ELSEVIER

Computers and Electronics in Agriculture
27 (2000) 155–165

Computers and electronics in agriculture

www.elsevier.com/locate/compag

Elicitation and representation of Traditional Ecological Knowledge, for use in forest management

Alan J. Thomson *

Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC, Canada V8S 4N4

Abstract

Canadian aboriginal (First Nations) groups wish not only to preserve their heritage, but also to see that heritage given its proper place in decisions that affect the land. Each community is unique in the diversity of problems and concerns that it faces. Modern knowledge-based systems permit customized solutions to complex issues, but there is currently no good method of representing traditional knowledge in the computer, in a way that helps the needs of communities to be individually addressed. Most traditional knowledge information is presented in anecdotal form and is therefore difficult to classify and analyze. Elicitation, representation and use of knowledge is a major area of research in the field of Artificial Intelligence, leading to development of knowledge bases and expert systems. The present study describes the elicitation and representation of the traditional knowledge from bands belonging to the Nicola Tribal Association in British Columbia. The study aims at representing the interaction of community and environment in a manner that can be used to show the differences among communities. This paper focuses on the relationship of the traditional knowledge to modern forest management. Crown Copyright © 2000 Published by Elsevier Science B.V. All rights reserved.

Keywords: Indigenous knowledge; TEK; Database; World Wide Web; Inferences; Adaptive Environmental Management

* Tel.: +1-250-3630632; fax: +1-250-3630775.
E-mail address: athomson@pfc.forestry.ca (A.J. Thomson)

PII: S0168-1699(00)00103-4

1. Introduction

Modern forest management aims to include social, cultural and spiritual values, although in practice full inclusion is rare. At the same time, First Nations groups (Canadian status and non-status aboriginal peoples, Metis and Inuit) wish not only to preserve their heritage, but also to see that heritage given its proper place in decisions that affect the land. A recent article by Brian Savage in the Western Native News (Savage, 1997), titled 'Wendy Grant-John, candidate for AFN grand Chief' describes some of the difficulties encountered in this process. The article indicated that a central problem for government officials is the incredible diversity of issues that each Native band faces across the country, and suggested that customized programs for each community were required.

Societies change, constantly adopting new technologies and practices. The term 'Indigenous ecological knowledge' captures the idea of a system of knowledge and beliefs being applied by native peoples to present conditions in the same manner as to the past. Indeed, the term 'Indigenous knowledge of the land' best captures the holistic views of native peoples (Berkes, 1993; Stevenson, 1996, 1997). However, the term 'Traditional Ecological Knowledge' (TEK) or TK is more widely recognized, and is the term often used in Canadian Government policy statements, so will be used in this study with the proviso that it includes modern knowledge.

Many Canadian First Nations communities have activities that depend on, or are affected by, forest management. Forest management is based to a great extent on analysis of information stored in computers, but there is currently no good method of representing traditional knowledge in the computer, in a way that helps the needs of communities to be individually addressed. For example, studies of traditional knowledge among the Dene of the Northwest Territories are described in the reports of the Dene Cultural Institute, which indicate that "Most traditional knowledge information is presented in anecdotal form and is therefore difficult to classify and analyze. Often people will discuss several different subjects in answer to one question. Because the information is often difficult to separate without taking it out of context it is necessary to develop some system of cross-referencing for any system of data classification. At the time of writing this document no computerized system of data management was in use for our Ft. Good Hope project."[1]

Elicitation, representation and use of knowledge is a major area of research in the field of Artificial Intelligence (AI), leading to development of knowledge bases and expert systems. A range of AI approaches have been proposed as possible ways of representing the interaction of community and environment in a manner that can be used to show the differences among communities (Thomson, 1993, 1996, 1997; Akenhead et al., 1996). AI methods for representing different codes of environmental ethics and for storage and analysis of anecdotal information were included in these proposals.

