The model may be accessed by community-based natural resource managers to provide an overview of the complexity of the savanna woodland system.

INTRODUCTION

The dry savanna woodlands of northern Namibia provide a number of different resources to the rural communities, ranging from construction material and a source of energy to food and tools. In 1992, Ollikainen (1992) estimated that, in total, 1.5 x 10^6 m^3 of wood were used for firewood alone. In 1996, the National Planning Commission determined a GDP (gross domestic product, agricultural production) of Namibian $2.6 billion, although the informal sector was ignored. During the same year, the total woodland resources that were used by the informal sector amounted to an equivalent value of almost Namibian $1060 million per annum (NFSP 1996:3).

Despite the dependence of rural people on woodland resources, little management besides law enforcement is currently implemented. This is partly due to the limited financial and human resources available, but also is due to limited knowledge of the woodlands and their ecology, which slows the implementation of management actions that support sustainable utilization. Models of the woodland areas may assist in directing data collection and identifying and testing management options before they are implemented (Starfield and Bleloch 1991:3).

Various models have been developed in the past to examine the savanna system (Starfield et al. 1993, Milton and Hoffman 1994, Jeltsch et al. 1996, Joubert and Rothauge 2001). Starfield et al. (1993) developed a frame-based model of woodlands in Zimbabwe, in order to investigate the interaction between different vegetation components. Graz (1996) simulated some known ecological processes with a simple systems model of the dry savanna woodlands in northern Namibia. Jeltsch et al. (1996) developed a spatial model to investigate the woody component in the Negev. The state and transition models proposed by Milton and Hoffman (1994) and Joubert and Rothauge (2001) are descriptive and static in nature. The authors describe the different states that the vegetation may assume under various environmental conditions. Changes in these conditions or in the intensity of different factors may cause a transition of the vegetation to another state. The two state and transition models provide diagrams to depict the interaction of ecological and management processes. Accompanying descriptions provide details about the different sections of these diagrams and the nature of the interactions.

Although such illustrations are very useful tools for obtaining a good overview of the savanna woodland system, Graz (1996) experienced problems with developing all of the necessary links, especially feedback loops, despite the limited complexity of the model. In order to cope with complexity, a top-down approach may be used, together with stepwise refinement. This technique that has been used in computer programming to break down a problem into components that can be worked on individually (Sterling and Shapiro 1997:67) or broken down into further sub-units. Analogous to this approach, a number of submodels may be developed, to be referenced by a parent diagram. Each of these submodels may be maintained or updated

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Polytechnic of Namibia

independently. Alternative approaches for coping with complexity are described by du Toit et al. (1995:64) for the development of mind maps, and by Novak (undated) for concept maps. These methods identify a core thought to which influencing factors or more specific concepts are linked by a series of lines. Links are extended not only toward the core, but also between the influencing factors, thus potentially forming complex networks.

The model presented in the Appendix consolidates existing information on the dry savanna ecosystem into a conceptual model, using an approach that combines stepwise refinement and the method for creating mind maps. Literature for the model is cited in the Appendix.

This paper presents the various factors that determine and modify the structure of the dry savanna woodlands, and identifies and describes the interactions between the different factors. Unlike the models previously referred to, this model is developed using Hypertext Markup Language (HTML), which is used in the development of Internet web pages. HTML, click-able diagrams, Java, and JavaScripts may be used to develop an interlinked/cross-linked hierarchy of text and figures as described in Graham (1997) and Kidder and Harris (1997). In this way, stepwise refinement may be implemented almost boundlessly, while retaining simple diagrammatic presentation.

A further advantage of this approach is that the model may be accessed using standard Internet web browsers, making it a useful teaching tool. Students, managers, and community leaders may browse through different components and levels of complexity on their own, backtracking to previous screens as desired. Additionally, the various components of the model may be revised and updated individually at a central point.

The structure used in compiling the model was chosen primarily to maintain easy access to the model. Parts of Namibia are served by slow communication lines, with substantial downloading times. A more sophisticated approach would make the model less accessible in these areas simply because of communication technology. Images, although very useful for the illustration of various aspects, were excluded for similar reasons.

