FINAL REPORT

A knowledge-based systems approach to interdisciplinary research on tree fodder

DFID Forestry Research Programme
Project R 6322

Fergus L. Sinclair, Laxman Joshi, James Doores, Balaram Thapa, Daniel H. Walker and David A. Randell

CONTENTS

1. EXECUTIVE SUMMARY

This document is the final report of the UK Department for International Development (DFID), Forestry Research Programme (FRP) Project R6322 'A knowledge-based systems approach to interdisciplinary research on tree fodder'. This report explains how the project objectives were achieved. Outputs from the project are appended as separate documents and the WinAKT software system is accessible via the internet.

The research aimed to improve the productivity and sustainability of on-farm tree fodder production in the mid-hills of Nepal by developing and using knowledge-based systems that integrate farmers' and researchers' knowledge. A pilot phase project (R5470) had identified that the planning of research at frontline agricultural research centres could be made more relevant to farmer's needs and circumstances by collation and analysis of what farmers and scientists already knew. Previous research (R4731) had shown that farmers in one village in the mid-hills had sophisticated knowledge about ecological processes, largely complementary to scientific knowledge, and that this could be acquired using knowledge-based systems methods. The research in the present project aimed to extend this approach to encompass the entire command area of a research centre (Pakhribas Agricultural Centre, PAC) and to develop specifications and tools for using the knowledge that was collected in planning interdisciplinary research and extension at an institutional level.

Methodological development was, therefore, required to cope with two major extensions of scope:

- acquisition of knowledge from multiple as opposed to single communities, and
- use of knowledge by a large and dispersed group of researchers across the whole of an institute as opposed to a close nit group within a specific project.

Implementation of software in a Windows environment was also required (the original AKT software had been developed on a MacIntosh platform), together with development of specifications for the use of formal reasoning in planning research and extension activity and implementation and testing of tools to achieve this. The project also involved evaluation of using a knowledge based systems approach, both in terms of:

- impact on how research was planned at centres where the approach was tried out, and
- the potential for wider dissemination of the approach through exposure to a wide audience of people working directly in rural development at a national workshop.

The project objectives were fully achieved and a great deal of enthusiasm expressed from research and development workers in governmental and non-governmental organisations in using a knowledge based systems approach to make better use of information which they were generating through interaction with rural people as a result of employing participatory methods. They also recommended further development of formal methods to incorporate socio-economic information.

Knowledge acquisition from multiple communities

Knowledge about tree fodder resources was evaluated by interviewing 220 farmers across four contrasting locations in the eastern mid-hills, representing the range of farming practice in the PAC command area. Recommendations on how to acquire knowledge to be used as a basis for designing research at an institutional-level, based on a characterisation of the distribution of knowledge across the client base were developed and principles of more general applicability for knowledge acquisition about agroforestry from resource-poor farmers drawn up (Joshi and Sinclair, 1997). These incorporate a focus on one site with high dependence on the resources under study in the early phases of knowledge acquisition to create a template which is then generalised across sites with a full range of resource dependency. Methods of group interview have also been developed, with group structures reflecting gender and extroversion to improve gender sensitivity in knowledge acquisition and the efficiency of conflict resolution.

Development of knowledge based systems software

Knowledge-based systems software and methodology (WinAKT) for use at an institutional level, was developed and used at PAC. It includes basic functionality for acquisition and reasoning with multiple knowledge bases in a Windows environment (Randell and Sinclair, 1997). In addition to being used at PAC, it has also been picked up by international centres (ICRAF and ICIMOD) and staff from a range of organisations in Nepal have expressed interest in using it in their work, including: NGOs (CARE, Action Aid and LI-BIRD); national agricultural and forest services (Nepal Agricultural Research Council, Department of Forestry and district Forest Offices, Department of Soil Conservation and the Forest Research and Survey Centre); other development projects and institutions (Nepal-Australia Community Resource Management Project, Institute of Forestry and Lumle Agricultural Research Centre).

Development of formal reasoning tools

The potential for using automated reasoning in planning research and extension was demonstrated and tools developed that can be used for this purpose. Some of these tools are generic and could be used on any knowledge base while others were specific to the example domain (fodder trees on farmland in the mid-hills of Nepal). It was shown that while formal reasoning procedures can assist research and extension workers in making full use of formally recorded knowledge in planning their activities, they provide elements of decision support and do not substitute for human judgement.

Automated reasoning across a formal knowledge base was found to be useful at three stages of the research planning process:

- identification of constraints
- considering what is already known; and

- exploring possible consequences of research and testing hypotheses on the basis of what is already known.

Examples of tools that use formal reasoning to assist researchers in exploring formal knowledge bases to achieve these tasks were developed. Assistance in identifying constraints was achieved by comparison of local knowledge and practice and by finding gaps in knowledge. Existing knowledge was successfully evaluated by using combinations of tools that allow the user to explore the consequences of various management actions (such as tree lopping) and the causes of particular processes or events (such as high levels of soil erosion). Hypotheses could be tested by marshalling what information was available from a knowledge base to support and/or refute explorative assertions made by the user.

Formal reasoning was also useful in the production of extension material. Information appropriate for dissemination to particular groups of people was identified by comparing knowledge from farmers, researchers and extension workers and so revealing items of knowledge that could usefully be communicated amongst these groups. Information on particular topics (such as a particular tree species) could then be automatically compiled. These tools can either be used dynamically by people interrogating a knowledge base for information on topics of interest or as a basis for developing paper-based extension materials for wider dissemination.