[1] Dene Cultural Institute web site: http://vcn.bc.ca/wcel/otherpub/fearo/5157.html

Traditional Ecological Knowledge, as an area of study, initially involved the eliciting and analyzing of the terminologies by which people in different cultures classify the objects in their natural and social environments. In recent years, the emphasis has changed from such classification-oriented studies to focus on understanding the ecologically sound practices that contribute to sustainable resource use among indigenous peoples. These new studies lead to a better understanding of the relationship of First Nations communities with the land. TEK is accumulated over generations and passed on by word of mouth and by direct experience (Dene Cultural Institute, 1994).

Canadian federal and provincial legislation and policies requiring consideration of TEK in resource management provided the impetus for the present study of the elicitation and representation of TEK in relation to forest management. In this study, the use of database and World Wide Web technologies are used to show the flow of knowledge from the interview question, through the set of answers to a question and the inferences drawn from the answers, to the link between the inferences and resource management.

2. Elicitation of TEK

In the summer of 1997, a project was initiated on elicitation, representation and use of Traditional Ecological Knowledge for landscape management, to bring modern AI Approaches to bear on this issue. The project was set up in collaboration with the Nicola Tribal Association in Merritt, BC, and with the involvement of the Nicola Valley Institute of Technology (NVIT) (a First Nations College). Fifteen members of five bands in the area were involved: Coldwater, Upper Nicola, Lower Nicola, Nooaitch and Shackan.

Tape recording of structured interviews (Johnson, 1992; TEK web sites[2]) was the basic knowledge elicitation technique of the project, which was conducted under ethical principles for research in the North described in these references. An initial question set was developed based on issues described in the literature, and then the questions were rephrased using appropriate language and concepts. The questions were grouped in several areas: Community, Hunting, Gathering, Learning and Project. Use of appropriate language is critical in knowledge acquisition (Benfer and Furbee, 1990).

As an example of the rephrasing, one of the questions in the Community section was originally 'How do you judge the health and well-being of your community? How important are resource indicators?' This was changed to 'How do you judge the health and well-being of your community? What things that you see on the land affect that judgment?' The change was in relation to the holistic view of the whole environment that was held by members of the Nicola Tribal Association, in comparison with the reductionist approach of western science that separates the

[2] TEK web sites: http://vcn.bc.ca/wcel/otherpub/fearo/5157.html; http://arcticculture.miningco.com/msub9.htm

landscape into components such as 'forest'. In addition, there were exploitative connotations of the term 'resource'. As suggested in the literature, direct questions about levels of hunting or gathering were avoided, as the interview subjects could be apprehensive about government monitoring or unwilling to be perceived as boastful. In addition, a series of photographs of a variety of landscapes were taken in the area, and subjects asked to comment on what they liked or disliked in each scene.

Interview subjects were suggested by the staff of the Nicola Tribal Association office, and by staff of the band offices participating in the project. Subjects were paid an honorarium at a rate established by the association that took into account the subject's status as an elder. At preliminary meetings, the purpose of the project was discussed, and a copy of the question set supplied so that the subject could obtain any translation required, decide on which questions they were willing to address, and formulate their responses. At a subsequent interview, their responses to specific questions were recorded, as well as their responses to additional questions asked by the interviewer in relation to the content of the material provided.

3. The interview database

The interviews were initially transcribed as Microsoft (MS) Word files. To facilitate their inclusion in a MS Access database, they were first converted into ASCII text files, and a MS Word Macro created to structure them in an appropriate format. The desired format of the interview table included four fields: a name field (the initials of the interview subject); a code number indicating the question (e.g. H01 — the first question in the hunting set of questions); a line number; and the answer itself. As the limit of a text field in MS Access is 256 characters, the MS Word Macro split the answers into separate records at the closest word boundary before 256 characters, and incremented a line counter for that answer. The Macro also prompted for the question code to insert. The name, question code, line number and current line of the answer were delimited with tabs, facilitating their import into an MS Access table. A convention was adopted to deal with the supplementary questions asked by the interviewer (Fig. 1). Another table in the database linked codes with specific questions (Fig. 2). Other tables included literature citations, inferences, images, and links to literature summaries; however, these tables will be discussed in relation to the World Wide Web implementation of the system[3].