HTML MODELING VS. DIAGRAMS

Diagrams such as those provided by Joubert and Rothauge (2001) or Graz (1996) are used to show the relationship between different components of a system. Flow diagrams may be developed easily with standard office software such as Microsoft Powerpoint, whereas more sophisticated applications such as Vensim (Ventana Systems, accessed in 2001) provide a tool to develop causal loop diagrams that may be expanded into dynamic systems models.

Another popular method of showing relationships between factors is through the implementation of mind maps (du Toit et al. 1995:64) or concept maps (Novak, undated). These techniques identify influencing factors and components that affect a specific concept. These techniques display information schematically, but without the addition of descriptive text. As detail and scope increase, however, it becomes increasingly difficult to depict a model on paper, particularly if the number of feedback loops increases, and text is then added.

To illustrate the problem, consider the two sections of a woodland model in Figs. 1 and 2. Fig. 1 depicts the factors that affect the mortality of adult trees in the woodlands. Tree mortality is affected by the severity of damage by fire, the availability of soil water, the vigor of the plants, and the effects of pests and diseases. Each of these factors is affected by others. For instance, the degree of fire damage is a function of the fire frequency, fire intensity, and fire season.

Fig. 2 shows the factors that govern the establishment of seedlings in dry woodlands. Here, the core component, seedling establishment, is affected by fruit production, germination, soil water availability, and fire damage. The figure shows that the components not only affect the establishment of seedlings, but also have an effect on each other, although indirectly.

Both sections are relatively simple and easy to understand, as links may be followed between the core components and the factors that affect them. Additionally, each section only includes the factors relevant to the topic at hand, i.e., mortality of trees (Fig. 1) and the establishment of seedlings (Fig. 2). The reader is therefore less likely to digress from the topic. There are relatively few factors in each of the two diagrams, so they may be loosely spaced on paper, thus improving readability.

Fig. 1. Schematic presentation of the factors that affect the mortality of adult trees in dry savanna woodlands.

