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Farmers, ecological knowledge about the management and use of farmland tree fodder resources in the mid-hills of eastern Nepal

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FARMERS' ECOLOGICAL KNOWLEDGE ABOUT THE MANAGEMENT AND USE OF FARMLAND TREE FODDER RESOURCES IN THE MID-HILLS OF EASTERN NEPAL

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ABSTRACT

The thesis presents an investigation into indigenous ecological knowledge about the management and use of farmland tree fodder resources in a rural village setting in the mid-hills of eastern Nepal. The study focused upon a collection of hamlets spread over an altitudinal range of 500 m to 2 000 m with a population of 3 500 people comprising a Village Development Committee. The study focused on the indigenous ecological knowledge associated with decision making criteria used by farmers in managing their farmland tree fodder resources. Knowledge was examined relating to how farmers perceived the vâlue of a particular fodder species and the underlying knowledge systems used by them in fodder evaluation and how farmers perceived the interactions occurring in their tree-crop-based farming systems and the underlying ecological knowledge used by farmers in managing the interactions. The knowledge acquired from key informants was evaluated in terms of its representativeness, the extent to which it was used by farmers and the extent to which it was complementary and/or contradictory to professional knowledge held by research workers operating in the study area.

The research relied upon concepts and approaches in knowledge elicitation developed in the field of anthropology and ethnography combined with a novel methodology for collecting, recording, accessing and evaluating indigenous ecological knowledge using knowledge based systems techniques. The defining feature of the approach adopted was the explicit representation of knowledge and incremental knowledge acquisition based on an iterative and rigorous evaluation of the usefulness of the knowledge already acquired. The practical utility of the approach was that once created, knowledge bases could be maintained and updated as a growing corporate record of current knowledge on the topic in question. A comprehensive knowledge base on tree fodder resources was created through interviews with key informants.

The research demonstrated that farmers possessed a detailed ecological knowledge of tree-crop interactions, tree fodder quality and tree fodder management techniques which they used in formulating fodder management and feeding strategies. It was also revealed that the farmers' ecological knowledge was explanatory, predictive and of technical relevance. Indigenous ecological knowledge research in general and farmers' ecological knowledge in particular was demonstrated to have the potential to improve the understanding that researchers have of the complex interdisciplinary field of tree fodder resources and to be used to improve the design of research and development programmes making them more responsive to the needs of the target community. The study has identified several key issues having direct implications for designing future tree fodder research and development programmes in Nepal. This along with some policy issues raised by the study and how the tree fodder knowledge base created during the course of this study may be further improved and used in a research and development context are discussed. Key areas for further research are indicated.

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CHAPTER 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

This Chapter outlines the background to the present research and provides the context for the remainder of this thesis. Indigenous ecological knowledge research about farmland tree fodder resource management and use is introduced, firstly, by providing a brief description of hill farming systems in Nepal and then by examining the role of tree fodder in hill farming systems. Current government initiatives, particularly private tree planting programmes as they relate to tree fodder, are examined. The role of indigenous knowledge in general and the issue of tree fodder and indigenous ecological knowledge research in Nepal are reviewed in light of the available literature. The research objectives and the structure of the thesis are outlined.

This study was undertaken as collaborative research between Pakhribas Agricultural Centre[1] (PAC), a multi-disciplinary agricultural research centre located in the eastern hills of Nepal in which the author has been employed for over a decade, and the UK Overseas Development Administration (ODA) funded research project on indigenous ecological knowledge involving collaboration between the University of Wales, Bangor and the University of Edinburgh. The main motivation of the overall research programme was to investigate the hypothesis that indigenous people, who have been operating agroforestry[2]

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[1] Pakhribas Agricultural Centre is a British aid project located in Dhankuta district, eastern Nepal which in the past 15 years has concentrated its research and extension activities across disciplines (agriculture, forestry and livestock) in 15 Village Development Committees in Dhankuta, Terathum and Taplejung districts. The extension activities of Pakhribas Agricultural Centre have recently been discontinued and the centre has been given a new responsibility with a wider geographical remit to function as a hill agricultural research centre by the National Agricultural Research Council (NARC). The centre currently concentrates on agriculture, forestry and livestock research in 11 hill districts in the eastern hills of Nepal.

[2] "Agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs, etc.) are grown in association with herbaceous plants (crops, pasture) and/or livestock in a spatial arrangement, a rotation, or both, and in which there are both ecological and economic interactions between the tree and non-tree components of the system" (Young, 1989).

practices for a long time, have developed an understanding of their ecological functioning which can be captured and incorporated in development programmes to improve agroforestry practices. The objectives of this programme were, broadly, to obtain indigenous ecological knowledge about agroforestry, develop means to represent, store and access it, and, establish the extent to which the collected knowledge could be used effectively in various facets of research and development programmes.

It was fortuitous that a growing awareness of the need to base research on farmers' knowledge and practice at Pakhribas Agricultural Centre coincided with ODA strategic funding for research on indigenous ecological knowledge. Recently, the recognition of the scope for targeting research at Pakhribas Agricultural Centre more effectively on the basis of a thorough assessment of the current knowledge and practice of farmers has led the centre to revise and redefine its mandate to become more client oriented (SEADD, 1991).

1.2 BACKGROUND AND CONTEXT

1.2.1 An overview of hill farming systems

The farmers in the mid-hills of Nepal generally pursue a mixed farming system comprising three closely and inseparably integrated components: crop production; animal husbandry; and forestry. The farmers who cultivate land also raise livestock and depend on tree resources for the support of both components. Change in one of the components of the farming systems thus has effects on the others (Mahat, 1987).

The combination and interactions of climate, topography, altitude, social organisation, religious belief and access to land and markets in the mid-hills has given rise to a wide variety of farming systems and great diversity within them. Several different farming systems have been identified in the area (LRMP, 1986) and are described by various authors (Mahat, 1987; Gibbon and Schultz, 1989; Thapa, 1989). Within these farming systems several agroforestry practices can be identified (Fonzen and Oberholzer, 1984; Thapa, 1987; Thapa *et al*., 1989).

The farmers in the mid-hills have been practising agroforestry techniques for many years (Fonzen and Oberholzer, 1984), as tree resources form an integral part of local farming systems. The most common agroforestry practice found in the area is the use of trees and shrubs on private farmland. These trees and shrubs are usually found growing in strips along the edges of the *bari* (upper slope non-irrigated cultivated land) land terraces which constitute about 79% of the cultivated land (Carter and Gilmour, 1989). The tree species found most commonly are those selected by farmers because of their fodder value. In Parbat district, in the western mid-hills of Nepal over 70 species of trees and shrubs are known to be cultivated on private farmland for fodder by a hill farming community (Rusten, 1989). Similarly, Upton (1990) reported some 70 species of trees and shrubs being used for fodder by a hill farming community south-east of the Kathmandu valley, in the central mid-hills. Farmland tree fodder[3] is lopped and carried to stall-fed animals. Leaves and twigs are fed to the animals and branches are used as fuelwood. More than 75% of the tree fodder that is fed to livestock is used during the period November to June (Panday, 1982).

1.2.2 The role of tree fodder in hill farming systems

Tree fodder is the primary constituent of animal feed in Nepal. The main value of tree fodder is in providing a store of green and nutritious feed for livestock during the dry season when other feeds are in limited supply. Farmers collect tree fodder from two sources: private farmland; and public forestland[4]. Studies carried out to quantify the relative contribution of these sources to the annual fodder supply show wide variation in different areas. Up to 90% of tree fodder is estimated to be provided from public forestland in some areas of Dolakha district (Panday, 1982), while estimates of the contribution of farmland

[3] Vegetative matter harvested from trees, shrubs or woody vines for feeding domestic animals. The term "tree fodder" is synonymous with "top feed" as used by Kumar and Vaithiyanathan (1990).

[4] The management and use of forest in the mid-hills is a shared responsibility and forest products such as fodder, fuelwood and leaf-litter are generally treated as free goods. Thus, the term "public forestland" is synonymous with" common property resources".

tree fodder to the annual fodder supply ranged from 5% to 60% across the whole of Nepal (Heuch, 1986). While the magnitude of these estimates clearly points to fodder trees being used in livestock production, their critical importance becomes apparent when it is realised that they often provide the only green fodder during parts of the dry season.

Livestock are an integral component of the hill farming systems, the land area cultivated and crop production achieved largely depend on it (Hopkins, 1985; Tulachan, 1985; Shrestha and Sherchand, 1988). Livestock are important in providing draught power for crop production and manure for maintaining cropland fertility. They are also an important source of farm income and protein for household nutrition. In the hill farming community decrease in animal numbers leads to reduction in the quantity of manure and draught power. This in turn results in a decline in agricultural productivity and a loss of farm income with severe consequences for human nutrition.

Recent studies have indicated that the fragmentation of land holdings coupled with the declining productivity of public forestland and, therefore, declining supply of tree fodder from public forest is motivating farmers to cultivate more trees on their private farmland (Carter and Gilmour, 1989; Gilmour and Nurse, 1991; Robinson, 1992; Subba, 1992). This has resulted in farmers increasingly developing complex agroforestry systems. Thus, in the development of agroforestry systems in the mid-hills it is envisaged that those systems designed to improve farmland tree fodder production are likely to make a significant contribution to farm productivity.

1.3 JUSTIFICATION

1.3.1 Private tree planting programme in Nepal

Since the publication of the landmark study "Forestry for Local Community Development" (FAO, 1978), there has been an increasing awareness of the importance of trees on farmland throughout the world. There are now numerous publications from different parts of the world that document incorporation of trees into farming systems (for example, Olofson, 1983; Altieri and Farrell, 1984; Foley and Barnard, 1984; Von Carlowitz, 1984; Shepherd, 1989; Saxena, 1990) including examples from Nepal (Fonzen and Oberholzer, 1984).

In response to the severe ecological problems in Nepal and encouraged by international initiatives and the general rise in interest in the role of forestry in development, increasing emphasis has been placed on forestry development in Nepal since the late 1970s. The primary aim has been to meet the needs of local communities and to protect the environment using a community forestry[5] approach. Private tree planting programmes[6] have been a feature of most community oriented forestry development projects in Nepal since their inception. However, the role of trees in farming systems was not fully understood until Wyatt-Smith (1982), observed that the agricultural systems in the mid-hills were dependent on tree resources for maintaining land fertility. Since then a number of studies have highlighted the linkages between farming and forestry, including socio-economic attributes of trees in farming systems in different parts of the country (Hawkins and Malla, 1983; Byrne, 1985; Gajurel *et al.*, 1987; Mahat, 1987; Malla and Fisher, 1987; Robinson, 1987; Dutt, 1993). In recent years, the importance of farmland trees, particularly tree fodder, in maintaining farming systems has been widely recognised. More recently the tree fodder component has emerged as a primary focus of rural development efforts in Nepal.

The government has recognised this and has developed a plan which gives high priority to tree planting on private farmland. This is reflected in the recently completed twenty-five year Master Plan for the Forestry Sector. Of the twelve programmes designed to address current problems, the Master Plan for the Forestry Sector places considerable stress upon the encouragement of private tree planting (this being one of the four main components of the community forestry programme), receiving almost half of the total investment in the forestry sector (Anon, 1988).

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[5] Management and protection of public forest by local communities for their own benefit and use.

[6] Promotion of tree planting by farmers on their own farmland by government agencies.

Currently, several government institutions, bilateral aid projects and non-governmental organisations are involved in promoting tree planting on farmland and providing seedlings to farmers. However, attempts to promote tree planting have frequently been unsuccessful. Evaluation of these programmes has shown that more than a decade of experience with private tree planting have failed to produce the desired results on a sustainable basis (Ghimire and Nielsen, 1984; Bhandari and Moestrup, 1986; Gautam, 1986; Neville, 1987; Forestry Services, 1992). Several factors have been identified as impediments to the successful implementation of private tree planting programmes, but failure to take adequate note of local needs and aspirations and, therefore, local knowledge and practices has been the major contributing factor. This situation has been succinctly summarised by Carter and Gilmour (1989):

> "... many government officials and policy planners perceive that the farmers lack awareness of their dependence on trees and lack any knowledge, expertise, or ability regarding the cultivation and management of trees on their private land ... It is little wonder that development projects are considered to have failed in so many places".

The number of studies and analyses which support this view continues to multiply (Thapa *et al.*, 1990; Carter and Gronow, 1993).

In many cases the private tree planting programmes seem to have been advocated on the simple assumption that it was necessary to provide villagers with seedlings, a view strongly argued by Wallace (1987). This assumption has led many of the private planting programmes to restrict their activity to the distribution of seedlings. Most of these programmes are "top down" in their approach, based on the simple assumption that if farmers were to plant trees, they would need seedlings, therefore, seedlings should be provided. Despite farmers' preference for fodder tree species, pines (*Pinus spp*) are most often raised in government nurseries. As a result very few farmers collect seedlings from the nurseries, even though seedlings are available free of cost (Robinson and Thompson, 1989; Panday *et al.*, 1991). In contrast, work by Malla (1988), Thapa *et al.* (1991) and Joshi and Thapa (1992) has shown that private tree planting programmes often go beyond the distribution of seedlings. The "farmer training and motivation" element has been one of the major components of many community forestry development projects including private tree planting programmes in Nepal. However, in light of the growing evidence that farmers are increasingly maintaining more trees on their farmland, the need to educate villagers about tree cultivation seems to have been overemphasised. This view is still held strongly by some workers as exemplified by Yadav (1992) citing a case from Jumla, a remote hill district in the far western region of Nepal:

> "... Farmers in Jumla district have little knowledge about how to manage fodder trees on their farmland. Training should be provided to teach the necessary skills".