4. Linking the database to the World Wide Web

The first stage in making the TEK database available on the web was to register

[3] http://www.pfc.cfs.nrcan.gc.ca/main/programs/fnfp/tek/index.html

it in the ODBC (Open Database Connectivity) system. Once registered, Java programs were created to send SQL queries to the database and format the result set into HTML code. The Java code writes new web pages in response to specific queries, such as providing a list of all the questions and their codes (Fig. 3). A radio button associated with the question permits display of the range of responses to a

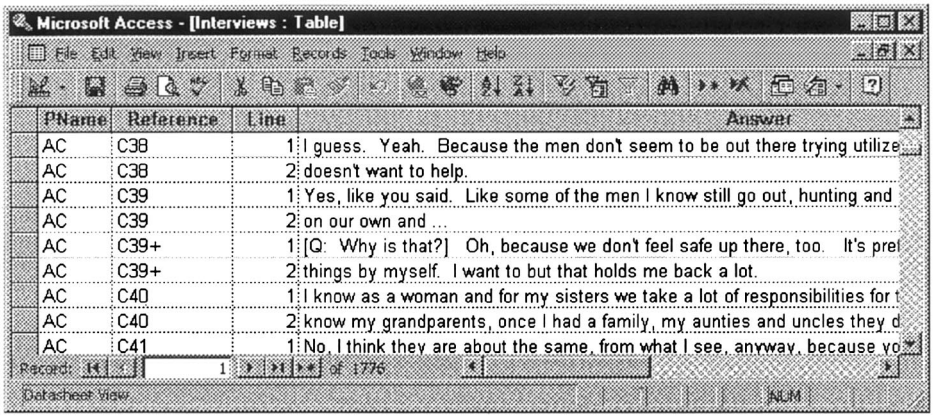

Fig. 1. The Interview Table from the MS Access database, illustrating the convention adopted to deal with supplementary questions. Such questions were indicated using the Code for the preceding question with a suffix of '+' for a single supplementary question, or '+a', '+b'... for a series of supplementary questions. The supplementary questions themselves were included in the answer field delimited by '[]'.

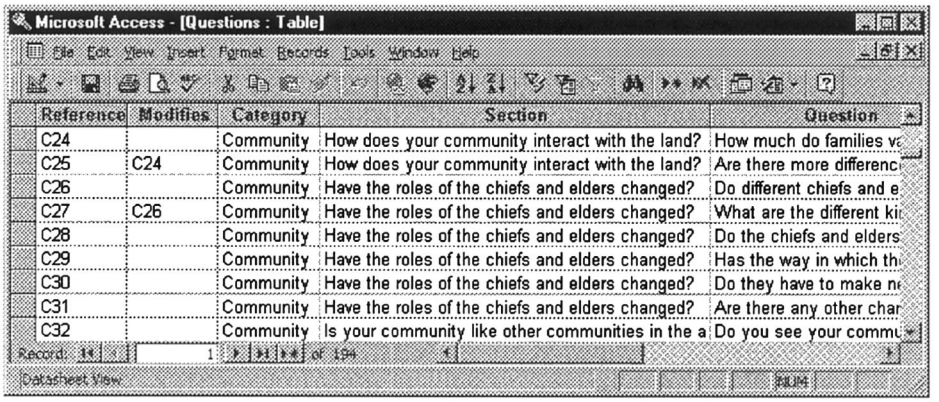

Fig. 2. The Question Table from the MS Access database, showing the linkage between the Question reference code and the question itself. Questions were grouped into Categories and Sections. Some questions specifically modified a preceding question, and this relationship was indicated in the 'Modifies' field.