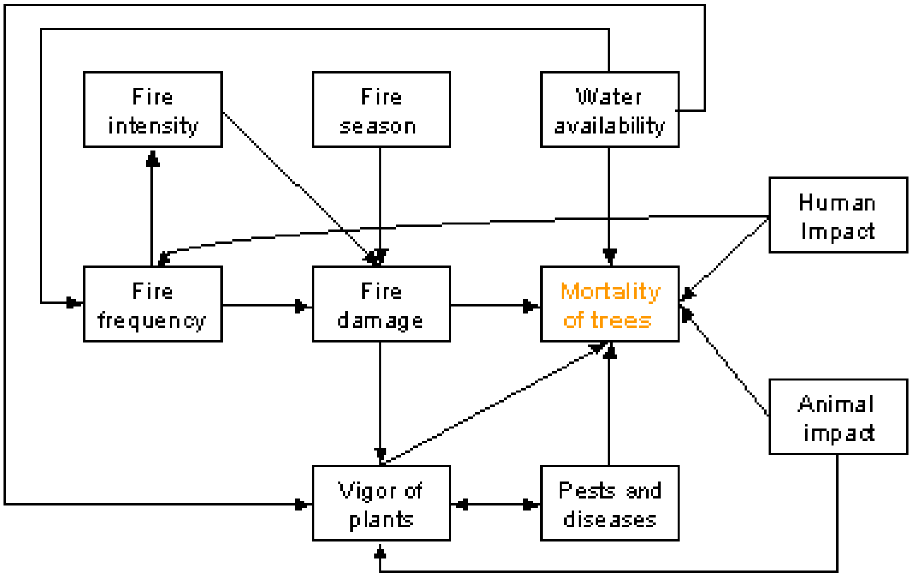
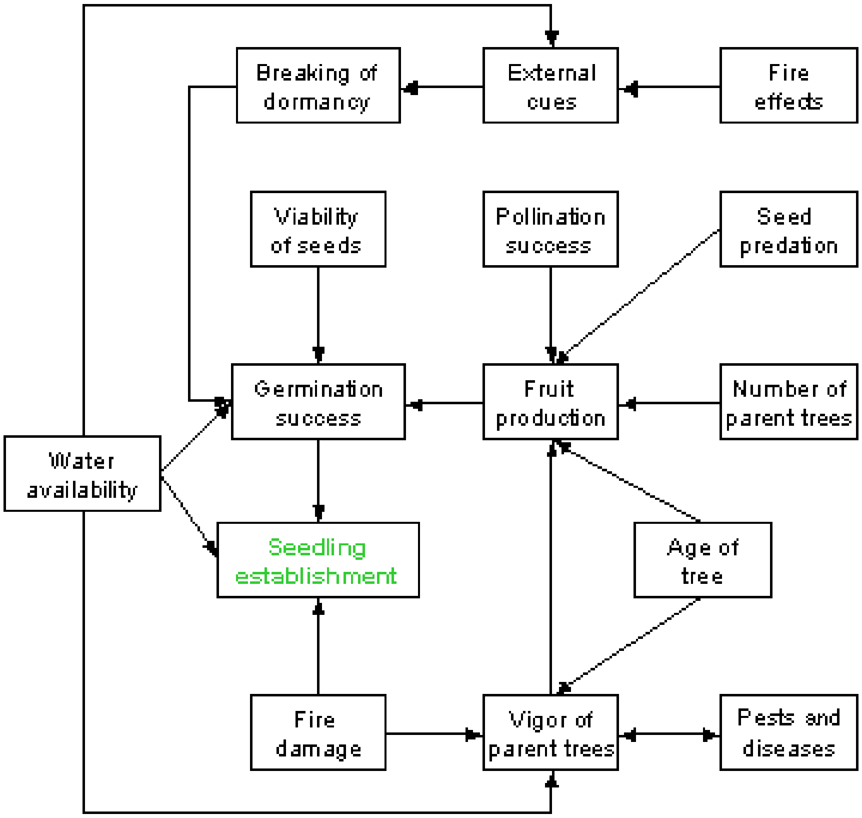
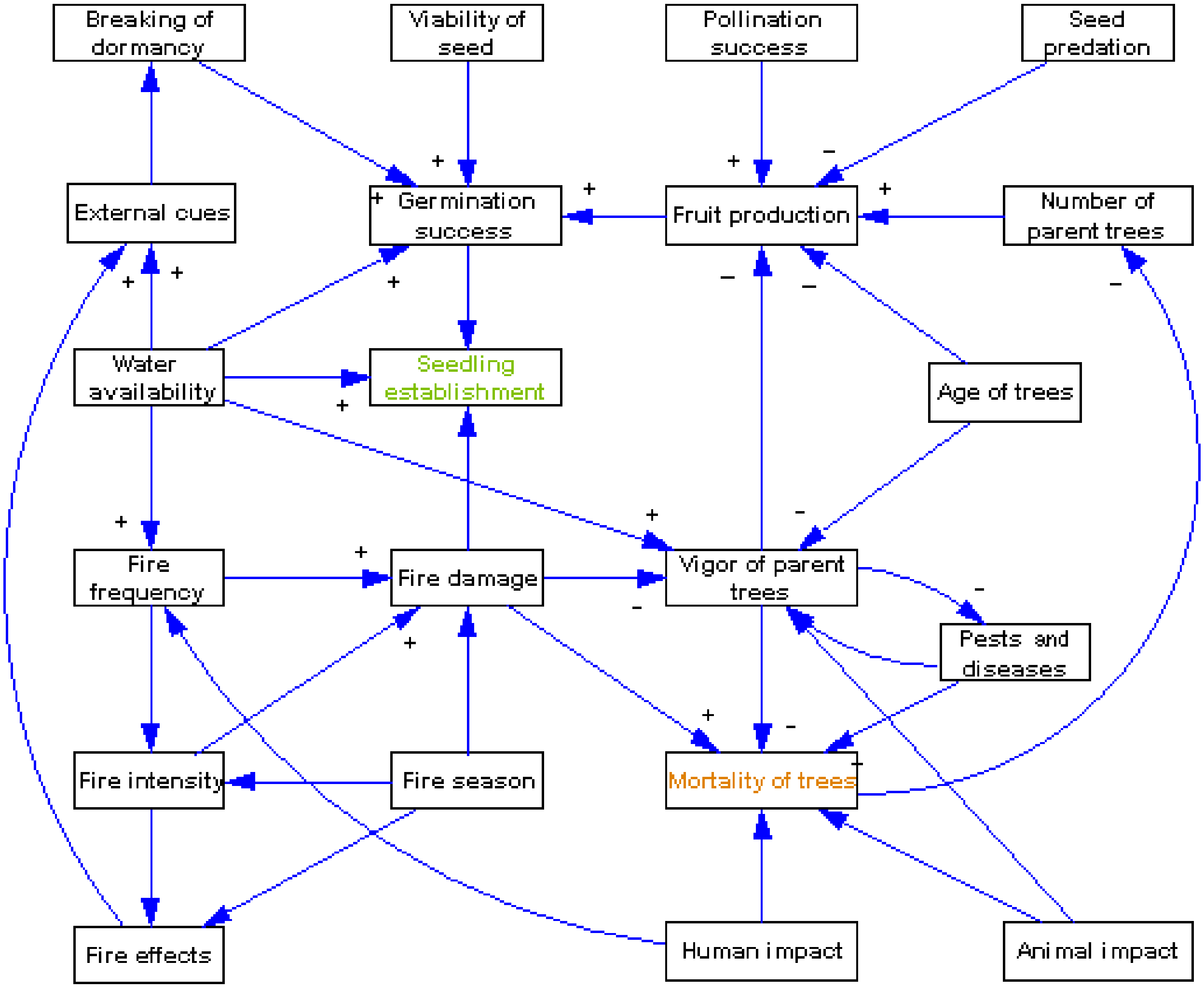