It is clear that the private tree planting programmes have often been designed with little or no consultation with the participating farmers. Fundamentally, programmes were advocated in the absence of information about villagers' views and knowledge on the subject. Therefore, appropriate strategies for planning private tree planting programmes responsive to local need were lacking.

1.3.2 Indigenous knowledge systems and development

1.3.2.1 Definitions and distinctions

In spite of the growing interest currently shown in the field of indigenous knowledge systems, confusion and ambiguity regarding its nature prevails. The complexity and diversity of ideas embodied within the concept have led to the term indigenous knowledge being used loosely in the literature. In many of the major texts on this subject (for example, Brokensha *et al.*, 1980), readers are left to formulate their own definitions. A range of similar terms have been variably used by previous authors such as "ethnoecology" (Brosius *et al.*, 1986; Muller-Boker, 1991), "peoples' science" (Richards, 1985), "indigenous technical knowledge" (Howes, 1980; Sharland, 1989; Mathias-Mundy *et al.*, 1990; Fairhead, 1990), "traditional knowledge" (Barrow, 1991), "ethnoscience" (Barker, 1977), "village science" (Barker *et al.*, 1977), "rural peoples' knowledge" (Chambers, 1983; Bebbington *et al.*, 1993) and "indigenous ecological knowledge" (Posey, 1983; Walker *et al.*, 1991).

Warren and Cashman (1988) define indigenous knowledge as "the sum of experience and knowledge of a given ethnic group that forms the basis for decision making in the face of familiar and unfamiliar problems and challenges". Warren (1991) defines indigenous knowledge as "local knowledge that is unique to a given culture or society" and suggests that indigenous knowledge contrasts with scientific knowledge generated by universities, research institutions and private firms. While the distinction between indigenous and scientific knowledge (often referred to as "international knowledge", Warren, 1991) is contentious, the main difference noted is that the former concentrates on adaptation of knowledge and is less formal in both its social organisation and its research methods (Biggs and Clay, 1981). Howes and Chambers (1980) suggested that "science and indigenous knowledge may be contrasted and evaluated according to three criteria: as systems of classification; as systems of explanation and prediction; and, in terms of speed of accumulation" and goes on to suggest that "while indigenous knowledge and science are comparable with respect to the first criterion, science is generally superior with respect to the second and markedly so in relation to the third". On a similar basis Walker *et al.* (1991) suggest that "the differences between indigenous and scientific knowledge are not at a fundamental, conceptual level but in terms of formal structure, institutional framework, technical facility and ability and scale of perspective".

The present research concentrates largely on specific knowledge about interactions and processes in agroforestry systems termed "indigenous ecological knowledge" (Walker *et al.*, 1991). A working definition proposed by Walker *et al.* (*op. cit.*) is adapted here to focus the present research. Indigenous knowledge is defined as "the culturally specific knowledge held by members of a culturally defined community" and ecological knowledge as "knowledge about components of established production systems that they operate, and the interactions amongst those components and between them and their environment".

1.3.2.2 Using indigenous knowledge

Scholars in the field of rural development have pointed out that many technological solutions that have been proposed to address problems in rural communities have failed in the field because they do not take into account local knowledge and practice (Chambers, 1983; Warren and Cashman, 1988; Chambers *et al.*, 1989; Haverkort *et al.*, 1991; Saravia, 1992). Brokensha *et al.* (1980) present several case studies arguing that participatory and sustainable approaches to rural development could be greatly enhanced through an understanding of the indigenous knowledge of the client group. As a result, the importance of involving farmers' perspectives in the development process are now increasingly recognised by researchers and development professionals throughout the world. This growth is witnessed by the recent establishment of various national, regional and international networks throughout the world. Currently a total of three international, two regional and nine national indigenous knowledge resource centres are known to exist in different parts of the world (CIRAN, 1993)[7].

There are now numerous studies that have recorded indigenous knowledge in many parts of the world. The bulk of literature available on the subject has been recently documented by a bibliographic study of indigenous technical knowledge of private tree management by Mathias-Mundy *et al.* (1990), in sustainable agriculture by Warren (1991) and in a special issue of the journal (*Agriculture and Human Values,* 1991) on indigenous

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[7] The international indigenous knowledge resource centres include: Centre for International Research and Advisory Network (CIRAN), The Hague, The Netherlands; Centre for Indigenous Knowledge for Agriculture and Rural Development (CIKARD), Iowa State University, USA; and, Leiden Ethnosystems and Development Programme (LEAD), University of Leiden, The Netherlands.

The regional centres include: African Resource Centre for Indigenous Knowledge (ARCIK), Ibadan, Nigeria; and, Regional Program for the Promotion of Indigenous Knowledge in Asia (REPPIKA), Silang, The Philippines.

The national centres include: Burkina Faso Resource Centre for Indigenous Knowledge (BURCIK), Burkina Faso; Ghana Resource Centre for Indigenous Knowledge (GHARCIK), University of Cape Coast, Ghana; Kenya Resource Centre for Indigenous Knowledge (KENRIK), Nairobi, Kenya; Indonesian Resource Centre for Indigenous Knowledge (INRIK), University of Padjadjaran, Indonesia; Philippine Resource Centre for Sustainable Development and Indigenous Knowledge (PHIRCSDIK), Los Banos, The Philippines; South African Resource Centre for Indigenous Knowledge (SARCIK), Cape Town, South Africa; Sri Lanka Resource Centre for Indigenous Knowledge (SLARCIK), University of Sri Jayewardenapura, Sri Lanka; Mexican Research, Training and Service Network on Indigenous Knowledge (RIDSCA), Mexico; and Venezuelan Resource Secretariat for Indigenous Knowledge (VERSIK), Venezuela.

agricultural knowledge and development. An increasing literature exists that documents indigenous systems for the management of natural resources by local people and illustrates how such knowledge could be usefully applied in the development context. For example, Brokensha and Riley (1980) describe the extensive knowledge developed by the Mbeere people of Kenya concerning vegetation found in their environment. They illustrate how knowledge of specific indigenous species of fodder trees could be applied to help alleviate shortages of animal fodder in the Mbeere region. Similarly, Posey (1985) described the knowledge developed by the Kayapo Indians of the Brazilian Amazon about native plants in their environment and illustrates how this indigenous knowledge could be usefully used in developing new strategies for tropical forest management in the Brazilian Amazon Basin. Barrow (1992) while investigating the ecological strategies (to cope with drought) of the Pokot pastoral communities in the drylands of East Africa found that their understanding of the benefits of individual plants were highly developed in the selection of animal fodder. The Pokot were able to identify species that could provide dry or wet season fodder, promote the production of milk or meat and provide suitable nourishment for specific categories of livestock. Barrow (*op. cit.*) goes on to suggest that the Pokots' intimate knowledge of their plants and environment could provide a sound basis for agroforestry intervention in the region.

A review of documents reveals that many farming systems are based on intimate knowledge of soils, vegetation, and climate (Conklin, 1957; Barker *et al.*, 1977; Posey, 1983). They reflect strategies that allow farmers to avoid uncertainty. Research also indicates that the farmers' decisions to reject an innovation are often rational when viewed from an indigenous perspective (Warren, 1991). Thus understanding the way that indigenous knowledge provides the basis for local level decision making for both individuals and groups could inform research and development endeavours.

There is a growing interest in understanding the role that indigenous knowledge can play in making research and development programmes more effective and efficient (Rochleau, 1987; Farrington and Martin, 1988; Warren *et al.*, 1989). The potential utility of indigenous knowledge in a research and development context has been succinctly summarised by Walker *et al.* (1991) who state that:

- "the understanding that cultivators (indigenous people) have developed can complement scientific understanding;

- indigenously developed techniques of investigation can complement scarce scientific manpower;

- understanding indigenous knowledge and incorporating it into the research and development process can avoid duplication of work; and

- understanding indigenous knowledge can help in targeting problem oriented scientific research by providing a firm basis for formulating realistic research objectives and hypotheses".

Chandler (1991) addressed the value and validity of indigenous knowledge when compared with scientific knowledge based on the case study of Chinese peasants' ecological knowledge relating to the production of *Cunninghamia lancelata* (locally known as "Shamu") and found that scientific knowledge proves the validity of the indigenous knowledge. Similarly, de Queiroz and Norton (1992) have examined the practical and technical validity of indigenous knowledge through a case study of indigenous soil classification systems used by farmers in the Caatinga region of Ceara State in Northeast Brazil against cluster analyses using morphological attributes from 36 soil profiles. They found that three major clusters produced by cluster analyses corresponded closely to the broad classes of the indigenous soil classification and suggest that the indigenous soil classification system could be used as a framework to group soils physiochemically in Northeast Brazil.

Many authors have depicted the creativity and innovativeness of farmers as they react to changing conditions (Richards, 1980; Rhoades, 1987; 1989; Chambers *et al.*, 1989; Gupta, 1989) and have suggested that these individuals operate and base their decisions on indigenous knowledge systems. Walker *et al.* (1991) state "it is precisely the nature and depth of this understanding that determine the smallholder's ability to adapt and improve production systems" as external pressures impact on the system. On this basis Walker *et al.* (*op. cit.*) have emphasised the need for research to establish the existence of indigenous ecological knowledge associated with decision making criteria used by farmers in managing their production systems.

Much indigenous knowledge research has concentrated on indigenous technical knowledge[8] and has focused attention on the labelling and classification of discrete objects in order to obtain information about the world view of the particular group of people studied. Such an approach has often been criticised as being "ethnosystematic" or "ethnotaxonomic" (Brosius *et al.*, 1986). In contrast, Johnson (1974) and Brosius *et al.* (*op. cit.*) suggested that indigenous people possess a wealth of environmental and ecological knowledge that goes beyond the simple naming and classification of discrete objects. For example, Brosius *et al.* (*op. cit.*) reported that the Negrito in Luzon in the Philippines, not only recognise more than 80 kinds of birds but also have considerable knowledge of bird-environment interactions including detailed knowledge of the habitats and food sources of each species, their seasonal abundance and distribution and what the presence or absence of particular species of birds indicates about the state of a given area. Such knowledge has been referred to as "explanatory ecological knowledge" (Walker *et al.*, 1991). On this basis Walker *et al.* (*op. cit.*) have argued that research should proceed further, to consider not only how the local classification and categories reflect an environmental world view, but also the degree to which this world view systematically explains ecological process and how it compares to one that might be derived from scientific investigation.

The extent to which local knowledge is useful in the context of agricultural development is dependent on both of these points, since local explanations may be important in themselves because they contain useful information and because they facilitate communication. The combination of local knowledge with scientific[9] as well as

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[8] Knowledge about how to achieve particular objectives.

[9] Knowledge generated through the application of scientific methodology.

professional[10] knowledge may be necessary to make rapid progress in development terms in the context of mounting land use pressures. However, it is apparent from the literature that very little effort has been made to record this type of explanatory knowledge and that little or no attempt has been made to synthesise local, scientific and professional knowledge into an integrated resource that can be used effectively in a research and development context.

1.3.3 Indigenous knowledge research in Nepal

Until recently, little attention has been paid to this topic in Nepal. However, recent thinking relating to resource poor farming communities has highlighted the importance of indigenous knowledge in rural development programmes and this topic is gaining more importance in recent development literature. The increasing number of studies in the field of indigenous knowledge in Nepal reflects a growing interest on the part of researchers and development professionals to learn from the existing systems and thereby suggest appropriate technologies for sustainable use of natural resources.

A literature search suggests that most of the studies carried out to date on indigenous knowledge in Nepal have concentrated on indigenous systems of public resource management, especially public forest management (Mahat, 1985; Fisher, 1989, 1991; Gilmour, 1989; Hobley, 1990; King, 1990; Messerschmidt, 1990; Metz, 1990; Tamang, 1990; Baral, 1991; Bartlett and Malla, 1992; Daniggelis, 1992; Nesheim, 1992; Saul, 1992). Literature also exists that deals with other knowledge systems indigenous to Nepal (Johnson *et al.*, 1982; Schroeder, 1985; Gurung, 1989; Brower, 1990; Zurick, 1990; Muller-Boker, 1991; Tamang, 1992). Significantly, the theme of private resource management, including some aspects of farmland tree fodder, also emerges from some of the studies (Panday, 1982; Heuch, 1986; Uprety, 1986; Rusten, 1989; Condon, 1990;

[10] Knowledge used by employed practitioners that is derived from a formal and recognised education or training.

Subedi *et al.*, 1990; Amatya, 1991; Carter, 1991; Upadhaya, 1991). However, a systematic review of the literature on indigenous knowledge, particularly indigenous ecological knowledge, revealed that little work has been undertaken on indigenous ecological knowledge surrounding farmland tree fodder resources and that such information is completely lacking in the eastern hills of Nepal. Therefore, an understanding of the indigenous ecological knowledge used by the farmers in managing their farmland tree fodder resources and the knowledge upon which they are based remains largely unexplored and much of what is known remains anecdotal. The lack of information and the need to know more about indigenous knowledge surrounding natural resource management in general in the eastern hills has also been stressed by Fisher (1991).

Currently several government institutions including non-governmental organisations are involved in agroforestry research and development programmes and research on various aspects of agroforestry-related problems are in progress (Denholm and Rayachhetry, 1990; Neil, 1990; Fairclough *et al.*, 1993). However, a review of available literature suggests that, to date, agroforestry research in Nepal has been restricted to: the description of traditional agroforestry systems (Fonzen and Oberholzer, 1984; Kanel, 1986; Denholm, 1991; Dhakal, 1993); the introduction of exotic species (Brewbaker, 1983); biological studies on productivity of agroforestry tree species (Wormald *et al.*, 1983; Amatya and Kiff, 1993; Karki and Gold, 1993); and the nutritional aspect of fodder tree species, particularly chemical analysis of fodder tree leaves (Mahato and Subba, 1988; Subba and Tamang, 1990; Shrestha and Tiwari, 1992; Panday and Osti, 1993).