Development and use of knowledge bases

A set of accessible knowledge bases representing, at an institutional level, an explicit and accessible record of farmers' and researchers' knowledge on key aspects of tree-fodder resources covering the PAC command area was produced by Laxman Joshi as an integral part of the present project. New knowledge bases on soil fertility and grain losses caused by weevil infestation, stimulated by project activity but created independently by other researchers at PAC were used in the preparation of project concept notes for HARP (Hill Agricultural Research Programme) that have subsequently been approved for funding. ICRAF in Indonesia have also, independently, used the software to develop a knowledge base on damar forest gardens which has led to a collaborative project proposal on incorporating local and scientific knowledge in developing improvement paths for rubber agroforests in Sumatra. The Nepalese NGO, LI-BIRD, have incorporated use of the WinAKT software into a new project on organic fertilizers in the terai and are creating a local knowledge base on green manure. HARP have funded a new participatory maize breeding project at PAC which includes development of a knowledge base containing farmers' knowledge about local maize varieties and their response to shade.

Impact of using knowledge based systems

Formal evaluation of using a knowledge based systems approach to plan research at PAC in the eastern mid-hills and Lumle Agricultural Research Centre (LARC) in the western development region, revealed that researcher's knowledge of the topics they were working on was enhanced, and the processes they went through in planning and prioritising research areas were significantly altered, through use of knowledge based

systems. The final project workshop, jointly organised with CARE and ICIMOD (see attached report), involved 22 participants from a range of government and non-governmental organisations who recommended use of the software and methodology at an institutional level in their own organisations and the setting up of a network of users in Nepal.

The project has demonstrated that systematic acquisition and use of local ecological knowledge is both possible and desirable in planning NR research for resource-poor farmers and leads to significant change in the research agenda. This requires commitment and investment at an institutional level which has policy implications for the institutions involved. Tools and methods to acquire local ecological knowledge from multiple communities and use it in planning interdisciplinary research have been produced. There is now a demand for an extension of these methods to more fully embrace socio-economic information.

2. BACKGROUND

This research aimed to develop methods for acquiring knowledge from a dispersed farming population and use it in planning interdisciplinary research. The research used fodder trees on farmland in the mid-hills of Nepal as an appropriate case study domain because it in involved a mixture of scientific disciplines (forestry, animal science and agronomy) and the hillside farming systems of Nepal are a suitable testbed for such methods since they are both ethnically and agroecologically diverse and involve resource-poor farmers with a sophisticated locally derived understanding of the role of trees in their farming system.

2.1 Problem context

Livestock play a critical role in crop cultivation and sustaining soil fertility in the farming systems in the mid-hills of eastern Nepal and are fed during the dry season on tree fodder (Figure 2.1). Land fragmentation with consequent decrease in the size of farm holdings combined with decreasing access to dwindling common property forest resources is causing farmers to incorporate an increasing number of fodder trees on their farmland. The productivity of fodder trees is critical for maintaining livestock health and numbers and, therefore, the productivity and sustainability of people's livelihood system, but trees planted on crop terrace risers may also influence soil erosion through leaf drip effects and compete with staple food crops for light, water and nutrients. Farmers need, therefore, to achieve a balance between generating enough high quality fodder at appropriate times in the season with minimising the competitive effects of trees on staple food crops.

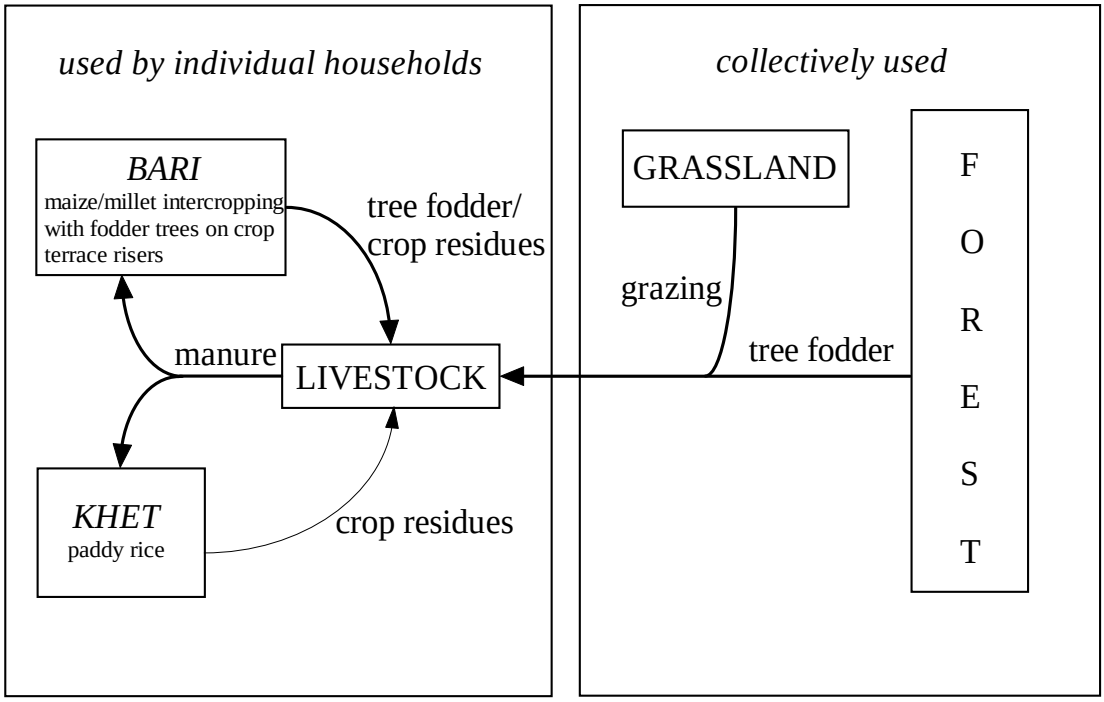

Figure 2.1. *The critical role of livestock in hillside farming systems in Nepal.* Bari *refers to upper slope rain-fed land and* khet *to lower slope irrigated land.*