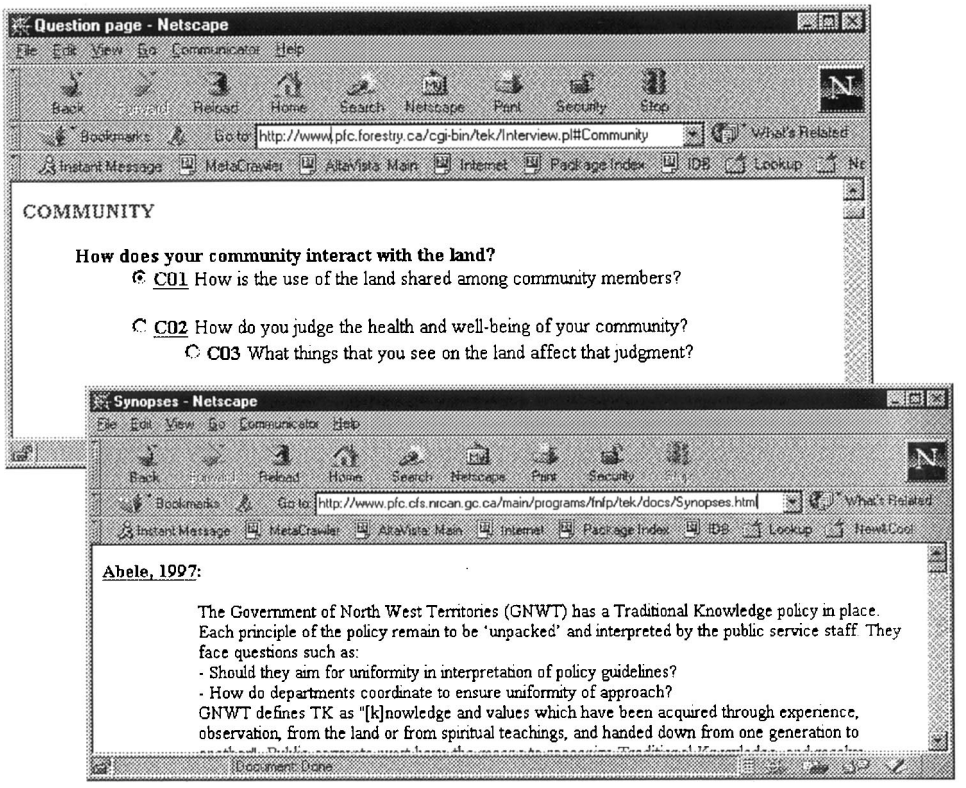

Fig. 3. The World Wide Web representation of the Question Table, showing the categorization of questions, and using indenting to illustrate the 'Modifies' relationship. The Question reference code is a link to a synopsis of published material (inset), which in turn would have a link from the author's name to the full citation. The radio buttons are used to select specific questions to obtain the range of responses.

particular question (Fig. 4). A number of questions related to changes in access to areas, as a major highway had recently been constructed through the area, which had previously been relatively remote.

Use of knowledge-based systems in relation to effects of events such as road construction on communities is discussed by Thomson (1996) (Table 1). Qualitative reasoning using such a system can show the range of potential outcomes, while the specific outcome will depend on the balance of the actual values of the elements of the system. The example of Table 1 is geared towards third world situations, and many aspects are not relevant to the Nicola Tribal Association system; thus, the inferences from the interview responses are not currently expressed in terms of this type of cause and effect network. At present, the inferences are simply expressed in text form (Fig. 5). A full qualitative reasoning system for web-based knowledge delivery is currently under investigation.