Various surveys (Campbell and Bhattarai, 1983; Robinson and Neupane, 1988; Robinson, 1990; Upton, 1990; Upadhaya, 1991) have provided useful insights into villagers' attitudes towards tree fodder resources, but have failed to document indigenous ecological knowledge used by farmers in managing their farmland tree fodder resources.

While the role of tree fodder becomes increasingly important for both livestock productivity and the stability of hill farming systems (1.2.2) and an increasing amount of literature demonstrates the importance of indigenous knowledge in research and development programmes, the investigation and documentation of indigenous knowledge has barely begun in Nepal. The amount of information currently available relating to tree fodder resources is inadequate to make any significant contribution in planning and designing research. This situation is identified in a statement by the Master Plan for the Forestry Sector, Nepal which identifies, as a core problem, the poor quality of information on which research and development programmes are first founded and then managed (Anon, 1988). Thus, before indigenous knowledge can be effectively used in the research and development process, it must be collected, evaluated and documented.

1.4 PURPOSE OF THE STUDY

Heuch (1986) comments that "Farmers in Nepal have had several generations of experience with tree fodder and have a wealth of knowledge that has barely been tapped by researchers". Thapa *et al.* (1990) further state "Fodder trees are an integral part of hill farming systems and farmers have been managing and using them for generations. There is already a wealth of knowledge and much can be learnt from the farmers". Thus, the present research derives from the premise that because of the importance of tree fodder in farming systems and as a result of generations of experience of managing them, farmers have developed an extensive ecological knowledge about tree fodder which can be captured and used in improving agroforestry practices.

The main aim of this study was to learn from Nepali farmers about their knowledge of cultivation, management and use of tree fodder resources. The main motivation behind the research lay in the belief that understanding local knowledge can help researchers and development professionals in designing appropriate research and development strategies that are responsive to local needs.

The study aimed to gain this understanding within one Village Development Committee (VDC)[11] representing a range of altitude, socio-economic and cultural

[11] Administratively, Nepal is divided into five development regions (Eastern, Central, Western, Mid-Western and Far-Western), 14 zones and 75 districts. Each district is divided into a large number of Village Development Committees. Village Development Committee (previously known as Panchayat before the fall of the single party panchayat system in April 1990) is the smallest administrative and political unit having a population of about 3 000 to 6 000 with approximately 500 to 800 households. Each Village

conditions in the eastern hills of Nepal and to use the insights obtained to suggest appropriate future strategies in planning tree fodder research and development programmes. More specifically the study aimed to document farmers' ecological knowledge associated with decision making criteria used by them in managing their farmland tree fodder resources by examining:

- how farmers perceive the value of a particular fodder species and the underlying knowledge systems used by them in fodder evaluation; and

- how farmers perceive interactions occurring in their tree-crop-based farming systems and the underlying knowledge systems used by farmers in managing them.

Furthermore, the study aimed to evaluate farmers' knowledge in terms of:

- the extent to which the knowledge of farmers interviewed was representative of the knowledge held by people generally;

- the extent to which the knowledge was predictive or used by farmers in decision making; and

- the extent to which local knowledge was complementary and/or contradictory to scientific knowledge and that used by research workers.

Finally, the study aimed to demonstrate the extent to which local knowledge could be used in planning and designing appropriate tree fodder research and development strategies for the improvement of farmland tree fodder resource management in the eastern hills of Nepal.

Development Committee is further divided into nine wards, each ward containing at least one, if not several hamlets. Elected political representation occurs at the ward, Village Development Committee and district level.

1.5 STRUCTURE OF THE THESIS

Having outlined the background and context to the research in Chapter 1, Chapter 2 considers the methodological requirements and options for doing so and sets out the conceptual, theoretical and methodological framework used in the research. An overview of research concepts, methods and strategy are presented in this chapter. Discussions of ethnoscience, ethnoecology, emic and etic approaches and the use of a knowledge based systems approach including the application of artificial intelligence techniques in knowledge acquisition as they relate to the present study are discussed.

Chapter 3 forms the specification stage of the research and presents the basic information required to formulate specific research hypotheses about farmers' ecological knowledge to be addressed in the subsequent knowledge acquisition phase (Chapter 4). On the basis of formal surveys carried out in this specification stage, background information about the study area, necessary to interpret local knowledge and its applicability in a research and development context, and preliminary findings relating to farmers' perceptions about cultivation, management and use of farmland tree species, are presented.

Chapter 4 outlines how the information presented in Chapter 3 and the principles discussed in Chapter 2, relating to the use of a knowledge base systems approach were used to acquire ecological knowledge from farmers in the creation of a tree fodder knowledge base. In this chapter, methodological approaches to knowledge elicitation and techniques of representing knowledge and how they were implemented are discussed.

Chapter 5 evaluates the knowledge recorded in the tree fodder knowledge base and presents the underlying knowledge systems used by farmers in fodder evaluation and in managing tree fodder resources on their farmland.

Further evaluation of the tree fodder knowledge base in terms of the extent to which knowledge in the knowledge base was representative of the knowledge held by the wider community, the extent to which it was complementary and/or contradictory to professional knowledge and the extent to which it was predictive appears in Chapter 6.

In the concluding chapter (Chapter 7), the understanding that can be derived from consideration of this study and its implications for future tree fodder research and development programmes in Nepal are addressed. The key issues having direct implications in designing future tree fodder research and development strategies responsive to local needs are identified. This, along with some policy issues raised by the study and how the tree fodder knowledge base created during the course of this study may be further improved and used in a research and development context, are discussed.

CHAPTER 2

CONCEPTUAL, THEORETICAL AND METHODOLOGICAL FRAMEWORK

2.1 INTRODUCTION

Having considered the background and context to the research in Chapter 1, this chapter considers the methodological requirements necessary to achieve the objectives. While the detailed description of the specific research methods employed are presented where appropriate in the thesis, this chapter provides an overview of the conceptual, theoretical and methodological framework used in the research.

Research on indigenous knowledge systems is still in its infancy and there is no established methodology that can be applied. Each research initiative need to draw on theory and methodology from a diverse array of disciplines that are appropriate to the needs of the research in question.

Previous work on indigenous knowledge in natural resource management has often adopted a multi-method approach involving combination of ethnographic, farming systems research and formal survey techniques (Rusten, 1989; Miller, 1990; Hobley, 1990; Carter, 1991). However, the overriding concern of the present research was the ultimate utility of local knowledge in the development of agricultural systems and, therefore, the methods developed in the field of artificial intelligence (AI) concerned with acquiring and using knowledge for practical purposes was also relevant. This chapter considers the relevant aspects of these disciplinary approaches and how they were combined in the present study.

2.2 RESEARCH CONCEPTS

2.2.1 Ethnoscience and ethnoecology

The present study drew upon conceptional elements primarily within the field of ethnoscience in general and ethnoecology in particular. Most anthropological studies of traditional knowledge have been conducted within the general framework of ethnoscience or ethnography which may be defined as "the study of systems of knowledge developed by a given culture to classify the objectives, activities, and events of its universe" (Hardesty, 1977). Vayda and Rappaport (1968) explain that the prefix 'ethno' is to be understood as "referring to a people's own view or knowledge of some subject matter whether it is science in general or ecology in particular". Thus, the term ethnoecology may be defined as "environments as understood by those who act within them" (Vayda and Rappaport, *op. cit.*)

Various authors (Conklin, 1954; Frake, 1962; Fowler, 1977; Bartlett, 1980; Posey, 1984; Brosius *et al.*, 1986) have emphasised ethnoecology as an approach to exploring and understanding native conceptions and how they interact with the environment, and have suggested that every language has a large folk terminology of a specifically ecological nature and that an understanding of such terms opens the way to understanding the concepts and processes that underlie them. Given that the main aim of the present study was to learn and record farmers' ecological knowledge about farmland tree fodder resource management, this required the application of an ethnoscientific research approach with an ethnoecological perspective.

2.2.2 Emic and etic perspectives

Within the general field of ethnoscientific research, there are two approaches that examine phenomena from two distinct perspectives. They are termed as "emic" which is often referred to as "cognitivist" and "etic" which is also called the "materialist" approach.

These terms are important because they provide the basis for formulating approaches to ethnoscientific research (Brislin, 1980; Werner and Schoepfle, 1987a).

The main differences between the two approaches are that the emic approach examines the phenomena from the native perspective, therefore, the fieldwork methodology is primarily dependent on interviewing in the native language. The intention is to seek the categories of meaning in the way the natives define things. Thus, the emic approach involves eliciting from people explanations for their behaviour. In contrast, an etic approach examines phenomena from a viewpoint other than that of the natives. The primary fieldwork methodology is observation of behaviour and the intention is to seek patterns of behaviour as defined by the observer.

Both approaches have well documented advantages and disadvantages (Sturtevant, 1964; Pelto and Pelto, 1978; Werner and Schoepfle, 1987a). Sturtevant (1964) states that 'etic' refers to "culture free" elements of analysis, hence, the research results are universally applicable across cultures. By contrast, 'emic' results are "culturally unique", therefore, research results are appropriate within only one cultural setting. Harris (1974) has shown important discrepancies between what people do and what they say they do from etic-based research on behavioural observation and has suggested that accounting for these differences is essential for developing accurate ethnographic description of cultural groups. However, etic-based research by its nature demands intensive observation of actual human behaviour and in practically oriented research, such as the present study, is too time consuming to be cost effective. For reasons discussed above, although the research started from an emic perspective, the approach adopted in the present study falls somewhere between these two approaches.

While the present study relied on the concepts and approaches to knowledge elicitation developed in anthropology and ethnography, which provided considerable insights into the process of accessing people's knowledge, the main concern of the present study was the practical use of local knowledge in a research and development context. Therefore, the concepts and approaches developed and used by knowledge engineers in the field of artificial intelligence concerned with producing articulated statements of knowledge for practical purposes were also of central concern to this research. The following section introduces the relevant aspects of artificial intelligence techniques as they relate to the present study and outlines the methodological requirements and approaches offering a means of achieving the research objectives.

2.3 METHODOLOGICAL REQUIREMENTS AND APPROACHES

2.3.1 The need for a rigorous approach

The recognition of the potential role that indigenous knowledge can play in making research and development programmes more effective and efficient has led to considerable methodological development for dealing with local practice and knowledge over the last decades. As a result, a number of approaches and techniques have evolved. Examples include: agroecosystem analysis (Conway, 1985); farming systems research and extension approach" (Hildebrand, 1990); and diagnosis and design (Raintree, 1987). Experience with these approaches has led to the development of rapid rural appraisal techniques which are currently widely used, particularly in agricultural development work (Chambers, 1987; Conway, 1987; McCraken *et al.*, 1990). These techniques are primarily aimed at better understanding the needs of farming communities and the constraints under which they operate. Similarly, anthropological and ethnographic techniques have undergone considerable methodological development towards understanding the knowledge held by local communities (Werner and Schoepfle, 1987a; 1987b).

Despite the numerous research approaches and techniques currently available and used in the field of indigenous knowledge research, much practically oriented indigenous knowledge research remains largely descriptive. Such information tends to be difficult to analyse, particularly for purposes other than that for which it was collected and is, therefore, of limited practical use. Ethnographic techniques that result in copious field notes and journals tend to be highly selective and difficult to analyse, resulting in a resource that has limited flexibility for use outside the descriptive interpretation of the author. In contrast, effective use of local knowledge in research and development requires a means of considering knowledge that can be rigorously evaluated and used in decision making.

2.3.2 Artificial intelligence and expert systems

Agricultural systems are characterised by their complexity. As a result, effective decision making in agricultural development programmes often depend on the effective evaluation and use of complex sets of knowledge (Warren, 1991). However, coping with and making practical use of such knowledge in a research and development context demands a more systematic and objective means of collating, recording and evaluating that knowledge.

The advent of a series of computer software tools in recent years has meant that researchers now have the opportunity to take a more comprehensive view. Approaches to formally representing and reasoning with knowledge developed within artificial intelligence offer means of systematically and objectively recording, storing and analysing indigenous ecological knowledge in ways which are useful in a research and development context. Artificial intelligence research and applications are most familiar as "expert systems" which reason with knowledge to produce answers to questions. Expert systems consist of three distinct sets of interfaces (Bratkot, 1990): a knowledge base (containing the knowledge that is used in the expert system); an inference engine (consisting of inference mechanisms that reason with that knowledge); and a user interface (facilitating communication between the system and the user).

By far the most widespread use of expert systems have been in the field of engineering and medicine. However, in recent years, expert systems technologies have been increasingly explored or given consideration in natural resource management. For example, in an agricultural context (Jones, 1989; Bennett, 1992; Grinspan *et al.*, 1994), in agroforestry (Warkentin *et al.*, 1990; McGregor, 1992), in forestry (Muetzelfeldt, 1984) and in anthropology (Werner and Schoepfle, 1987b; Benfer and Furbee, 1990). The journal *AI Applications* (previously *AI Applications in Natural Resource Management*) contains many articles on expert system applications in the renewable natural resource management area.

Despite the considerable potential of expert systems to deliver expert management advice, current applications of artificial intelligence-based expert systems are limited to well defined problems. Most of the expert systems developed to date are restricted to software that employs rigid Yes/No rules for drawing conclusions (Grinspan *et al.*, 1994). They are, therefore, not able to deal with vague, incomplete and contradictory or uncertain information which often characterise the real world problems particularly in the farming systems in the mid-hills of Nepal (3.5).

Agricultural systems in the mid-hills of Nepal are inherently complex because of the variable nature of the social, economic, biological and environmental processes involved. As a result, much of the knowledge held by farmers can be expected to be widely dispersed amongst a range of sources. Available information is often predominantly qualitative as farmers tend to base their decisions on qualitative assessments. Thus, precise quantitative information is rarely available.