It has already been established that farmers have a sophisticated understanding of how fodder quality varies between and within species and of above-ground interactive effects of trees on crops and soil. They are less knowledgeable about below-ground processes. Competitive tree species that are known to promote erosive effects are still cultivated on crop terrace risers because of the value of their fodder. Research, building on what farmers already know and on the germplasm with which they are familiar, and appropriately targeted at constraints imposed by lack of knowledge, could improve the productivity of fodder-tree/crop associations and, therefore, improve the productivity and sustainability of the farming system while reducing pressure on the residual forest resource. The ability to design interdisciplinary research on the basis of an evaluation of farmer's knowledge is critical to the production of adoptable research output from front-line agroforestry research institutions like PAC.

2.2 Previous research

Research in project R4731 demonstrated that farmers in Nepal (as well as in other places) possess detailed knowledge of ecological processes and of tree attributes that influence them and how these attributes vary amongst a large number of native species. Because natural language is imprecise, and a large part of communication during interviews with farmers involves implicit elements defined by the context of the discussion, recording the actual form of words used by people was found to be less important than confirming their precise underlying meaning. Developing an explicit and unambiguous record of local ecological knowledge is, therefore, critical to understanding and using that knowledge and it has been demonstrated that this can be effectively achieved at a project level using the proprietary knowledge based systems software and methodology AKT, developed during the R4731 project and now on general release (Walker *et al.*, 1994; Walker, Sinclair and Kendon, 1995). The software supports the use of a restricted syntax to represent knowledge diagrammatically and as unitary text statements that render the knowledge amenable to analysis using automated reasoning techniques. The software also incorporates a task language that allows users to specify automated reasoning procedures, rather like they might do a macro in a spreadsheet package (Kendon *et al.*, 1995).

Use of the AKT software and methodology in a detailed study of the ecological knowledge held in one Village Development Committee in Nepal led to the acquisition of sophisticated knowledge about tree fodder quality and tree-crop interactions (Thapa, 1994; Thapa, Sinclair and Walker, 1995; Thapa, Walker and Sinclair, 1997), much of which was previously unknown to researchers at PAC and the scientific community more generally. Furthermore, analysis of information flows at PAC during the R5470 pilot phase, revealed that research was also constrained by insufficient access to previous research findings while new research was being planned. In this context it was suggested that an explicit statement of what new knowledge specific research activities were expected to create, could facilitate monitoring and that subsequent explicit documentation of what new knowledge they did create, could facilitate evaluation and subsequent use of research output (Sinclair *et al.*, 1993).

2.3 Present objective

In practice, PAC as an established centre of excellence in agricultural research in Nepal, with links with many other institutions, has a significant and growing corporate knowledge about farming systems of the mid hills of eastern Nepal. However, this is held in both documented and undocumented forms and is dispersed across a number of physical locations and amongst a large and impermanent staff. The present need, therefore, is to develop a means of maintaining a corporate body of knowledge on interdisciplinary, problem-oriented research topics, that combines farmers' and researchers' knowledge, can be readily updated and can be accessed during the planning, monitoring and evaluation of research activity. While it has been shown that knowledge can be acquired from farmers and researchers appropriate to this task at a project level, with respect to a well-defined and limited geographical range and subject domain, using the AKT knowledge based systems approach (Thapa, 1994); extension of the approach and software to an institutional level so that a number of interacting knowledge bases, relevant to the entire command area of PAC can be created, maintained and used, required further adaptive research that was the subject of the present project.

3. SUMMARY OF WORK CARRIED OUT

The aim of this section is to give an overview of the work that was done during the project without repeating the next section that explains how this contributed to achievement of the project objectives (the outputs).

The project involved two major strands of work (Table 3.1). The first of these was specification, use and evaluation of knowledge-based systems software in planning research and extension at PAC which was done principally by the PAC collaborator Laxman Joshi (LJ) whose attachment to the project as a postgraduate study fellow was funded bilaterally through SEADD. The second strand, which involved implementation of specifications in development of the WinAKT software system was done by knowledge engineers working largely at Bangor: initially Dr David Randell (DAR) who was replaced by Jim Doores (JD) in the second half of 1997.

The first strand involved seven principal stages:

i) training of the PAC collaborator (LJ) in knowledge based systems methods,

ii) rationalisation and re-implementation of the Solma knowledge base (originally created by BT in R4731) at PAC, in the light of enhancements to the WinAKT software and methodology,

iii) definition of the extrapolatable domain of the Solma knowledge base across the command area of PAC and development of guidelines for acquiring knowledge from multiple communities,

iv) development of specifications for the use of automated reasoning procedures in planning interdisciplinary research,

v) training of researchers at PAC in knowledge based systems methods and development and use of knowledge bases in planning research at PAC,

vi) evaluation of using knowledge bases in planning research at PAC and LARC,

vii) evaluation and dissemination of knowledge-based systems methods amongst development organisations in Nepal through a participatory workshop.

In addition LJ committed himself beyond the project life to continuing to support a network of knowledge based systems users in Nepal and training PAC staff prior to his anticipated departure from the institute in June 1998. Software implementation was responsive to the changing specifications developed in Nepal through experience of using the system. Latterly, the independent use of the software by ICRAF in Indonesia also provided useful feedback leading to refinement of the software.