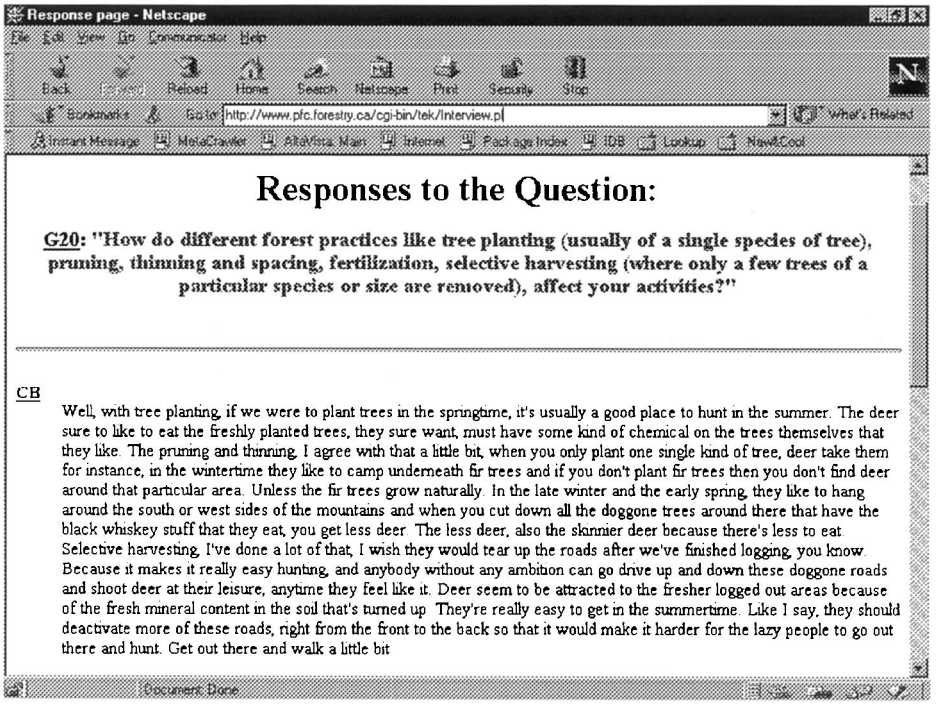

Fig. 4. The responses to Question G20: 'How do different forest practices like tree planting (usually of a single species of tree), pruning, thinning and spacing, fertilization, selective harvesting (where only a few trees of a particular species or size are removed), affect your activities?' The responses of each interview subject who answered that particular question are indicated by the subject's initials, which provide links to the inferences drawn from the response. The Question reference code is a link that lists all inferences drawn from responses to that question.

Adaptive Environmental Management (AEM) is a process that uses management interventions to probe the functioning of ecosystems (Holling, 1978; Walters, 1986; Thomson, 2000). Potential actions and indicators of performance are selected based on their ability to differentiate among hypotheses concerning uncertainties about the systems being managed. As AEM is being widely adopted in North America (McDonald, 1988; Anonymous, 1993), including First Nations studies, the consequences that result from a particular inference are therefore expressed as a set of actions and indicators. For example, one inference from the response of subject CB to question G20 was 'Roads constructed for selective logging permit easy access for lazy hunters' (Fig. 5). Actions could include road deactivation or locked gates, while indicators could include deer population changes and numbers of hunters using the area (Fig. 6). At present, this is the limit of the knowledge base. Future developments will link actions and indicators to related web pages. For example, the action 'Road deactivation' could link to the web page describing this activity under the BC Forest Practices Code[4]. This link need not be to a single document,