Given the complexity of the system under investigation and the sparse and qualitative nature of available information, the adoption of an expert systems approach (requiring key processes to be known and parameterised such that accurate modelling and prediction is possible) in the present study would have been unlikely to produce any meaningful results. Thus, in order to provide appropriate decision support to facilitate decision making processes in agricultural development, procedures needed to be developed to deal with the qualitative, incomplete and uncertain nature of the information available as well as its collection from a diverse range of sources.

2.3.3 The knowledge based systems approach

The final research structure and approach adopted in the present study referred here to as a knowledge based systems approach resulted from the collaboration with the ODA funded strategic research at the University of Wales, Bangor and the University of Edinburgh (Walker *et al.*, in press). The major distinction between the knowledge based system approach and the development of more conventional expert systems is that while the latter are designed to answer a set of narrowly defined types of question the former facilitates exploration of a central body of knowledge for diverse purposes. A comprehensive description of the techniques used are presented in Chapter 4. The following discussion briefly introduces some of the important features of the knowledge based system approach as they relate to the present study.

The key element of the approach is the development of an explicit record of knowledge that is formally represented in such a way that it can be automatically reasoned with. Unlike expert systems where the content of the knowledge base is dictated by the requirements of the reasoning tasks envisaged and in contrast to database technology which can only provide minimal mechanisms for automating reasoning on the content of databases, the content of the knowledge base created through the application of a knowledge based systems approach is largely dictated by a need to capture available knowledge from a defined set of sources on a defined topic irrespective of the requirements of inference mechanisms which can be specifically tailored to the task in hand (Kendon *et al.*, in preparation).

Within the knowledge based systems approach, formal representations are developed in order to allow automated reasoning with knowledge. However, formal representation is more than simply encoding knowledge on a computer, because it necessarily involves interpretation of knowledge in order to make explicit the meaning of what people articulated. This results in a rigorous evaluation of knowledge as it is gathered that rapidly exposes ambiguity, inconsistency and omission. The process of knowledge elicitation and knowledge representation in the knowledge based systems approach involves the iterative and interactive construction of a knowledge base involving repeated interaction between the knowledge base developer and the informant (s). The defining feature of this approach is the explicit representation of knowledge. The explicit representation of knowledge facilitates the consistent use of terms and the creation of coherent, consistent and unambiguous sets of knowledge which can be rigorously evaluated and used in the decision making process. Although formalism is a central task in ethnographic and natural resource management research, the potential role of formalism in the rigorous evaluation of knowledge has not been fully recognised and, therefore, has received little or no attention. Essentially, the knowledge based systems approach involves evaluating knowledge in terms of its utility which is the appropriate criteria in terms of the imperatives of agricultural development. Utility is defined in terms of the extent to which knowledge can be used in reasoning to answer questions about domain.

Knowledge based systems approaches are useful for more than the analysis of knowledge systems. Knowledge from a diverse set of sources can be brought together in a knowledge base. The collective power of the collated knowledge may be substantial because combining knowledge from a range of sources may bring together knowledge from researcher and development workers and that held by target communities on a defined domain. Such knowledge may be synthesised into an integrated resource to form encyclopaedic knowledge base that may be used effectively in a research and development context.

In summary, knowledge based systems techniques may provide a means for rigorous analysis of indigenous ecological knowledge and, once created, the knowledge bases may be maintained as a record of corporate knowledge which may be used for a variety of purposes in a research and development context. For these reasons a knowledge based systems approach was adopted in the present research to provide a framework for facilitating systematic and objective means of collating, recording and evaluating farmers' ecological knowledge about the management and use of farmland tree fodder resources.

2.4. RESEARCH STRATEGY

A major assumption of this study was that local people know a great deal about the management and use of the natural resources that they depend on for their livelihood (Chapter 1). However, while this may seem a reasonable expectation it was not supported in published literature concerning indigenous ecological knowledge specific to farmland tree fodder resource management, beyond unsupported assertions and anecdotal hints. Because of the paucity of supporting literature, initially the research strategy was kept flexible. As learning about the community and the way they manage and use their tree fodder resources progressed, this flexible and open framework was increasingly focused on the basis of the knowledge collected. Thus, a progressive and iterative process was adopted in developing research methods appropriate to what is, in effect, a novel area of research.

Examples from literature were used to guide the selection of appropriate research techniques (Spradley, 1979; Knight, 1980; Ellen, 1984; Werner and Schoepfle, 1987a; 1987b; Walker *et al.,* 1991). The fieldwork approach and strategy used by various authors (Mahat, 1985; Rusten, 1989; Hobley, 1990; Miller, 1990; Carter, 1991) researching other topics in Nepal also provided useful examples. The work by Knight (1980) provided considerable insights and was useful in developing the fieldwork approach and strategy. Knight's approach involved three stages:

- specification (surveying a small group of people, usually elderly, in order to get outlines of theories, terminology and domains);
- formalisation (surveying a small sample from the community to ensure that the community's knowledge systems are covered in depth); and
- generalisation (surveying a large sample from the community to assess the distribution and coherence of knowledge in the community).

The fieldwork strategy adopted in this study was adapted from the approach as advocated by Knight (*op. cit.*).

Given that local people's ideas, understanding and knowledge was the central interest of the study, it was reasonable to suppose that the best way of getting hold of this information was to talk to local people. Since interaction with the local community formed the primary element of the fieldwork, interviewing was a central component of the research. Various interview techniques and their implications for knowledge elicitation have been discussed by various authors (Kumar, 1987a; 1987b; Werner and Schoepfle, 1987a; 1987b; Dove, 1989) and their experience was used to guide the selection of appropriate interview strategies.

According to Spradley (1979) much research in biological and social sciences is centred on the systematic testing of explicit hypotheses. While this process of formalising research hypotheses before commencing fieldwork has proved useful, especially in biological sciences, for some research, such as the present study, where the researcher must assume the role of a learner, this approach is less useful. Given that the main aim of the research was to learn and record farmers' knowledge surrounding farmland tree fodder resource management and because of the anecdotal nature of supporting literature, initially it was appropriate to adopt an exploratory research strategy rather than formulating specific hypotheses for testing. Many authors (Spradley, 1979; Agar, 1986) have argued against formalising hypotheses before commencing fieldwork on the basis that the research process may be inhibited. However, these authors do recognise the need to define a general perspective, questions of interest and focus. Most anthropological studies commence in the field with a range of theoretically informed questions about research themes rather than with specific hypotheses to test (Lyon and Fischer, *pers. comm.*)[1]. It is this approach to fieldwork that most closely resembles that of this study.

Within social science research, Spradley (1979) distinguishes two types of research: informant-oriented; and subject-oriented research. Subject-oriented social science research usually has a specific goal, to test hypotheses. Work with subject-oriented research begins with preconceived ideas, while work with informant-oriented research

[1] Dr Wenonah Lyon and Dr Mike Fischer are anthropologists in the Department of Social Anthropology, University of Kent at Canterbury, UK.

begins with an assumption of ignorance. The fundamental differences between these two research approaches are summarised in Table 2.1.

Table 2.1 Fundamental differences between informant-oriented and subject-oriented research approaches.

Informant-oriented research	Subject-oriented research
What do my informants know about their culture that I can discover ?	What do I know about a problem that will allow me to formulate and test a hypothesis ?
What concepts do my informants use to classify their experiences ?	What concepts can I use to test my hypothesis ?
How do my informants define these concepts ?	How can I operationally define these concepts ?
What folk theory do my informants use to express their experiences ?	What scientific theory can explain the data ?
How can I translate the cultural knowledge of my informants into a cultural description my colleagues will understand ?	How can I interpret the results and report them in the language of my colleagues ?

Source: Spradley (1979)

The nature of this study required that it be approached in a way similar to that suggested by Spradley (*op. cit.*) using an informant-oriented rather than a subject-oriented research approach. Thus, in order to structure the information gathering process, initially the following broad research questions were posed:

- what are the farmers perceptions and what do they know about cultivation, management and use of farmland tree fodder resources ?
- what trees are most valued by villagers for fodder and why ? Is there a local system of classification and evaluation of fodder trees, and if so what are the attributes of the trees that are recognised and used ?
- are fodder trees planted randomly on farmland ? Are there any associations between fodder tree species and agricultural crops ? What factors influence villagers interest in where to plant a particular fodder tree species on their farmland ?

To address the above questions a multi-method research approach was adopted. This included: household level survey (3.3); inventory of trees grown on farmland (3.4); and the use of knowledge based systems techniques (Chapter 4). Although each of these methods was employed individually, they were selected and used to function in an integrated fashion. The use of a multi-method research approach facilitated the collection of different types of information essential to achieve research objectives. They also served as a cross-check on the consistency and reliability of information obtained from one method against another. Detailed description of each of these research methods are presented where results are presented from using them but a general overview is outlined below.

The household level survey was designed to gather both quantitative and qualitative information relating to: household composition; land holdings; livestock holdings; different types of crops and tree species grown on farmland; tree species preference by type (for example, fodder, fuelwood and timber); and general attitudes of farmers towards the cultivation, management and use of farmland tree resources. A random sample of 60 heads of household were surveyed using a structured questionnaire.

The farmland tree inventory was designed to gather information on different tree species being grown by the community, their uses and location on farmland. Data were collected from 30 out of the 60 farms in the household survey. By conducting an inventory of farmland tree resources, it was possible to obtain quantitative information to check verbal accounts. Additionally, it was also possible to use inventory information to check general observation and impressions gained about the management and use of farmland tree resources over the period of fieldwork.

The combination of information from the household level survey and farmland tree inventory provided the basic information required to define the boundaries of the study and formulate specific research hypotheses about farmers' ecological knowledge to be addressed in the subsequent knowledge acquisition phase. Additionally, they also helped to familiarise the author with the community and vice versa and helped to identify key informants for later stages of research.

The final method involved the creation of the tree fodder knowledge base through the application of a knowledge based systems approach involving the use of artificial intelligence techniques to formally represent and reason with knowledge (Chapter 4).

These methods were further supplemented by field inspection, direct observation and informal discussion with individuals and groups. However, information collected from casual observation and discussion was kept separate from knowledge derived from interview and was used only to further understanding by developing appropriate questions for later interview. Only knowledge articulated by key informants was used as primary data.

2.5 CONCLUSIONS

Agricultural systems in the mid-hills of Nepal are characterised by their complexity and variability. As a result, knowledge held by farmers can be expected to be complex, contradictory and widely dispersed amongst a range of sources. Coping with such knowledge and making use of it in agricultural development demands a systematic and objective means of collating, recording and evaluating knowledge from a range of sources.

Although there are numerous research techniques currently available and used in indigenous knowledge research, much practically oriented research remains largely descriptive and, therefore, of limited practical use in development. The effective use of local knowledge in a research and development context requires a means of capturing and recording available knowledge relating to land use problems which combines rigorous evaluation and facilities for using the knowledge for a variety of purposes to provide decision support.

While this research relied upon concepts and approaches in knowledge elicitation developed in the fields of anthropology and ethnography, knowledge based systems techniques involving the use of artificial intelligence methods to formally represent and reason with knowledge were proposed as an appropriate means of achieving the research objectives.

CHAPTER 3

SPECIFICATION

3.1 INTRODUCTION

The main objective of the research reported in this chapter was to obtain basic information about the cultivation, management and use of farmland tree resources in the study area that could be used to define the boundaries of the present study and generate specific research hypotheses about farmers' ecological knowledge to be addressed in the subsequent knowledge acquisition phase. Because of the anecdotal nature of existing literature (2.4), surveys were used to collect the basic information required. The surveys aimed to collect information on:

- what resources were available to the study population;
- what resource management systems were employed; and
- what the general perceptions and attitudes of farmers were towards the cultivation, management and use of farmland tree resources.

In order to achieve these objectives two surveys were carried out during this specification stage: the household level survey based on a structured questionnaire and the farmland tree inventory. The household survey gathered information on what farmers said they knew and did in regard to their farmland tree resources. The farmland tree inventory gathered quantitative information to check verbal accounts. On the basis of the household survey and farmland tree inventory, the distribution and use of farmland trees in the study area and preliminary findings relating to farmers' perceptions and attitudes towards the cultivation, management and use of farmland tree resources in general and tree fodder in particular are described.

3.2 THE CHOICE OF STUDY AREA

A village level approach to research was adopted. The choice of research site was, therefore, critical to achieve the research objectives and was discussed in detail with Pakhribas Agricultural Centre and local government as well as with the Koshi Hill Area Development Programme officials involved in the area. Previous research carried out along these lines has indicated that socio-economic variables such as wealth, gender and ethnic identity (Schroeder, 1985; Muller-Boker, 1987; Smith, 1990; Miller, 1990), geographical variables such as elevation, aspect and soil type (Upton, 1990) and tree product availability (Gilmour, 1990) should be considered when selecting a research site. It was, therefore, considered desirable to select a research site that would include a sufficient range in each of these variables to be able to consider their importance in determining knowledge held by farmers and to ensure that farmers knowledge from a range of conditions was sampled.

Following detailed consultation, a list of eight Village Development Committees were prepared. All of these Village Development Committees were visited before the final choice was made. After visiting these potential research sites, Solma Village Development Committee in Terathum district was selected as the research site. The criteria used for this selection were as follows:

- the site needed to have well managed fodder trees and shrubs on private farmland, which restricted the selection to between 500 to 2 000 m in altitude, as this is the altitudinal zone in which fodder trees are intensively managed on private farmland;
- the site needed to be populated by a mixture of different ethnic groups;
- the site needed to be a reasonable distance (at least four to five hours walk) from a motorable road and district headquarter in order to avoid potential bias, as such areas close to these infrastructural developments represent only a small portion of the mid-hills of Nepal; and

- the site needed to be outside the Pakhribas Agricultural Centre Local and Northern Target Area[1] to avoid bias associated with the influence created by previous Pakhribas Agricultural centre activity in the region.