Fig. 2. Schematic presentation of the factors that affect seedling establishment in dry savanna woodlands.



Because both sections reference water availability, fire damage, and the vigor of trees, they could also be combined to form a single diagram, linked through these three factors. This is done in Fig. 3, in a causal loop-type diagram, using Vensim (Ventana Systems, accessed in 2001). Although the combination of the two diagrams provides a more complete picture, it also becomes increasingly complex and more difficult to read. Therefore, in order to ease comparison with the previous diagrams, the core components of Figs. 1 and 2 have been highlighted using different colors. In order to maintain readability, the factors might be spaced more widely on paper. This would result in a drawn-out diagram. On the other hand, the figure could be restricted in size, thus making some sections appear very busy. Consider, for instance, "vigor of parent trees" and its influencing factors in Fig. 3. Although the vigor of the parent trees is an important aspect, the number of uni- and bi-directional links seems to emphasize the significance of that factor above others, subsequently causing bias in the interpretation of the diagram.

Fig. 3. A causal loop-type diagram that combines the mortality of trees in Fig. 1 and the establishment of seedlings in Fig. 2. The + and - signs indicate positive and negative relationships between factors, respectively.



It must be noted that the complexity of Figs. 1–3 has been restricted by summarizing factors. Water availability is, for instance, influenced by soil conditions, rainfall, and competition with other woodland plants. The factors "soil condition" and "competition with other woodland plants" could again be subdivided. The expansion of the factors would, however, make the figure less legible and the reader would be more likely to digress because of an information overload.

Although the diagrams in Figs. 1 and 2 show the various factors that affect one another, they do not provide information on the type of association. The causal loop diagram in Fig. 3 attempts to resolve this by indicating a positive relationship (indicated by a “+”) or a negative relationship (indicated by a “-”) between the factors. Here, a positive relationship implies that an increase in one factor would result in an increase in the other, whereas a negative relationship indicates that an increase in one factor would cause a decrease in the other. Because the nature of the links are only known in a general way, they cannot be quantified using constants or equations.