Consultant advice on the development of the WinAKT software and methodology was provided by Dr Daniel Walker (DHW) of CSIRO, who attended the first two annual evaluations, CSIRO also produced a prototype version of diagramming interface for the WinAKT software.

Consultant advice on the use and adoption of knowledge based systems methods by research and development organisations in Nepal was provided by Dr Balaram Thapa (BT) of CARE International. Dr Thapa took part in the first and second annual evaluations of progress, was the local supervisor for LJ's PhD work and was instrumental in the organisation of the final workshop which was run jointly by PAC, CARE and ICIMOD.

Table 3.1 Chronology of project activities. Abbreviations of staff names are explained in the text.

Time	Nepal	UK
April '95		Training of PAC study fellow (LJ) in knowledge based systems methods
		Development of initial specifications for software system (LJ, DAR, FLS)
Jul;y '95	Rationalisation and re-implementation of Solma tree fodder knowledge base, including fieldwork in Solma (LJ).	Implementation of software specifications (DAR)
March '96	First annual evaluation of progress at PAC (FLS, BT, DHW, DAR and LJ): modification of software specifications.	
April '96	Fieldwork across PAC command area to explore the extrapolatable domain of the Solma knowledge bases (LJ).	Prototype version of WinAKT software in use. Implementation of modifications to software specifications (DAR)
July '96	Benchmark evaluation of researchers' knowledge and planning approaches at PAC and LARC (LJ).	
August '96	Development and use of knowledge bases by researchers at PAC	Interpretation and writing up of fieldwork: production of recommendations on knowledge acquisition from multiple communities (Joshi and Sinclair 1997).
March '97	Evaluation of change in researchers' knowledge and approach to planning research after exposure to knowledge based methods and resources (LJ, FLS)	Version 1.00 of WinAKT software available (Randell and Sinclair, 1997)
April '97	Second annual evaluation of progress at PAC (FLS, BT, DHW, DAR and LJ): development of new specifications for automated reasoning tools.	
May '97	Implementation and use of reasoning tools and new knowledge bases (on soil fertility and grain weevil control) at an institutional level at PAC	Modification and refinement of software system in line with requirements for formal reasoning tools - recruitment of JD (started June '97; DAR left Sept '97)
Oct '97	Continued use and development of knowledge bases at PAC	Interpretation and writing up of work on formal reasoning (Joshi and Sinclair '98a) and evaluation of impact of using knowledge based systems (Joshi and Sinclair '98b).
	Preparation of final workshop (BT)	
		Continued refinement of software (JD).
		Submission and successful examination of LJ's PhD thesis - *Incorporating farmers' knowledge in the planning of interdisciplinary research and extension*.
		Preparation of final workshop (LJ & FLS)
March '98	Final workshop on *the incorporation of local knowledge in rural development* - at Nagarkot, Nepal (FLS, BT & LJ).	Version 2.00 of WinAKT software available (JD).

4. ASSESSMENT OF RESEACH IN RELATION TO OBJECTIVES

The project objectives (the outputs), as they appear in Section 12 of the funding application for the project, are listed below as boxed text followed by a report of how each was achieved. The objectives are listed in reverse chronological order.

1.	A process for effective targeting of research and extension on tree fodder at PAC to the needs and circumstances of resource-poor farmers, resulting in appropriate and adoptable research outputs from PAC, will be developed and in operational use.

This was the overall objective of the project and was predicated on achieving all of the other objectives. We can be certain that it was achieved in as much as a knowledge-based systems approach is being used at PAC and an evaluation of its use has shown that it improves researchers knowledge of farmer's circumstances and changes the way in which they approach planning research (Joshi and Sinclair, 1998b). Post project evaluation would be required to ascertain whether research outputs are significantly different as a result of using knowledge-based systems methods and whether they are adopted by farmers and lead to improvement in rural livelihoods.

The major constraint to achieving the final deliverables at PAC itself was the institutional stability of the centre. The transition from direct DFID funding of PAC to its incorporation within the Nepal Agricultural Research Council was problematic with staff strikes and a very high staff turnover. This institutional instability threatened major assumptions in the logical framework (that staff at PAC would have resources to implement the knowledge-based systems approach and that those who were trained in using and developing knowledge bases would be retained for a sufficient length of time to do so, or to train the staff that replace them). It is difficult to predict the extent of disruption that will continue at PAC or the final state of the institution in terms of staffing and resources that will result. It is clear however that Dr Laxman Joshi, who has been the major collaborator from PAC on this project will not be eligible to join NARC (because a condition of entry is to have a first degree in agriculture) he has, however, arranged to run training workshops with staff prior to his departure (PAC becomes part of NARC in July) and to continue to support a network of knowledge based systems users in Nepal after leaving PAC. Continuity at PAC is evident in new projects on participatory maize breeding and grain weevil control that have used a knowledge based systems approach in their design and incorporate development of formal knowledge bases within their activities. These projects have been approved for funding through the new Hill Agricultural Research Programme (HARP). Wider dissemination to a range of organisations in Nepal and internationally has also been achieved and one of the recommendations of the final project workshop was to set up a network of users in Nepal (see 2 below).

The enthusiasm for using the software at PAC itself and in other organisations in Nepal and internationally has far exceeded our initial expectations. Supporting these institutions in using the approach and customising it to their requirements is a new challenge. There is certainly a strong demand for formal methods and tools for handling the copious amounts of qualitative information being generated through interactions with rural people in the course of participatory development.