3.3 HOUSEHOLD LEVEL SURVEY

3.3.1 Survey rationale

Given that the primary aim of the study was to learn from local communities about their knowledge of tree fodder management and use and because of the paucity of supporting literature, it was initially important that some understanding of the knowledge held by the local communities in the study area be gained and relationships established. Therefore, it was appropriate at this stage to conduct an exploratory survey in the study area. The instrument used for this stage was a structured questionnaire worked out in advance and pretested in a village situation for intelligibility, an English translation of the questionnaire used in the survey is presented in Appendix 1.

The survey was designed to gather both quantitative and qualitative information relating to: household composition; land holdings; livestock holdings; different types of crops and tree species grown on farmland; tree species preference by type (for example, fodder, fuelwood and timber); and general attitudes of farmers towards the cultivation, management and use of farmland tree resources including farmers' perceptions of the effect of farmland trees on crops. The limitations of using questionnaires to obtain information from farmers has been well documented (Moser and Calton, 1975; Gardener, 1976;

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[1] Pakhribas Agricultural Centre has concentrated its research and extension programme over the past 15 years across disciplines (agriculture, livestock and forestry) in seven Village Development Committees in Dhankuta district (known as the Local Target Area) and in seven Village Development Committees in Taplejung and two in Terathum district (known as the Northern Target Area). Because of its long-term involvement and the intensive nature of research and extension programme, Tollervey (*pers. comm.*), strongly argued that the results from these areas would be influenced by Pakhribas Agricultural Centre activity and, therefore, not representative of the larger part of the mid-hills of eastern Nepal. The research site was, therefore, selected outside the Pakhribas Agricultural Centre Local and Northern Target Area to avoid this potential bias. Mr F E Tollervey is the current Director of Pakhribas Agricultural Centre.

Richards, 1980) and the accuracy and validity of information collected using surveys in rural populations in Nepal has been discussed by Campbell *et al.* (1979) and Fisher (1987). The main criticism levelled against questionnaire based surveys is that the meaning ascribed to terms and concepts in the questionnaire often differ between researchers and informants, and questions are usually designed according to the researcher's world view which may differ from that of the population under consideration. For this reason, care was taken to use local terms and concepts appropriate to the local community. For example, although a cadastral survey was carried out in Solma some years ago (hence, farmers were expected to know their land holdings accurately), local land measurement units (for example, *mato-muri, mana-pathi,* and *hal*)[2] were used whenever farmers felt uncomfortable expressing their land holdings in *ropani* (the official land measurement unit in the hills - one *ropani* being approximately equivalent to 0.05 ha). The local measurement units were later converted to hectares. Efforts were also made to use as much open-ended questioning as possible. The intention was to put farmers at ease and to gain information through friendly interaction.

In addition to the use of the questionnaire form, interviews were tape recorded. The author was aware that the use of a medium (tape recorder) which is unintelligible to most of the rural population in Nepal could potentially create suspicion among farmers about the motive of the research project. For this reason, each farmer before being interviewed was asked whether recording of the discussion was acceptable to them. All of the 60 heads of household interviewed accepted the idea willingly. This process led to the questionnaire being used as a check list which facilitated open and easy discussion. Previous experience has shown that questionnaires are not flexible enough to accommodate the additional pool of information that often comes across during the course of an interview (Campbell *et al.*, 1979; Fisher, 1987). Recording interviews was a successful means of capturing useful

[2] The term *mato-muri* relates to the amount of land that produces a given amount of grain (one *muri* is approximately equivalent to 90 l); *mana-pathi* relates to the volume of seed required for sowing a given amount of land (*mana* is approximately equivalent to 750 ml and eight *mana* makes a *pathi*); and, *hal* relates to the amount of land that can be ploughed by a pair of oxen in a day.

information arising during the course of the interview but not covered by the questionnaire which otherwise would have been lost. The survey was carried out during July -August 1992.

3.3.2 Sampling and survey procedure

The preparatory phase of the study coincided with the local elections which were held during May 1992. This made it easier to obtain an updated electoral roll of the study area. However, because of uncertainty about its reliability the list was further cross-checked and corrected by consulting with the local people. This occasion was also taken as an opportunity for introduction, rapport establishment, and more importantly, presentation of the research proposal to the Solma villagers.

In order to obtain a representative sample from different ethnic groups and altitude each ward[3] was considered as a separate sampling unit and a 10% random sample of people selected in each ward. This resulted in a final sample population of 60 households. A summary of the sample population including their ethnic group composition, gender, age structure and socio-economic status[4] is presented in Figure 3.1.

[3] Each Village Development Committee is divided into nine wards. Each ward consists of at least one if not several hamlets.

[4] The socio-economic status of the study population was worked out using a simple wealth ranking technique (card sorting) described by Grandin (1989). Farmers in each ward were requested to conduct a wealth ranking using their own criteria. The most important criteria used by the farmer in determining economic status of an individual household was the number of months of food sufficiency that they obtain in a year. On the basis of food sufficiency, four economic categories were identified. Those households producing: surplus food for the family year round; just enough for a year; enough for about half the year; and enough for less than half the year. The information thus obtained was further supplemented by other subjective assessment based largely on observation of the size of participant's house and roofing materials used. McCraken *et al.* (1988) have advocated these supplementary parameters and Tamang (1992) has used them and found them to be useful and relevant indicators of prosperity among hill farming communities in Nepal. This information correlated closely with the donation list prepared by the school committees (using wealth as a main criteria) in a different ward of the study Village Development Committee.

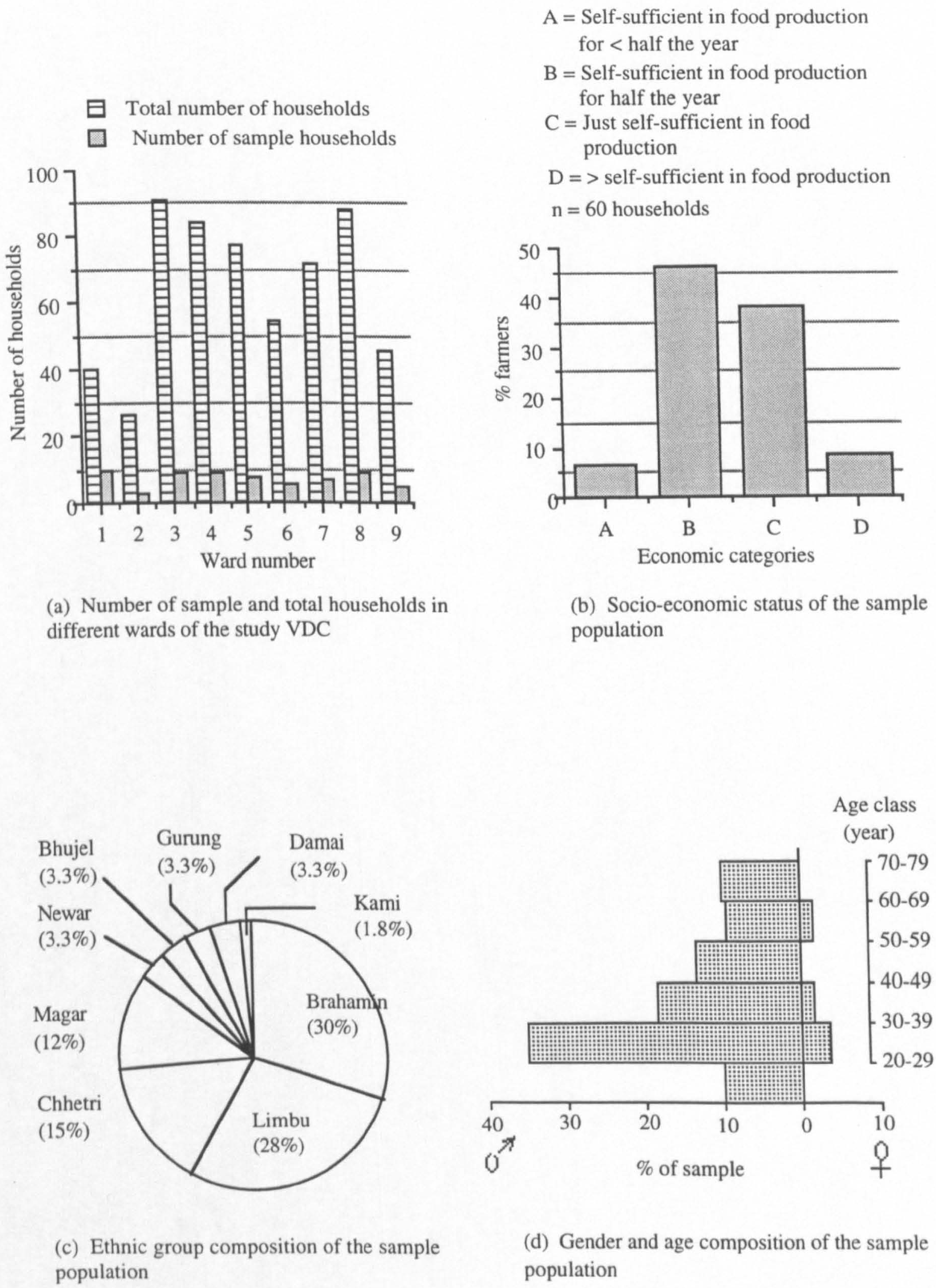


Figure 3.1 Composition of the sample population.

A list of alternate farmers was also prepared (selected randomly using the above criteria). Whenever a sampled farmer was unavailable at the scheduled time, an alternate farmer was interviewed. A total of 19 alternate farmers were needed to satisfy the desired final sample size. Three research assistants were used to administer the survey. They were divided into two groups (including the author), each group consisting of two members. Bell and Hardiman (1989) suggest that ideally there should be two interviewers in any interview process - an interviewer and a note taker or tape recorder operator. The first can then concentrate entirely on the interviewee while the latter will be free to observe the process and may, for example, be able to pick up an important issue missed or hinted at. Interviews were undertaken at the participants premises mostly either early in the morning or late in the evening as most farmers were busy transplanting rice and millet during the day time. Only the head of households[5] were interviewed (four out of 60 were women). This strategy, therefore, led to women being under-represented in the sample. As the objectives of the study were to get a general impression of tree fodder resource use prior to more detailed research involving sample stratification by gender, interviewing heads of household was an expedient choice. Because of the monsoon weather and, therefore, intensive seasonal agricultural activity, the heads of households were contacted to arrange an appointment one day before the scheduled time. For this reason only one farmer was interviewed per day by each group. At the end of each day a brief discussion was held with the research assistants to discuss the days work and any problems encountered and to plan the next day's research.

[5] Household is defined here as a family who eat food and farm their land together and head of household as a member of the household family who formally makes decisions regarding his/her family matters and day to day management of his/her farm. The head of households are usually elderly people who are, therefore, expected to be more knowledgeable about their local conditions and farm management. Of the total sample population, 10% of the heads of household were relatively young between 20-29 years of age who had recently separated from their parent family.

3.3.3 Research assistants

For the administration of the questionnaire to the 60 households, three research assistants were hired locally. The selection criteria used were as follows:

- the research assistants needed to be local residents;
- the research assistants needed to be able to read and write; and
- the research assistants needed to be able to communicate and work with the local residents.

The reasoning behind these criteria are obvious. However, from the reconnaissance visit it became clear that local dialects among the two major ethnic groups (Magar and Limbu) in the study area were widely spoken and it was necessary that at least one of the research assistants could understand and speak each dialect.

The research assistants underwent three training sessions. In the first session, the purpose and aims of the research project and survey were discussed. This was followed by reading the questionnaire and discussing each question in detail. In the last session, they were sent off to practice administering the survey in neighbouring households who were not part of the sample. The problems encountered during the practice sessions were also discussed. Some editorial changes in the wording of questions were made as a result.

3.4 FARMLAND TREE INVENTORY

3.4.1 Inventory rationale

The household level survey gathered information on what farmers said they know about and what they do with their farmland tree resources. Verbal statements often differ from behaviour as Harris (1974) has shown there may be significant discrepancies between what people do and what they say they do as determined by behavioural observation.

However, adoption of a long-term observational study would have been extremely time consuming. It was, therefore, necessary to devise a more cost effective method to capture some of the behavioural aspects relating to the management and use of farmland tree resources by the study population. By conducting an inventory of farmland tree resources, it was possible to obtain quantitative information to check verbal accounts. Additionally, it was also possible to use inventory information to check general observation and impressions gained about the management and use of farmland tree resources over the period of fieldwork.

There is a growing body of evidence to support the view that farmers in the mid-hills of Nepal are becoming more conscious about their farmland tree resources in response to pressure caused by rapid population growth, fragmentation of land holdings and reduced access to public forestland (Carter and Gilmour, 1989). As elsewhere in the mid-hills of Nepal, land is at a premium in Solma as nearly 80% of the households are barely self-sufficient in food production (3.4.2.2). As a result, it is reasoned that most, if not all trees grown on farmland are purposely cultivated and managed by the farmers.

3.4.2 Sampling and inventory procedure

For reasons discussed above, it was necessary that the participating farmers for the inventory work came from among those who participated in the previous household level survey. Of the 60 households who participated in the household survey, 30 households (50%) were chosen representing different ethnic groups, altitudinal ranges and socio-economic status. Farmer willingness to participate in the research process remained the single most important criteria for sample selection. Therefore, unlike the previous household level survey, sampling was purposive rather than random.

Before commencing the inventory work, the purpose of the inventory work was explained to the participating head of household and to his or her family members. Three research assistants who had conducted the previous survey were employed for the purpose and trained as necessary. They were divided into two groups (including the author), each group consisting of two members (one counted and took the measurements while the other kept the records).