However, not all relationships can be labeled in this way. For example, the effect of fire may initially increase germination, but as fires become more intense, seed is damaged. Van Daalen (1991) found that a higher percentage of *Pterocarpus angolensis* seed germinated in response to medium-intensity fires as compared to very high or very low intensity fires.

To compound the problem, the nature of the links from one factor to the others may differ. For instance, water availability affecting seedling establishment refers to the amount of soil water; fire frequency is indirectly affected by the development of herbaceous vegetation as a result of water; and the breaking of dormancy considers the amount of water that may remove inhibitory chemicals.

Milton and Hoffman (1994) and Joubert and Rothauge (2001) attempted to overcome this problem by numbering the individual states and transitions, and by providing descriptive text separately. A disadvantage of this system is that a reader is required to cross-reference the diagram and text on different pages. The problem would not be solved by using a larger sheet of paper. The user of the model would be required to view the model from a greater distance to see it in its entirety, in which case the writing would become increasingly less readable.

A further alternative would be to combine space and color coding, i.e., allocating different colors to different submodules of the model. However, as the number of submodules increases, different shades of the same color become increasingly difficult to distinguish. This problem is similar to the allocation of colors when preparing maps (ESRI 1994). Also, this approach would require decisions about where such color-coded submodels would begin or end.

The technique described here presents a simple tool to break down a complex model into sub-units that can be displayed separately or in groups. The various sections of the model are stored in separate HTML documents that are linked to a parent document using uniform resource locators (URL) (Graham, 1997). Each of the sub-documents, in turn, may act as parent document for further refinement. Similar to the implementation of hyperlinks on the Internet, many documents may point to one parent; conversely, a single document may point to many parent or child documents. The various child documents may also cross-reference one another.

This characteristic has important implications for model development. Once a section has been developed, it may be referenced by multiple higher level models. For instance, a subsection that deals with the development of soil moisture is important for seedling development, plant vigor, and growth. The subsection can therefore be referenced by all three. Similarly, the vigor of adult trees affects not only tree survival and seed production, but also the plants’ susceptibility to attacks by pests and diseases.

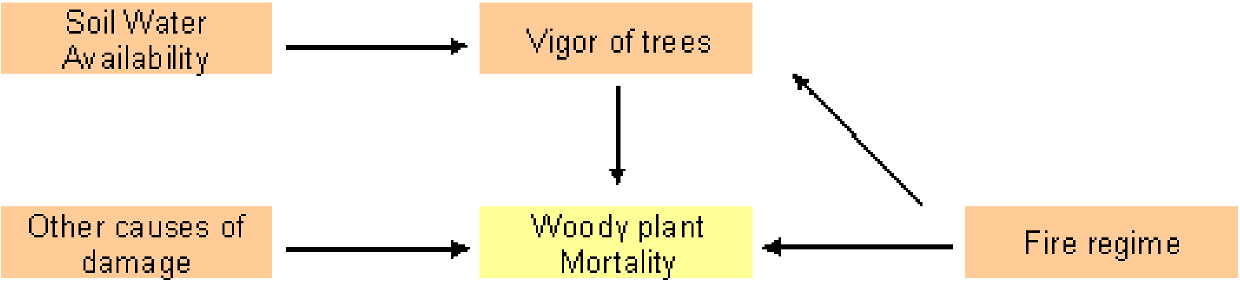
An important advantage of the use of URLs is the ease of dealing with feedback loops. For instance, reduced light intensity on the woodland floor due to shading by woody plants results in a weaker herbaceous layer. This, in turn, eases the establishment of woody seedlings and the subsequent development of the woody layer.

IMPLEMENTATION OF THE HTML DOCUMENTS

To facilitate easy access and navigation through the model and its component descriptions, the browser window is divided into three horizontal sections using frames; with the implementation of frames, the individual sections of the screen may be changed independently. The uppermost frame (model frame) permits the reader to navigate through the individual submodels, whereas the central frame (description frame) is used to display the descriptive text requested by the reader. The last frame contains a menu that provides navigation aids and access to a list of the literature referenced by the model. The menu could be extended to solicit feedback from the readers.