The critical development required at PAC has been to balance institutional benefits of centralising information resources with that of individual researchers to develop and customise knowledge bases for their own use. This is not a trivial issue because knowledge bases are likely to interact (Figure 4.1) and for this to be effective there has to be some consistency in the use and ordering of terms amongst the knowledge bases. The solution is to have a centralised read-only resource at an institutional level with individual researchers customising versions of knowledge bases for their own use. The key to this working effectively, however, is a mechanism for updating the central record. This requires interdisciplinary co-operation and regular meetings of the people developing knowledge bases, with different subject foci and agreement on the structure of the central record. This has proved an effective forum for interdisciplinary communication. A central knowledge base manager is required who is able to develop and rationalise the central set of knowledge bases and tools to facilitate access to them. This person needs to have a reasonable computing background and familiarity with the software system thereby representing a significant institutional investment and there may be a heavy reliance on the individual concerned. Simplification of the user interface for the task language (see 3 below) would make this more easily attainable.

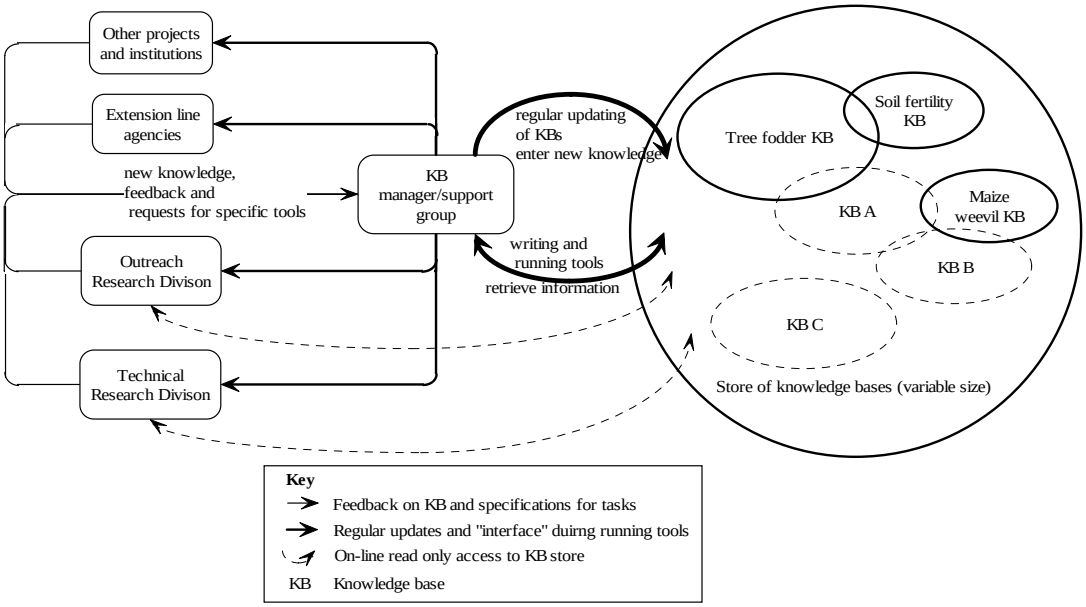

Figure 4.1 *Institutional organisation of knowledge bases at PAC.*

In terms of the use of formal methods of handling knowledge more generally in development organisations, the final project workshop recommended extending the approach to cope with economic and social information as well as the ecological knowledge that is its current focus. It was envisaged that a suite of tools, including other existing database and GIS software, could be used to integrate information resources more effectively within an institution and, therefore, make better use of what is available.

2. A proven knowledge-based systems software toolkit and methodology, developed and in operational use at an institutional-level at PAC, supporting the design and monitoring of interdisciplinary, problem-oriented research on the basis of an evaluation of what is known by farmers and researchers. This will also be applicable, with some customisation, to other institutions.

This objective was achieved at PAC despite considerable institutional disruption occasioned by the move from direct DFID funding to incorporation in the Nepal Agricultural Research Council (NARC) with project-based funding by competitive tender through the DFID Hill Agricultural Research Programme. The software is also already in use by other organisations in Nepal (the NGO, LI-BIRD) and internationally (ICRAF in Indonesia). Over 20 delegates at a national workshop to evaluate the methodology recommended using it in their own organisations and setting up a network of users in Nepal (see attached workshop report). These organisations include:

- **NGOs** - CARE, Action Aid and LI-BIRD
- **National agricultural and forest services** - Nepal Agricultural Research Council, Department of Forestry and District Forest Offices, Department of Soil Conservation and the Forest Research and Survey Centre, and
- **Other development projects and institutions** - Nepal-Australia Community Resource Management Project, Institute of Forestry and Lumle Agricultural Research Centre.

The software toolkit is fully implemented and in use at PAC. Version 1 of WinAKT with basic functionality for acquisition and reasoning with multiple knowledge bases in a Windows environment was documented and has been in use at PAC since 1996 (Randell and Sinclair, 1997). Enhancements have been made throughout the life of the project in response to feedback from users and Version 2.6 is now available on the internet. Use of the software in planning research and extension at PAC has been documented (Joshi and Sinclair, 1998a) and the use of knowledge-based systems methods has been evaluated at PAC and LARC (Joshi and Sinclair, 1998b).

3. Specifications for the use of automated reasoning techniques to assist in the evaluation of knowledge held by farmers, researchers and the scientific literature developed.

This objective was fully achieved, specifications were drawn up and then implemented using the WinAKT task language (Joshi and Sinclair, 1998a).