Each head of household was contacted a day before the scheduled time in order to make an appointment. A member of the household was requested to accompany the team in order to identify farm plots, boundaries and to provide details regarding tree history. Farms were rarely one contiguous piece of land, but four or five pieces scattered across more than one agro-ecological zone. For this reason only one farm could be inventoried per day by each group.

3.4.3 Inventory timing and recording

The inventory work was carried out from mid November to mid December 1992. It was assumed that by this time weeds and ground vegetation would be minimal and crops already harvested by the farmers. The timing proved to be quite appropriate as the cultivated land was free of any unwanted vegetation and allowed small seedlings to be easily visible. Because it was an agriculturally slack period, farmers also had more time to devote to discussion.

Each plot of land owned by the sample households was visited and any woody perennial plants (however small) growing in it were included in the inventory. Each plant entered in the inventory was identified by farmer code and plot name, species[6], form (tree, shrub or bush, bamboo, woody vine), size (diameter), age, location within the plot and source of seedlings. Additional information on the altitude at which a particular plant was found growing, their uses, quality rating of species for major tree products (fodder, fuelwood and timber), characteristics of fodder tree species and any other comments made by the farmer relating to individual plants were also recorded on the inventory form. The

[6] All the plants counted in the inventory were recorded using the local name and later identified botanically from their Nepali name using references given by various authors: HMGN, 1976; Regmi, 1976; Panday, 1982; Howland and Howland, 1984; Shrestha, 1984; Kayastha, 1985; Jackson, 1987; Amatya, 1989; Carter, 1991.

detailed information recorded during the inventory including the inventory code details are given in Appendix 2.

3.4.4 Definition of plants to be measured

An equivalent Nepali word for tree is *rukh.* Each farmer was free to identify which plants growing on their farmland were considered to be trees or *rukh.* This led to inconsistency as some species considered as *rukh* by some farmers were considered merely as *buto* or *butiyaan* (shrubs or bushes) by others (this being largely influenced by the management practice applied to the plants by individual farmers). Therefore, all plants which farmers said had potential to grow into trees were recorded as trees. Since bamboo species were also considered *rukh,* these were also recorded as trees but separate notes were taken. The diameter of each tree above 5 cm dbh (diameter at breast height, measured at 1.3 m above ground level) was measured using a diameter tape. For multistemmed trees and trees branching below 1.3 m the diameter of each stem was measured at 30 cm above ground level. Trees below 5 cm dbh and those shorter than 1.3 m were counted as seedlings. Bamboo and banana were counted as clumps. Tree age was estimated by farmers with often convincing associations correlating the planting of trees with events such as weddings, births or deaths that occurred at the same time.

Some sample households in the study area were managing private forest of varying size mostly inter-cropped with cardamom, an important cash crop in the eastern hills of Nepal. A full inventory of small sized private forests was conducted. For larger plots (three out of the 15 plots of private forests recorded in the inventory fell into this category), estimation by establishing sample plots was considered but rejected as impractical for reasons of both time and accuracy, instead only observational notes were made.

3.5 BACKGROUND INFORMATION

This section examines and provides background information on the study area necessary to interpret local knowledge and its applicability in a wider context. General background information on the eastern hills of Nepal obtained from secondary sources are presented (3.5.1). On the basis of a household level survey detailed information including socio-economic conditions, description of the various ethnic groups and farming systems practised in the study area are described (3.5.2).

3.5.1 An outline of the eastern hills of Nepal

The mid-hills of eastern Nepal consist of strongly dissected relief ranging in altitude from 300 m to 500 m in the main river valleys with land rising steeply to the main ridges to 3 000 m. Most of the settled agriculture occurs between these altitudes. The wide range of altitudinal, topographical and geological variation results in a great range of climate and natural vegetation and contributes to the variation in the trees and crops cultivated in the area.

The climate is monsoonal with 80% to 90% of the annual precipitation falling between May to September. The meteorological data recorded at Pakhribas Agricultural Centre (the most reliable and representative of the larger part of the mid-hills of eastern Nepal available) are presented in Figure 3.2. These data are given to provide a general indication of climatic type and seasonal patterns. The wide altitudinal variation results in distinct climatic differences between settlements. Relatively dry or late monsoons occur every four to seven years on average (Conlin and Falk, 1979). At elevations above 1 500 m frosts can be expected from the first week in December to the third week in February.

Goldsmith (1982) noted that although soils in the area vary considerably over short distances, at elevations below 1 000 m, soils are weakly acid (pH 6.0-7.0) with a low cation exchange capacity but high base saturation, indicating that they are reasonably fertile.

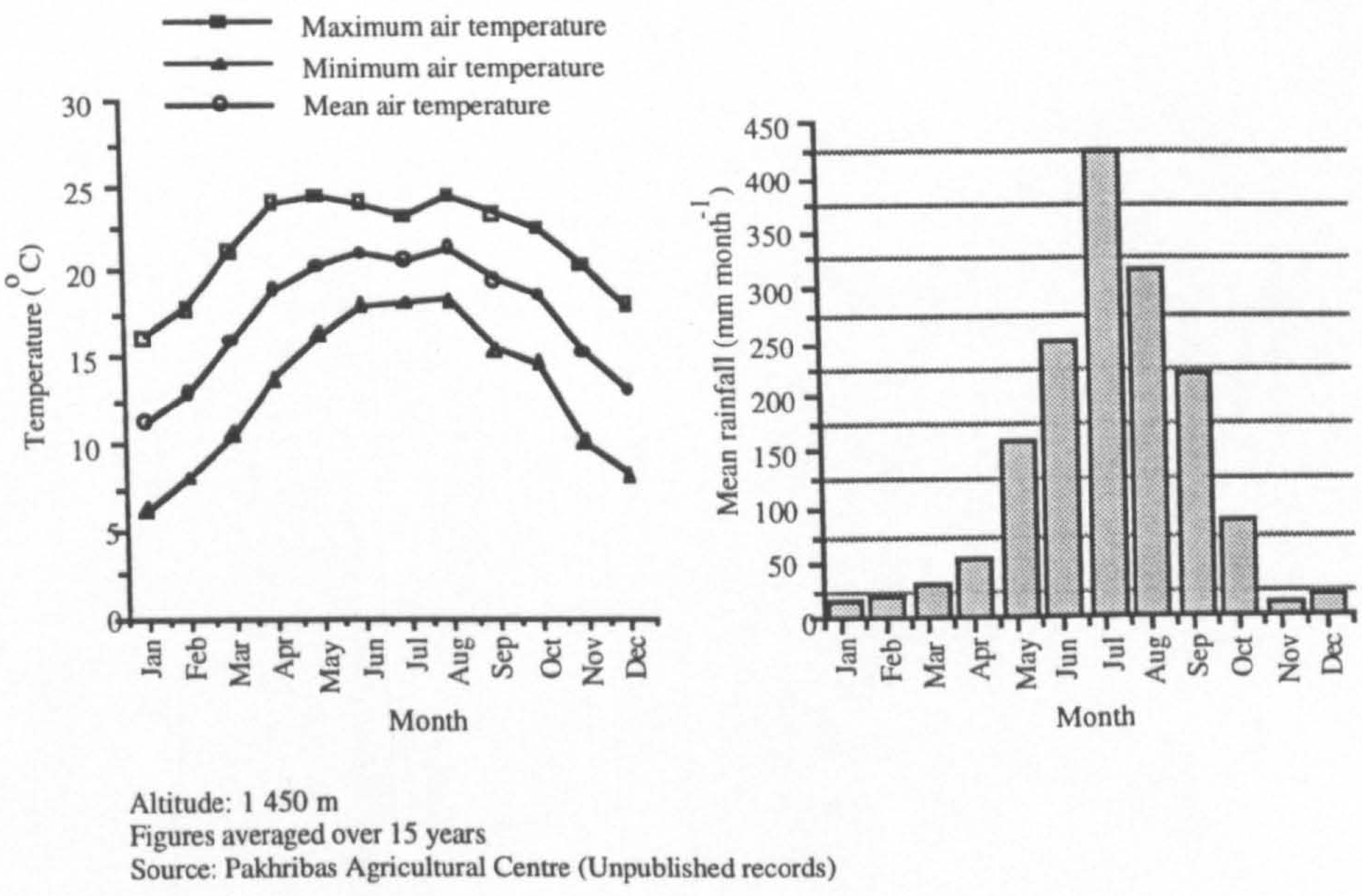


Figure 3.2 Meteorological data recorded at Pakhribas Agricultural Centre.

On the middle slopes (1 000 m to 1 500 m), soils are often deficient in nitrogen, but usually possess moderate amounts of available phosphorous and a high level of potassium. They are moderately fertile. Between 1 500 m and the upper cultivation zone at 2 000 m, the soils tend to be more acidic (pH 4.5-6.0) with a low cation exchange capacity and a low base saturation. Fertility is highly variable. Above 2 000 m, the soils become progressively more acidic and infertile.

The area is inhabited by a great variety of ethnic groups including Brahamin, Chhetri, Magar, Gurung, Rai, Limbu, Tamang, Sherpa, Newar, Damai, Kami and Sarki, with a population density of 85 persons per km^2 (Gibbon and Schultz, 1989). The agricultural system is subsistence to semi-subsistence in nature with 43% of the population having holdings less than 0.5 hectare (Conlin and Falk, 1979).

The study area, Solma Village Development Committee is located in Terathum district of the Koshi zone in the eastern hills of Nepal (Figure 3.3). The geographical location is $27^0 05' N$ - $27^0 10' N$ and $87^0 25' E$ - $87^0 30' E$. Solma is environmentally diverse (Figure 3.4). The area is situated on a long south and south-east facing slope with an elevation ranging from 500 m to 3 000 m. The study area forms a part of the catchment area of the Pinguwa *khola* (perennial hill stream), a tributary of the Tamur river (Figure 3.4).

Location map of Nepal showing Eastern Development Region

Map of Eastern Development Region showing the location of Terathum district

Map of Terathum district showing the location of Solma VDC

Figure 3.3 Location map of the study Area (Solma VDC)