[4] http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/fordev/fdps16.htm

Table 1
Example of knowledge base constructed from the information in pages 1–25 of Blaikie et al. (1994)[a]

effect('road network',+,'urban diseases',+,1,16)
effect('urban diseases',+,'disaster vulnerability',+,1,16)
effect('road network',+,'access to clinics',+,1,16)
effect('access to clinics',+,'urban diseases',−,1,16)
effect('urban diseases',−,'disaster vulnerability',−,1,16)

effect('road network',+,'arable land',−,1,16)
effect('arable land',−,'famine vulnerability',+,1,16)
effect('road network',+,'access to food sources',+,1,16)
effect('access to food sources',+,'famine vulnerability',−,1,16)
effect('famine vulnerability',−,'disaster vulnerability',−,1,16)

effect('road network',+,'drift to cities',+,1,16)
effect('drift to cities',+,'local labor',−,1,16)
effect('local labor',−,'crop yield',−,1,16)
effect('crop yield',−,'famine vulnerability',+,1,16)
effect('local labor',−,'building maintenance',−,1,16)
effect('building maintenance',−,'earthquake vulnerability',+,1,16)
effect('local labor',−,erosion,+,1,16)
effect(erosion,+,'famine vulnerability',+,1,16)

effect('drift to cities',+,migration,+,1,16)
effect(migration,+,'local institutions',−,1,25)
effect(migration,+,'local knowledge',−,1,25)
effect('local knowledge',+,'familiarity with land',+,1,25)
effect('familiarity with land',−,income,−,1,17)
effect('familiarity with land',−,nutrition,−,1,17)
effect(nutrition,−,malnourishment,+,1,24)
effect(malnourishment,+,'disaster vulnerability',+,1,24)

[a] After Thomson (1996). The facts are in a form which could be understood by the AI language, prolog. Facts have the form: effect(Cause, Cause_direction, Effect, Effect_direction, Reference_code, Page), where Cause is the causal factor, and Effect is the effect of changing the causal factor in a particular direction. Both Cause_direction and Effect_direction have values of '+' or '−', indicating an increase or decrease. Reference_code is a numeric index to the publication from which the knowledge was inferred, with Page being the specific page reference.

but to a new page specifically constructed from entries in the knowledge base, providing multiple sources of information on that action or indicator.

Comments on the series of photographs were included in the same manner as responses to questions, except that a picture reference number was used in place of the question reference code.

5. Discussion

A system has been developed to store anecdotal information on Traditional Knowledge in a database in a manner that facilitates the organization and browsing of the knowledge over the World Wide Web. The system operates through Java

programs sending SQL queries to a Microsoft Access database through the ODBC, and formatting the result set into HTML code.

The knowledge is organized around a set of questions that were used in structured interviews. This approach generated a good set of responses, as the subjects were provided with the questions ahead of time, giving them time to formulate responses. However, the interview format did permit pursuit of ancillary questions. Responses to a question tended to be relatively brief, consisting of a few sentences, but on occasion a question or photograph triggered a longer comment, sometimes in the form of a story. Stories were recorded under a separate category in the database.

Future development of the system will permit association of an inference with a particular line number of a story, if required. However, there would be no specific question to associate that knowledge with; thus such a system would require entry of a knowledge category. This would be a subjective association, rather than the objective association of a response with a question.

While considerable care was taken over the wording of the questions, that does not ensure that the knowledge elicited will be of the expected nature, due to differences between western science, which is reductionist, based on cause and effect