Previously, in project R4731, the need for automated reasoning to be customised by users was identified (Walker et al., 1995). This was because, while software engineers knew about what inference mechanisms could do, they did not know what particular mechanisms would be appropriate for people using local knowledge bases in support of research and extension in developing countries. Conversely, users in developing countries, unfamiliar with what was possible, could not specify what they wanted in terms of automated reasoning without familiarisation with what could be achieved. A customisable task language was created in the AKT software package on the MacIntosh platform to meet this need (Kendon et al., 1995). The task language was developed to enable users to design, construct and maintain their own inference engines for exploring knowledge bases created locally. Essentially, the task language

allows complex reasoning procedures to be accessed using simple sets of procedural commands, providing a service similar to the construction of macros in a commercial spreadsheet package. In this project a characterisation of where reasoning can assist in appraising knowledge bases when planning research and extension was produced and the task language, re-implemented for a Windows platform, used to illustrate this utility with respect to interdisciplinary knowledge about tree fodder.

The utility of automated reasoning across a formal knowledge base was found to be useful at three stages of the research planning process (Figure 4.2):

- identification of constraints
- considering what is already known; and
- exploring possible consequences of research and testing hypotheses on the basis of what is already known.

Examples of tools that use formal reasoning to assist researchers in exploring formal knowledge bases to achieve these tasks were implemented in the task language.

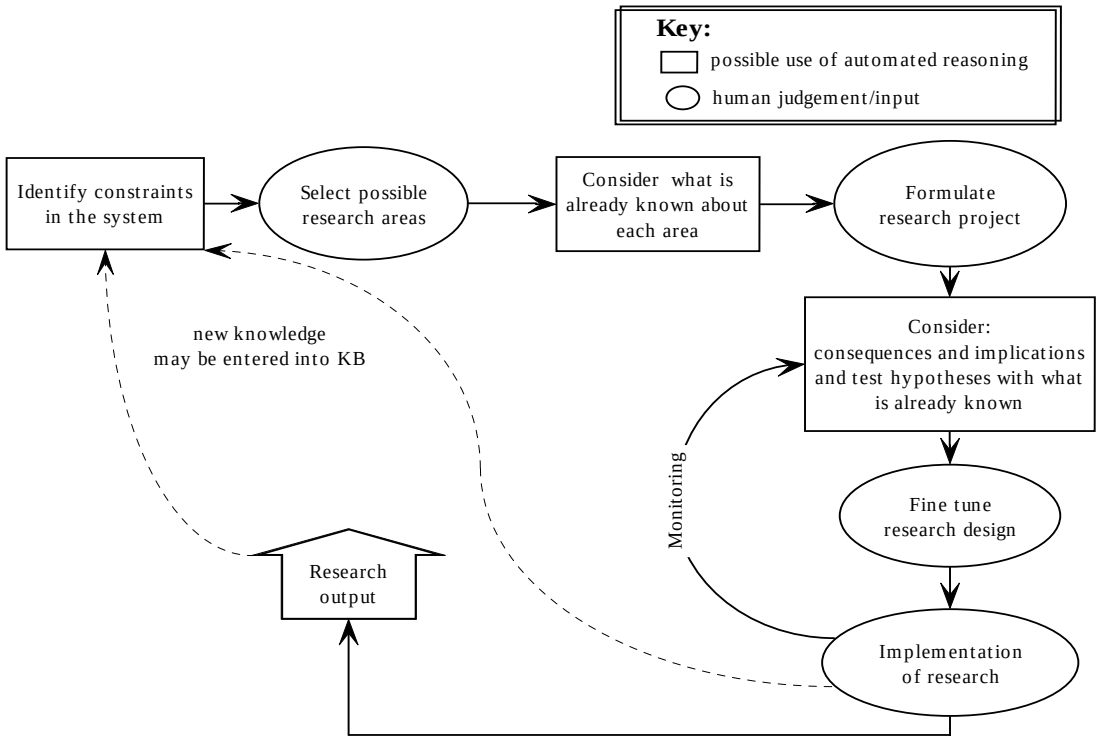

Figure 4.2. *Stages of research planning where automated reasoning may be used.*

Assistance in identifying constraints was provided by tools for comparing local knowledge and practice and by finding gaps in knowledge. Existing knowledge was evaluated using combinations of tools that allowed the user to explore the consequences of various management actions (such as tree lopping) and the causes of particular processes or events (such as high levels of soil erosion). Hypotheses were tested by using tools that marshal what information is available from the knowledge base to support and/or refute explorative assertions made by the user.

Formal reasoning was also useful in the production of extension material. Firstly, information appropriate for dissemination to particular groups of people was identified by comparing knowledge from farmers, researchers and extension workers

and so revealing items of knowledge that could usefully be communicated amongst groups. Secondly, information on particular topics (such as a particular tree species) was automatically compiled. This feature can either be used dynamically by people interrogating a knowledge base for information on topics of interest or as a basis for developing paper-based extension materials.

The potential for using automated reasoning in planning research and extension was demonstrated and tools developed that can be used for this purpose. Some of these tools are generic and could be used on any knowledge base while others were specific to the example domain (fodder trees on farmland in the mid-hills of Nepal). It was shown that while formal reasoning procedures can assist research and extension workers in making full use of formally recorded knowledge in planning their activities, they provide elements of decision support and do not substitute for human judgement. Their use often requires the user to dissaggregate tasks into manageable units and, if developing new tools, as opposed to using those that already exist, to have a reasonable familiarity with the software. Consideration of a simpler user interface for novice users would, therefore, be worthwhile.