The html documents that contain the submodels use a simple table structure to present the individual factors or elements and the linkages between them in a systematic way. Fig. 4 provides an example, showing the factors that influence woody plant mortality. The factors are entered as text into the table, whereas leader lines to other components are displayed using images of arrows.

Fig. 4. Factors that affect woody plant mortality in the dry savanna woodland system, with links indicating where the various factors influence one another.



Any element of a submodel that is subdivided further provides a hyperlink to the next level of refinement. For instance, following the hyperlink attached to the factor “Fire regime” would show a submodel dealing with fire frequency, season, and intensity.

Descriptions of model components may be called up from the model frame, to be displayed in the description frame underneath. This permits the reader to access more than one relevant description for a submodel while still viewing the submodel.

To distinguish between hyperlinks to submodels and those to descriptions, the links to descriptions are enclosed in parentheses and are provided below the name of the factor. Explanatory text is also provided for some leader lines between individual elements within a submodel. Following a hyperlink attached to such a leader line will also cause text to be displayed in the description frame. For example, the effect that fuel load development has on fire frequency is linked to a leader line, whereas detailed information on the development of fuel loads and fire frequency is provided by descriptions of the factors themselves.

Images that offer a hyperlink are, by default, displayed with a box. Further consideration has suggested, however, that the box distracts the reader by drawing attention to the leader line rather than to the submodel as a whole. Hyperlinked leader lines are therefore blue, as opposed to the normal black.

DISCUSSION AND CONCLUSIONS

The conceptual model described here organizes knowledge in the form of text, thereby making it freely readable to the user, and functioning as an important primer to more detailed mathematical models or even expert systems.

HTML is inappropriate for the development of mathematical modeling and is very inefficient in the development of an expert-system approach. Both techniques would be more effectively implemented with Java, e.g., the Mandarax expert system shell .

In view of the simplicity of the approach, access to the knowledge base is facilitated through a web browser rather than through sophisticated software. This is important in a society where people are computer literate, but have only limited numerical skills. Simplicity is also important from the technological side. Browsers differ in their ability to recognize or interpret some HTML mark-up tags, although standards have been recommended by the W3 Consortium (Münz 2001). The simple table structure, the placement of images within tables, and hyperlinks are, however, a standard implementation. The structure of the HTML documents therefore makes the model more widely and consistently accessible. At the same time, the simple documents result in small files that require relatively short downloading times.

HTML permits the extension of a conceptual model almost indefinitely, while providing a simple method for the incorporation of feedback loops. The simplicity, however, also entices the modeler to expand in one particular area of interest while neglecting others. It is therefore important to keep in mind the purpose for the model and to monitor its development to ensure that it does not digress in one direction. This problem is shown in the model in the Appendix. Because there is much conceptual information available on the effect of fire on the savanna woodland system, the submodels concerning fire are considerably more detailed than other sections. Any necessary extensions, such as species-specific considerations, could be appended to, or incorporated in, the model as they are required.

The construction of an HTML model may be simplified by defining a document template that provides the basic table structure. Such a template will have the added advantage of supporting layout consistency. Development of a central style sheet that defines text and general display attributes may further promote consistency.

In order for the model to adhere to its original objective, to provide an overview of the ecological interactions and not to become too detailed as to become widely applicable, the information has been limited, although numerous examples are provided in the text. More detailed information on the various factors has been documented in the past. The impact of fire on savanna woodlands has been dealt with by von Breitenbach (1968), Rutherford (1981), and Jankowitz (1983). Grazing is discussed in more detail by Savory and Butterfield (1999) and Tainton (1999).

HTML provides an effective method for storing information that cannot be structured into a tabular format: hyperlinks may be maintained between different parts of the data, permitting feedback loops. Where communication technology and browser software permit HTML, JavaScript, Java, and XML may provide additional tools in structuring knowledge and making it readily accessible to a wide variety of users.

Responses to this article can be read online at:
http://www.consecol.org/vol7/iss1/art9/responses/index.html

Appendix 1. Dry Savanna Woodland Ecology.

To view the model, please go to http://www.consecol.org/vol7/iss1/art9/append1.html.

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