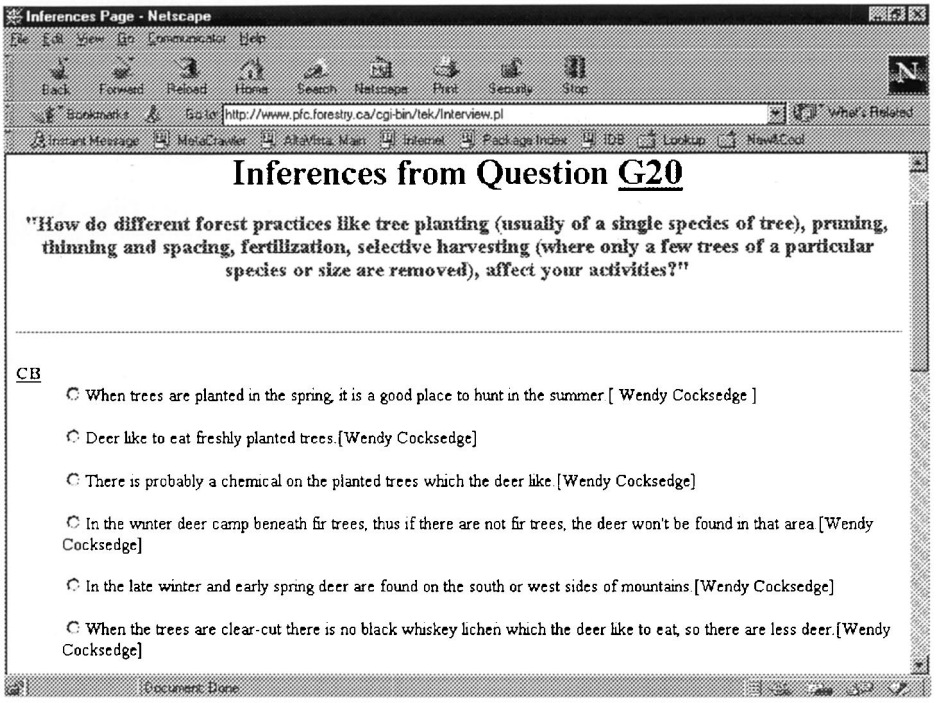

Fig. 5. Inferences drawn from the response of one interview subject (CB) to a particular question (G20). The question code is a link back to the specific response (Fig. 4), while the radio button permits selection of the consequences attached to that inference (Fig. 6).

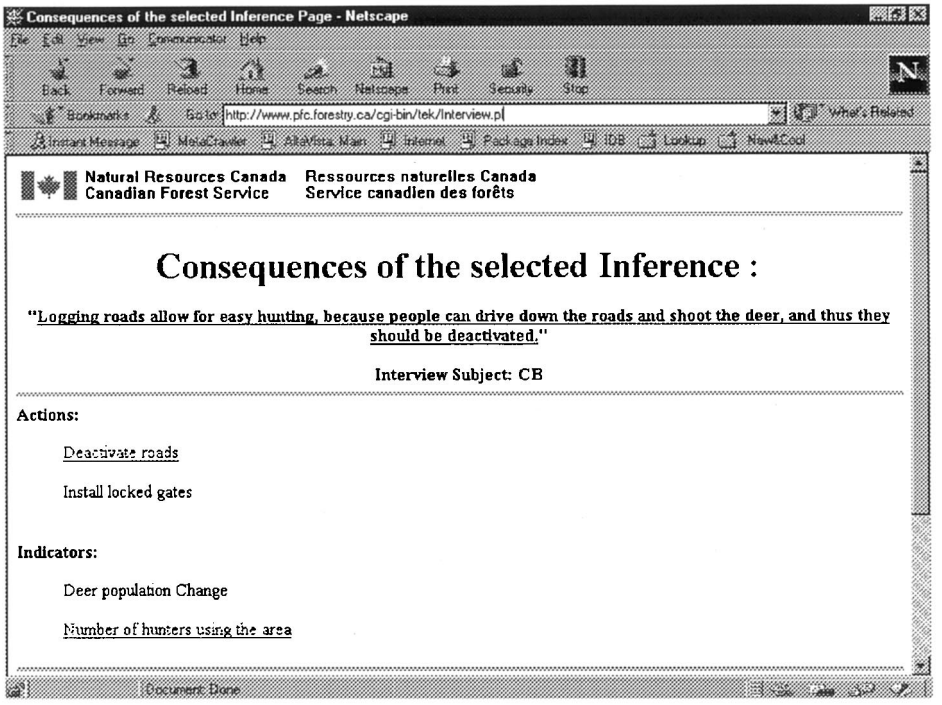

Fig. 6. Consequences of the inference 'Roads constructed for selective logging permit easy access for lazy hunters', based on the response of subject CB to question G20. The inference provides a link back to the initial response.

relationships, and TEK which is based on a holistic, experiential approach (Ross, 1992, p. 51).