4. Recommendations on how to acquire knowledge appropriate as a basis for designing research at an institutional-level at PAC, based on a characterisation of the distribution of knowledge across the heterogeneous client base encompassed by the PAC command area developed. Principles of more general applicability for knowledge acquisition about agroforestry from resource-poor farmers will be discernible.

This has been achieved and fully documented (Joshi and Sinclair, 1997). Knowledge about tree fodder resources was evaluated by interviewing 220 farmers across four contrasting sites, representing the range of farming practice in the PAC command area. General classification of trees with respect to their interactive effects on crops and of fodders was found to occur across a wide geographical area in the eastern mid-hills of Nepal. The knowledge base generated at Solma provided an effective template for knowledge acquisition elsewhere and made the process of eliciting knowledge from new communties much faster than would have been the case had concepts and terminology had to be ascertained prior to dicussions about resource use and management at each site.

While conceptual frameworks were commonly held, detailed knowledge about particular attributes of tree species and their effects on crops and animals varied according to how important these species were to farmers at different sites. Most species occurred at most sites but their use varied according to the characteristics of the farming system. Some new knowledge was encountered in the process of exploring the relevance of the knowledge acquired from Solma at the three other contrasting sites and location had a far larger influence on what people knew than either gender or wealth. Women were more knowledgeable than men about some detailed aspects of tree-crop interactions and the feeding value of tree fodder and it is necessary to employ gender sensitivity in knowledge acquisition to involve women fully.

Recommendations for knowledge acquisition from multiple communities have been produced. These incoporate a focus on one site with high dependence on the

resources under study in the early phases of knowledge aquisition to create a template which is then generalised across sites with a full range of resource dependency.

5.	A set of accessible knowledge bases representing, at an institutional-level, an explicit and accessible record of farmers' and researchers' knowledge on key aspects of tree-fodder resources covering the PAC command area, produced.

This objective was fully achieved for the tree fodder domain and surpassed in that knowledge bases in other subject areas were also produced at PAC and in other institutions in Nepal and at ICRAF in Indonesia.

The knowledge collected by Thapa (1994) as part of project R4731 was re-evaluated and augmented through further fieldwork in Solma (the original case study village) and reformulated in a more accessible way by consistent application of the AKT methodology (Chapter 3 of Laxman Joshi's thesis, 1998, pp. 44-82). The relevance of this knowledge across the PAC command was evaluated through fieldwork in a further three contrasting sites (Joshi and Sinclair, 1997, attached) and knowledge from these sites, not available in Solma, has been incorporated into the set of institutional knowledge bases. This has not only led to a more coherent representation of farmer's knowledge using the current AKT representational structures but has also contributed to the specification of software developments geared towards making the contents of knowledge bases more accessible.

New knowledge bases on other topics were also created by researchers at PAC on soil fertility management, grain weevil control and maize varietal selection (see under 1 above). Beyond PAC, the Nepalese NGO LI-BIRD are developing a knowledge base on green manure and internationally ICRAF have used the WinAKT software and methodology to create a knowledge base on damar forest gardens in Indonesia.

5. OUTPUTS

The most significant output from this project is the activity in Nepal and Indonesia where the knowledge-based systems software and methodology is in use as outlined in the previous sections of this report. Documented project outputs produced are listed below.

5.1 Publications

Joshi L. and Sinclair (1998) Indigenous knowledge and use of biodiversity in control of resource flows in sustainable agriculture. *Society for Experimental Biology, Annual Meeting, York, 23-27 March, 1998*

Joshi L. (1998) *Incorporating farmers' knowledge in the planning of agroforestry research and extension*. PhD Thesis. School of Agricultural and Forest Sciences, University of Wales, Bangor 270pp (Submitted 23/12/97; successful examination 15/01/98).

†Sinclair, F.L. and Walker D.H. (1998). Qualitative knowledge about complex agroecosystems. Part 1: a natural language approach to representation. *Agricultural Systems* **56**: 341-363

†Walker, D.H. and Sinclair, F.L. (1998). Qualitative knowledge about complex agroecosystems. Part 2: formal representation. *Agricultural Systems* **56**: 365-386.

‡Walker, D.H., Sinclair, F.L., Joshi, L. and Ambrose, B. (1997). Prospects for the use of corporate knowledge bases in the generation, management and communication of knowledge at a frontline agricultural research centre. *Agricultural Systems* **54**: 291-312.

†Thapa, B., Walker, D.H. and Sinclair, F.L. (1997). Indigenous knowledge of the feeding value of tree fodder. *Animal Feed Science and Technology* **67**: 97-114.

†associated with previous project R4731; ‡associated with pilot project R5470

5.2 Internal reports

Joshi L. and Sinclair, F.L. (1998a). *The use of automated reasoning in planning research and extension*. School of Agricultural and Forest Sciences, University of Wales, Bangor. Project report, 51 pp.

Joshi L. and Sinclair, F.L. (1998b). *Impact of using a knowledge based systems approach*. School of Agricultural and Forest Sciences, University of Wales, Bangor. Project report, 44 pp.

Joshi, L. and Sinclair, F.L. (1997). *Knowledge acquisition from multiple communities*. School of Agricultural and Forest Sciences, University of Wales, Bangor. Project report, 34 pp.

Randell D.A. and Sinclair, F.L. (1997). *WinAKT Version 1.00: software description and user notes*. School of Agricultural and Forest Sciences, University of Wales, Bangor. Project report, 25 pp.