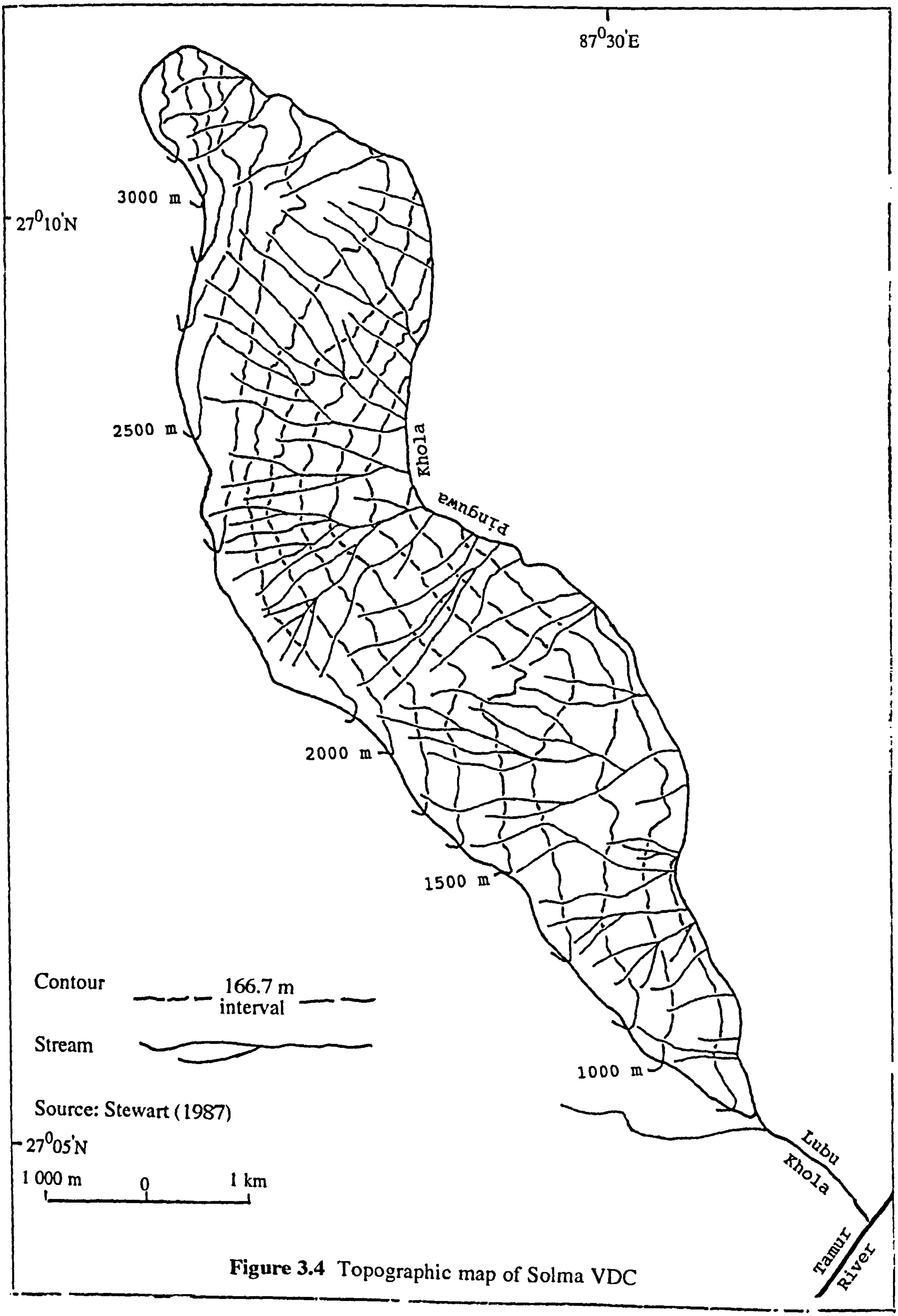


Figure 3.4 Topographic map of Solma VDC

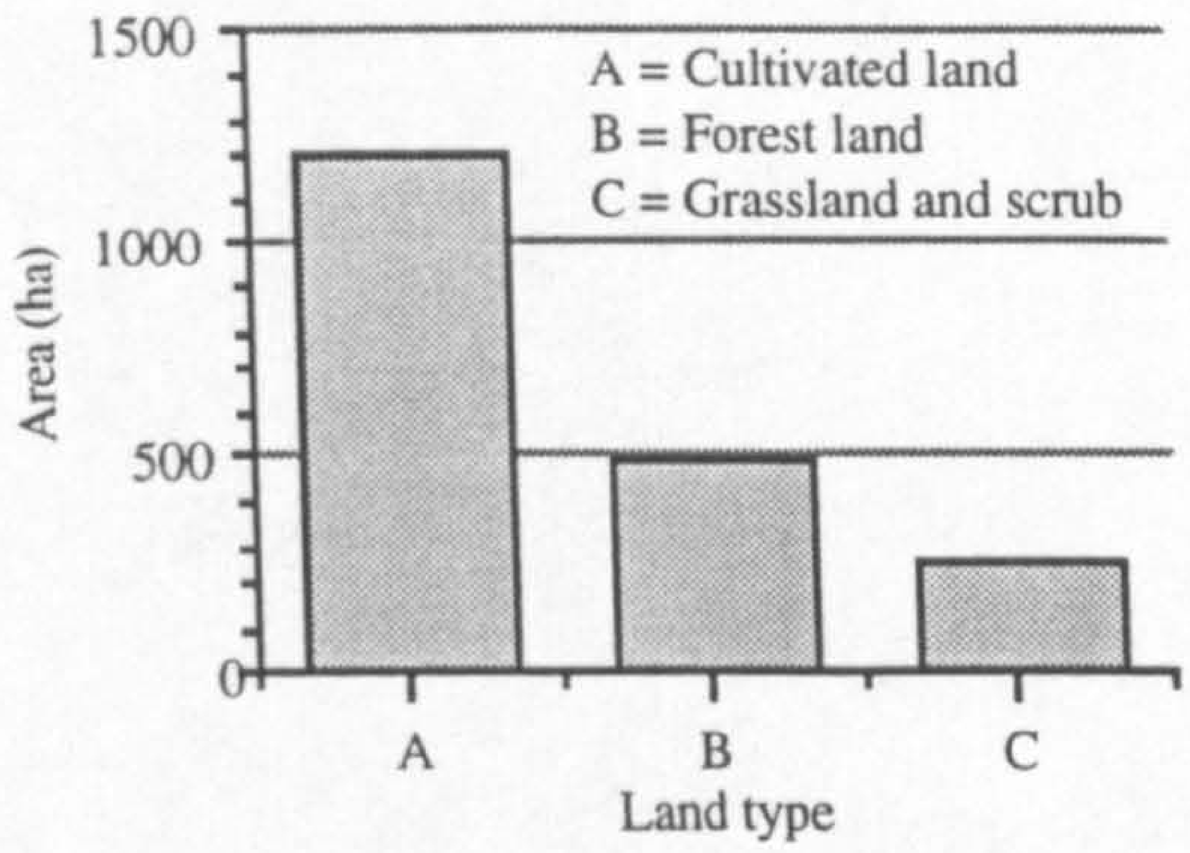
3.5.2 Description of the study area

3.5.2.1 Land use systems

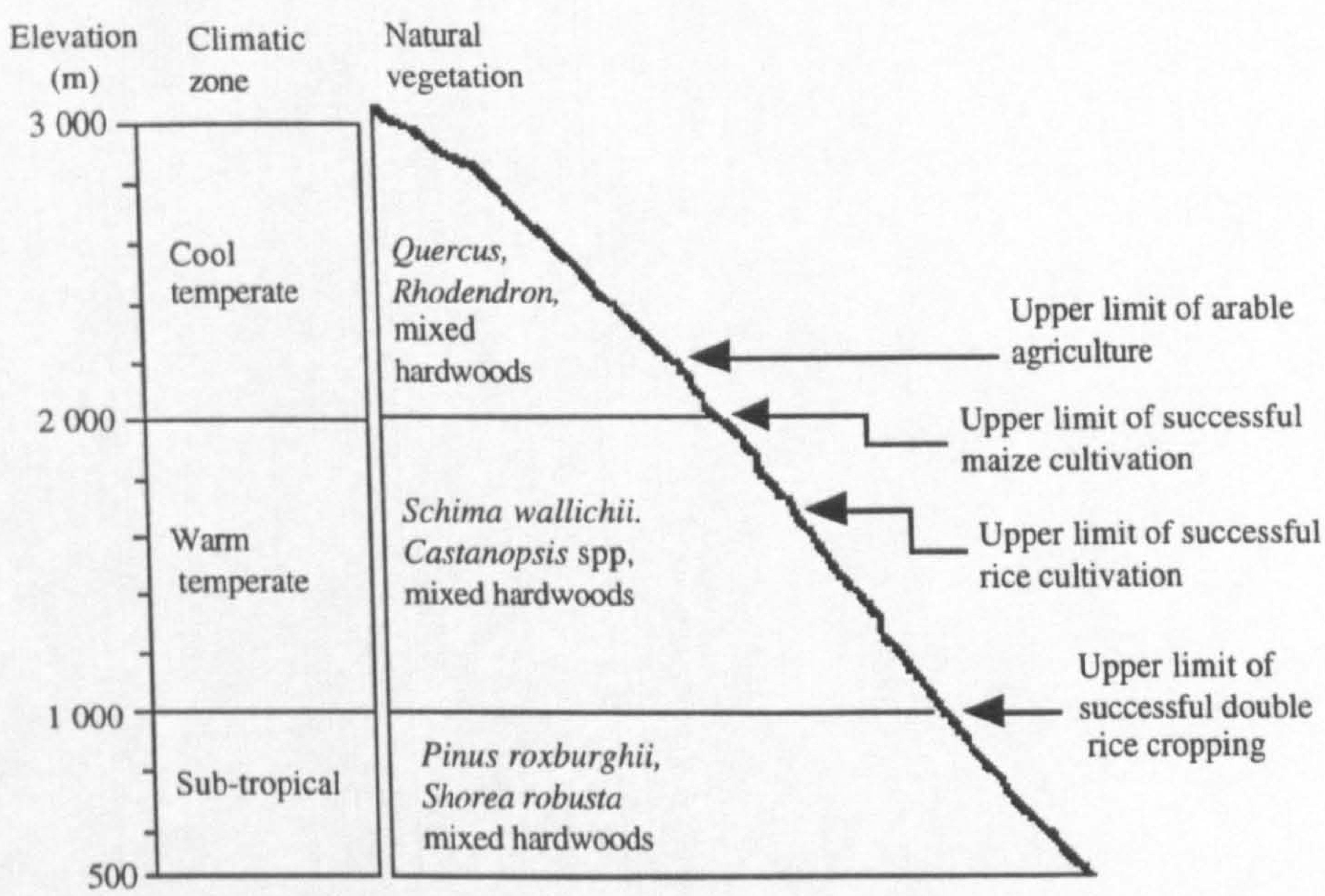
The available land use information including the relationships between elevation, climatic zone and land use in the study area are presented in Figure 3.5. Land use data for Terathum district at Village Development Committee level was not available. The figures presented here are calculated from the Land Resources Development Centre (LRDC) map (the most recent available) produced by Stewart (1987). This map was based on aerial photographs taken in 1978, hence, in the 14 years since the photographs were taken, it is probable that the amount of land under forest cover has decreased significantly and the area of cultivated land has increased as a result of agricultural expansion.

Of the total forested area (estimated at 482 ha), most of the forests used by Solma residents were concentrated above and below the areas of settlement, although they also occurred in small patches - often in a degraded form - around settlement areas. Using the definition of forest types given by Jackson (1987), three broad types of forest could be identified in the study area. At lower altitudes (below 1 000 m), Chir pine forests with *Pinus roxburghii* and *Shorea robusta* were characteristic of drier sites. Mixed hardwood forests on lower slopes occupied areas between 1 000 m to 2 000 m and were characterised by the presence of *Schima wallichii, Castanopsis* spp and *Alnus nepalensis.* At elevations above 2 000 m, upper slope mixed hardwood forests with *Rhododendron* and *Quercus* spp were dominant.

Grassland (locally known as *nagi*) estimated at 251 ha in Solma VDC, was a feature of the higher altitudes and represented an important grazing resource. The cultivated land was estimated at 1 200 ha in the study area. Within this cultivated land, trees were scattered over the whole area (predominantly fodder species) with broader bands of trees in drainage ways (predominantly *Alnus nepalensis*). Human settlements and cultivated land were largely confined to areas below 2 000 m in elevation.



(a) Land use in Solma VDC



(b) Relationship between elevation, climatic zone and vegetation in Solma VDC

Figure 3.5 Relationships between elevation, climatic zone, vegetation and land use in Solma.

Source: Derived from Stewart (1987)

3.5.2.2 Socio-economic considerations

3.5.2.2.1 The people of Solma

The total population of Solma according to records provided by the Village Development Committee office as at May 1992 is estimated at about 3 500, comprising 578 households. The average household size is estimated to be six persons per family.

Solma is inhabited by a great variety of ethnic groups that can be classified according to four caste hierarchies (Bennett, 1983). There are at least 13 distinct ethnic groups or *jat* that can be identified (Table 3.1). Four major caste hierarchies are recognised in Nepal: Brahamin; Ksatriya; Vaisya; and Sudra. Traditionally Brahamins held the role of priest while Ksatriya were considered as warriors. Ethnically, Brahamins and Chhetris are Indo-Aryan in origin and do not drink alcohol, although this is no longer strictly observed. The largest group are the Vaisya also termed *matawali* (meaning those who drink alcohol). These group include Magars, Rais, Limbus, Newars, Tamangs, Sherpas, Gurungs and Bhujels. Ethnically, they are Tibeto-Burman in origin. The last group are the Sudra and include Damais, Kamis and Sarkis. Their ethnic origin is uncertain. They are also termed the occupational caste (they are considered untouchable and water drawn by them is not accepted by other groups). Although the revised legal code of Nepal 1977 (*Muluki Ain* 2035) does not recognise any caste distinctions under law, in Solma as in other rural areas of Nepal caste dictates much of the social interaction.

Table 3.1 The caste hierarchy in Solma.

Sanskrit varna equivalent	Nepali varna or caste group	Caste or *jat* in Solma	Ritual category
Brahamin	Brahamin	Brahamin	
Ksatriya	Chhetri	Chhetri	
Vaisya	Matawali	Magar Gurung Rai Limbu Sherpa Tamang Newar Bhujel	Pure, water accepted by all the groups
Sudra	*Sano jat* (low or occupational caste)	Damai Kami Sarki	Impure, water not accepted by other groups

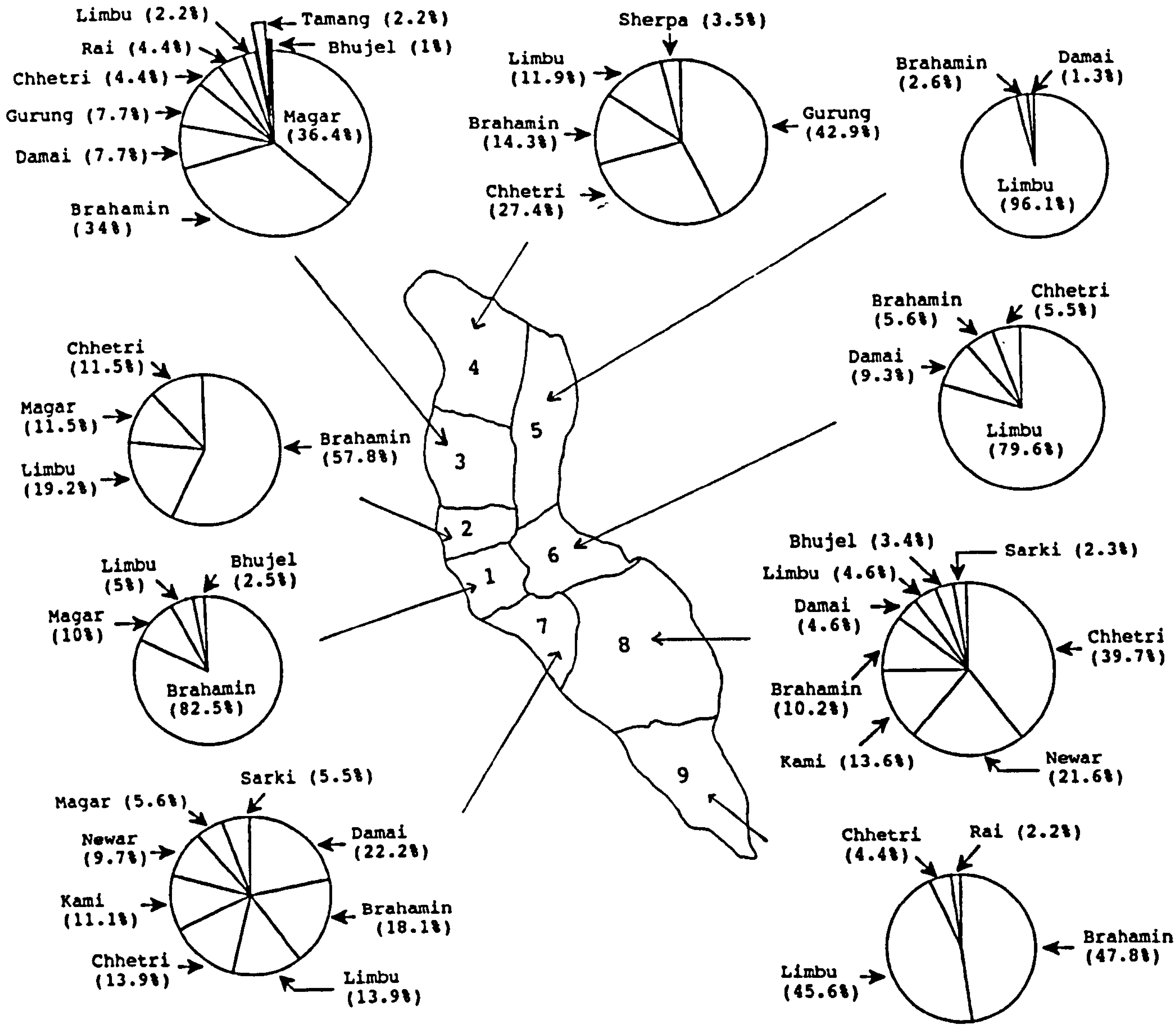
Source: Adapted from Bennett (1983)

As in other parts of the eastern hills, in Solma, although households are dispersed and there is some mixing of ethnic groups, the groups are often localised in terms of their settlement (Figure 3.6). Brahamins and Chhetris tend to live at mid to low altitudes where the agricultural fields are fertile and the climate is more favourable for intensive agricultural production. Limbus have come to dominate the middle elevations. Gurungs, Magars, Tamangs, Bhujels and Sherpas tend to live in the high altitude areas while Damais, Kamis and Sarkis, though limited in number, are scattered throughout the study area.