The question set used covered a very diverse subject matter area, and the interview format allowed subjects to select the questions they wished to answer; thus, some questions were not answered by any subject, while others had few responses, limiting the utility of the present knowledge base. However, the present study demonstrates the feasibility of developing a database system that can manage the TEK content of anecdotal information, and can easily be expanded to new situations.

Acknowledgements

The assistance of Harold Aljam and Mandy Jimmie of the Nicola Tribal Association and Sharon McIvor of the Nicola Valley Institute of Technology in setting up the project, and refining the questions, is gratefully acknowledged. The interview skills of Holly Meuse contributed greatly to the success of the process. I wish to thank the members of the Coldwater, Upper Nicola, Lower Nicola, Nooaitch and Shackan bands who shared their knowledge with us.

References

Akenhead, S.A., Thomson, A.J., Morgan, D., Adams, B., Strome, W.M., 1996. Planning sustainable forestry when there are complicated rules and many stakeholders. Proc. Eco-Informa '96, Lake Buena Vista, FL, 4–7 November, 1996, pp. 399–404.

Anonymous, 1993. An assessment of Indian Forests and Forest Management in the United States. Indian Forest Management Assessment Team for the Intertribal Timber Council.

Benfer, R.A., Furbee, L., 1990. Knowledge acquisition: lessons from anthropology. AI Appl. 4 (3), 19–26.

Berkes, F., 1993. Traditional knowledge in perspective. In: Inglis, J.T. (Ed.), Traditional Ecological Knowledge: Concepts and Cases. International Development Research Centre, pp. 1–10.

Blaikie, P, Cannon, T., Davis, I., Wisner, B., 1994. At Risk. Natural Hazards, People's Vulnerability, and Disasters. Routledge, London, p. 284.

Dene Cultural Institute, 1994. Traditional Ecological Knowledge and Environmental Assessment. In: Sadler, B., Boothroyd, P. (Eds.), Traditional Ecological Knowledge and Modern Environmental Assessment. Canadian Environmental Assessment Agency, pp. 5–19.

Holling, C.S., 1978. Adaptive Environmental Assessment and Management. Wiley, London.

Johnson, M. (Ed.), 1992. Lore: Capturing Traditional Environmental Knowledge. Dene Cultural Institute and International Development Research Centre.

McDonald, M., 1988. An overview of adaptive management of renewable resources. In: Freeman, M.M.R., Carbyn, L.N. (Eds.), Traditional knowledge and renewable resource management in northern regions. IUCN Commission on Ecology and Boreal Institute for Northern Studies. Occasional Publication No. 23, pp. 65–71.

Ross, R., 1992. Dancing with a Ghost: Exploring Indian Reality. Reed, Canada.

Savage, B., 1997. Wendy Grant-John, candidate for AFN grand Chief. Western Native News, July 1997.

Stevenson, M.G., 1996. Indigenous knowledge in environmental assessment. Arctic 49, 278–291.

Stevenson, M.G., 1997. Ignorance and prejudice threaten environmental assessment. Policy Options 18 (2), 25–28.

Thomson, A.J., 1993. Paradigm Green: AI approaches to evaluating the economic consequences of changing environmental viewpoints. AI Appl. 7 (4), 61–68.

Thomson, A.J., 1996. Asimov's psychohistory: vision of the future or present reality? AI Appl. 10 (3), 1–8.

Thomson, A.J., 1997. Artificial intelligence and environmental ethics. AI Appl. 11 (1), 69–73.

Thomson, A.J., 2000. Distributed development of Adaptive Environmental Management DSS using Java applets interacting over the World Wide Web. Comput. Electron. Agric., in press.

Walters, C.J., 1986. Adaptive management of renewable resources. Macmillan, New York.