Sinclair, F.L., Joshi, L. and Thapa, B. (1998). *Incorporation of local knowledge in rural development: key outcomes from a workshop held from 8 - 11th March,*

1998 at Nagarkot in Nepal. School of Agricultural and Forest Sciences, University of Wales, Bangor. Project report.

Sinclair, F.L. (1997). *A knowledge based systems approach to interdisciplinary research on tree fodder: second annual report*. School of Agricultural and Forest Sciences, University of Wales, Bangor. Project report 16 pp.

Sinclair, F.L. (1996). *A knowledge based systems approach to interdisciplinary research on tree fodder: first annual report*. School of Agricultural and Forest Sciences, University of Wales, Bangor, 20 pp.

Joshi, L. (1996). *The use of explicit records of indigenous and scientific knowledge in agroforestry reserach and extension*. First year progress report January 1995 - January 1996. 71 pp.

Grantham, K. (1996a). *Gender and indigenous knowledge: the role of Nepalese women in agricultural research and development*. Occasional paper, School of Agricultural and Forest Sciences, University of Wales, Bangor 10pp.

Grantham, K. (1996b). *A review of hierarchical representation of ethnobiological knowledge*. Occasional paper, School of Agricultural and Forest Sciences, University of Wales, Bangor 20pp.

5.3 Other dissemination of results

WinAKT software is available on our FTP site: safsftp.bangor.ac.uk; userid: anonymous; choose the IEK directory and within this the winAKT subdirectory.

Laxman Joshi's thesis has been produced in an A5 book format and distributed to 30 institutions in Nepal and beyond. Three manuscripts are in preparation on:

- knowledge acquisition from multiple communities
- use of automated reasoning in marshalling local knowledge in research planning, and
- evaluation of the use of knowledge based systems in planning research.

ICIMOD have agreed to collaborate on production and dissemination of proceedings of the final project workshop and resources for this are being sought from HARP.

6. IMPLICATIONS OF RESULTS

The final project workshop, at which 22 people from a range of governmental and non-governmental organisations participated, recommended:

1) use of the software and methodology by institutions in Nepal and the setting up of a network of users, and
2) analysis of requirements, at an institutional level, for dealing with social, cultural and economic knowledge to develop a suite of tools to make effective use of the copious amounts of information being generated through the use of participatory methods.

Funding is being sought from HARP in Nepal to support setting up a network of users in Nepal and associated with this, the production and dissemination of full proceedings of the final workshop in conjunction with ICIMOD. A joint proposal with ICRAF in Indonesia, IITA in Cameroon and the Centre for Environment and Society at the University of Essex, that involves extending the methodology to incorporate socio-economic knowledge has been submitted to FRP.

It is clear from the work of this project that there is an enthusiasm for using formal methods to make more effective use of qualitative knowledge already being generated through participatory development and to improve knowledge acquisition. Two major challenges remain.

Firstly, as was identified at the final project workshop, use of a knowledge based systems approach requires an institutional commitment and an initial investment in staff training. Maintenance and updating of the software system also requires a continued responsive capacity in Bangor. Simplification of the user interface of the task language may make it easier for institutions to start up but a means needs to be found to continue to support use of methods and software beyond the research phase and to kick start institutional investment.

Secondly, while there is a clear demand from development organisations for formal methods to handle knowledge, their requirement is for an integrated system for dealing with both qualitative and quantitative information. This will require a suite of software tools, many of which already exist (such as database and GIS software packages) but integrating their use with qualitative knowledge based systems requires new methodological development.

Clearly the research in this area is increasingly being driven by well articulated demand from grass roots organisations for methods to enable them to work more effectively with rural people. This is possible because they can now appreciate what is possible when formal methods are applied to knowledge acquisition, storage and use.

7. REFERENCES

References cited in the text that are not ready listed in Section 5 as outputs from this project.

Kendon, G., Walker, D.H., Robertson, D., Haggith, M., Sinclair, F.L. and Muetzelfeldt, R.I. (1995) Supporting customised reasoning in the agroforestry domain. *New Review of Applied Expert Systems* **1**: 179-192.

Sinclair, F.L., Walker, D.H., Joshi, L., Ambrose, B. and Thapa, B. (1993). *Use of a knowledge based systems approach in the improvement of tree fodder resources on farmland in the eastern hills of Nepal*. Pilot phase report, August 1993. School of Agricultural and Forest Sciences, University of Wales, Bangor.

Thapa, B. (1994). *Farmers ecological about the management and use of farmland tree fodder resources in the mid-hills of Eastern Nepal*. PhD thesis, University of Wales, Bangor.

Thapa, B., Sinclair, F.L., and Walker, D.H., (1995) Incorporation of indigenous knowledge and perspectives in agroforestry development. Part Two: Case-study on the impact of explicit representation of farmers' knowledge. *Agroforestry Systems* **30**: 249 - 261

Thapa, B., Walker, D.H. and Sinclair, F.L. (1997). Indigenous knowledge of the feeding value of tree fodder. *Animal Feed Science and Technology* **67**: 97-114.

Walker, D.H., Sinclair, F.L., Kendon, G., Robertson, D., Muetzelfeldt, R.I., Haggith, M. and Turner, G.S. (1994). *Agroforestry Knowledge Toolkit: methodological guidelines, computer software and manual for AKT1 and AKT2, supporting the use of a knowledge-based systems approach in agroforestry research and extension*. School of Agricultural and Forest Sciences, University of Wales, Bangor, 132 pp.

Walker, D.H., Sinclair, F.L. and Kendon, G., (1995). A knowledge based systems approach to agroforestry research and extension**.** *AI Applications* **9** (3): 61-72 .