The male and female literacy rate in the study area was estimated to be 67% and 40% respectively, giving a figure of 53.5% for the population as a whole. The percentage is higher, both for men and women, than figures given for the whole of Terathum district which are 52.7% for males, 15.2% for females and 33.8% averaged for the district (Adhikari *et al.*, 1987). Despite the presence of a number of primary schools in the study area (their distribution in the study area being fairly uniform), a great variation in literacy exists among different ethnic groups from the most literate Brahamins (74%) to the lowest literacy rate of 18% for Gurungs.

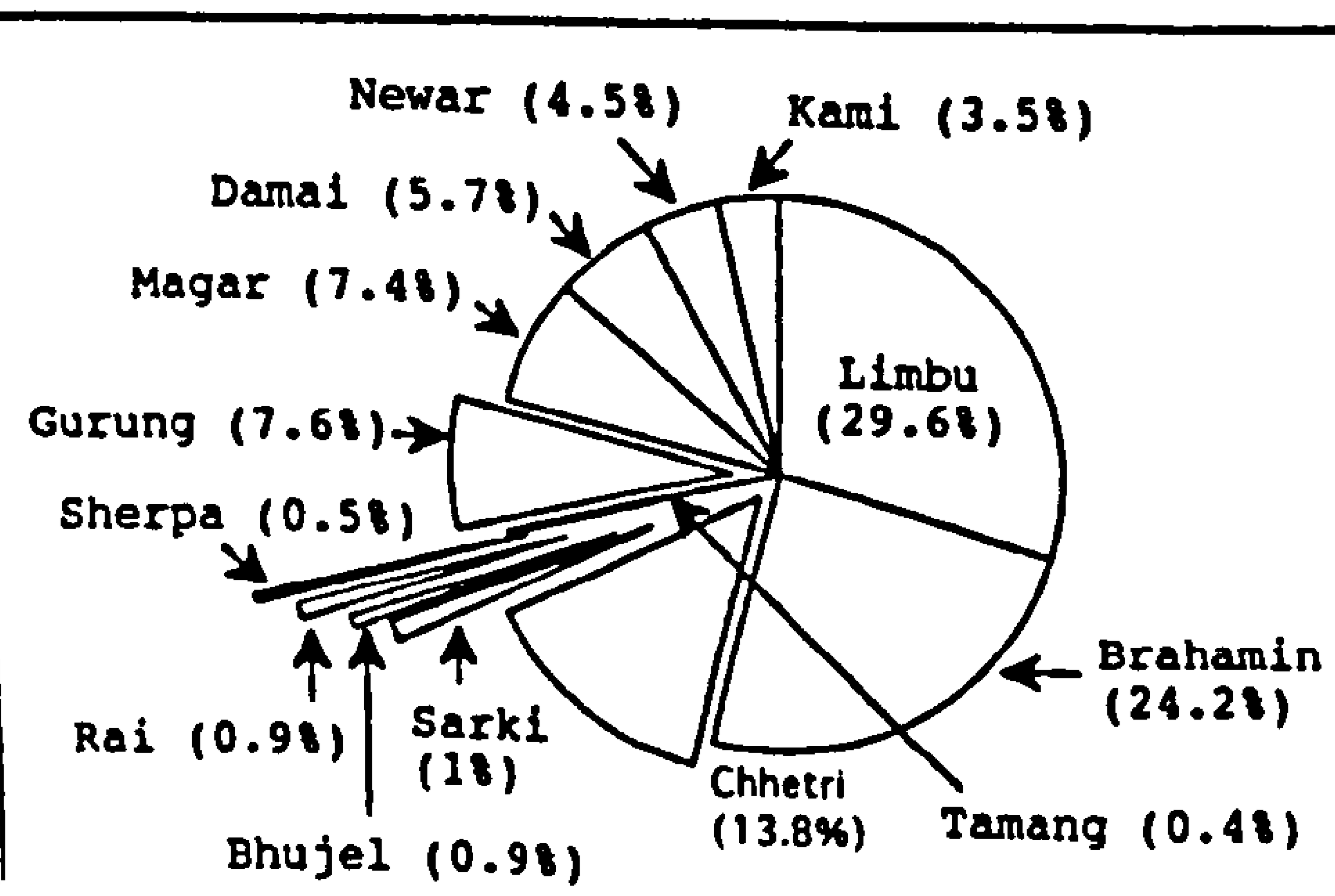
3.5.2.2.2 Economic activity

The major economic activity in the study area was agriculture. The farming systems in the area were largely of a subsistence nature. Conlin and Falk (1979) suggest that in the Koshi hill area (including Solma) farms under one hectare produce only 60-70% of household requirements. It can be noted that nearly 50% of the farms were cultivating less than a hectare of land (Figure 3.7.a). The land holdings is often fragmented. Economic categorisation of households by Solma farmers on the basis of food sufficiency also suggested that nearly 80% of the farm households were barely self-sufficient in food production (Figure 3.7.b).



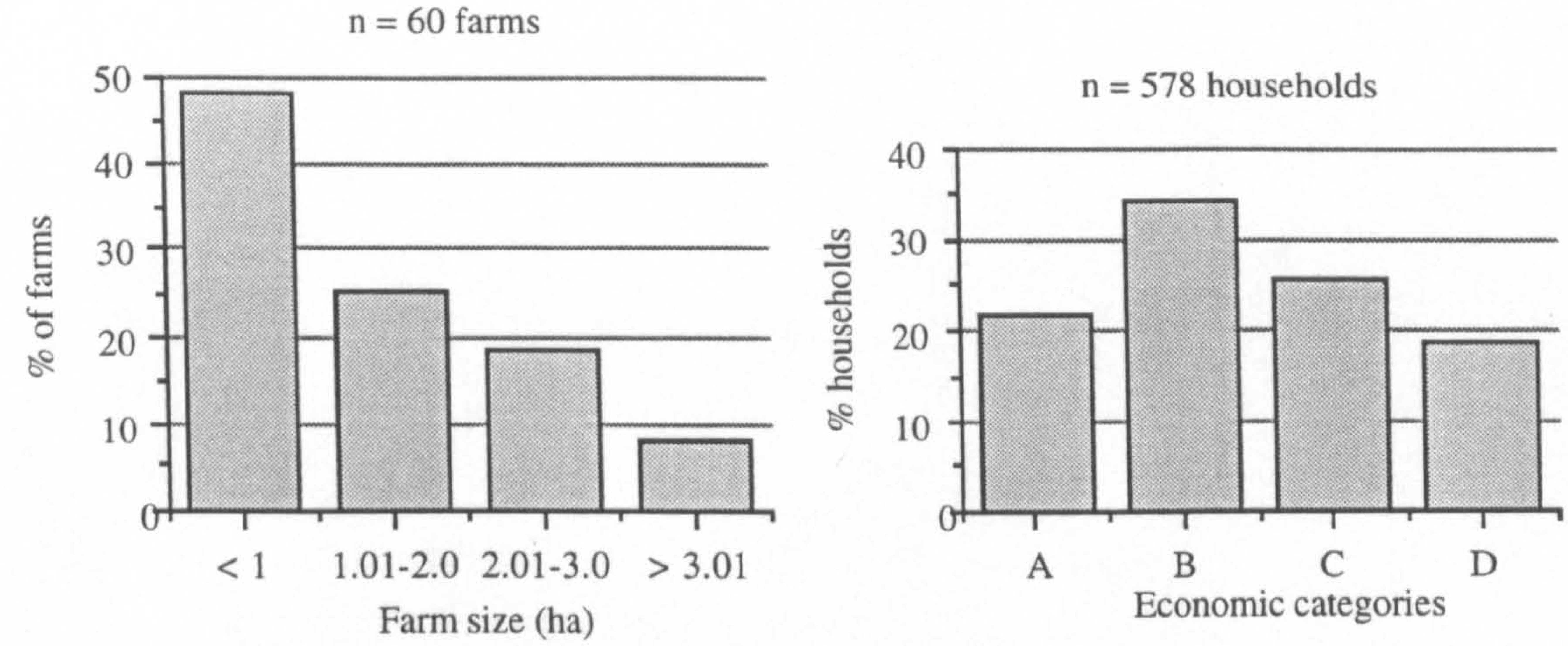
(a) Distribution of population by caste (ethnic group) in different wards of Solma VDC

Ward Number	Total Number of Households
1	40
2	26
3	91
4	84
5	77
6	54
7	72
8	88
9	46
Total	578



(b) Distribution of population by caste (ethnic group) in Solma VDC as a whole

Figure 3.6 Distribution of population by caste (ethnic group) in Solma VDC



(a) Land available for cultivation for farms in Solma by farm size

(b) Economic categorisation of households in Solma (based on food sufficiency)

A = Self-sufficient in food production for < half the year; B = Self-sufficient in food production for half the year; C = Just self-sufficient in food production; D = > self-sufficient in food production.

Figure 3.7 Land available for cultivation for farms by farm size and economic categorisation of households in Solma.

Many farms were dependent on gaining income from other sources to buy food. These sources include working on the farms of others, raising and selling small livestock (pig, poultry and goats), cottage crafts, portering and the army (both in-country and foreign, notably the Indian and British armies). Migration, temporary or permanent, by one or more members of the family was also traditional[7] (Blaikie *et al.*, 1980).

Solma has reasonable access to markets locally known as *haat* (local market held on weekly or fortnightly basis where goods are traded, mostly on a barter system) such as at Basantapur and Myaglung, both located at a distance of about four to five hours walk from the centre of Solma. Basantapur is the nearest motorable road head. Many people from Solma make a weekly trek to Basantapur and Myaglung where agricultural commodities and manufactured products are bought and sold each Monday and Friday respectively.

[7] At least one or two members of seven out of 60 households (roughly 12% of the households in Solma) at the time of this survey were working in India (mostly in Achham, engaged in mining and tea plantation) for one or two years. Many others leave the village periodically for weeks or months to supplement their farm income with wages.

3.5.2.2.3 Infrastructural development

As in other Village Development committees in Terathum district and elsewhere in the mid-hills of Nepal, Solma is served by various government agencies headquartered at Myaglung. Solma has one high school and each ward has a primary school. Solma also hosts a health post, livestock and agricultural services sub-centre, *Sajha* (co-operatives) and a forest and tea nursery. The major services provided by these government agencies include: primary health care; livestock extension and veterinary services; agricultural extension, credit and inputs; and distribution of tree and tea saplings to the farmers.

3.5.2.3 Farming system characteristics

3.5.2.3.1 Crop production

At least seven distinct types of agricultural land were identified in the study area: *bari* land (upper slope non-irrigated cultivated land); *khet* land (lower slope irrigated cultivated land); *kharbari* (land kept aside for growing thatch grass with widely spaced fodder or fuelwood trees); *nagi* land (upland grassland used primarily for rough grazing); *kharka* (an open grassland often in patches in forested areas at high altitude where animals are kept seasonally or permanently); *allaichii bari* (land used for growing cardamom predominantly intercropped with *Alnus nepalensis*); and *chiya bari* (land used for growing tea). However, *bari* land and *khet* land were the most important in terms of crop production. *Khet* land was generally the most productive and desirable agricultural land and was considered resistant to erosion. *Bari* land was often prone to erosion, however, in some cases soil nutrient losses through topsoil erosion were replaced by compost addition.

The mean land holding per household and the percentage of farmers owning different land types are presented in Table 3.2. There were virtually no absolutely landless households in Solma, and none amongst those sampled. The cultivated land was predominantly *bari* land with 100% of households owning some *bari* land as opposed to only 71% owning *khet* land. Although several cropping patterns can be identified, the most important in the study area were paddy based activities on *khet* land and maize based activities on *bari* land.

Table 3.2 Land type distribution and ownership pattern in Solma.

Land type	Mean land holding per household (ha), range in brackets	% of farmers sampled that owned each land type
Bari land	0.8 (0.05 - 4.7)	100
Khet land	0.7 (0.05 - 2.8)	71
Allaichii bari	0.2 (0.05 - 0.8)	38
Kharbari	0.4 (0.05 - 1.0)	14
Nagi	0.4 (0.20 - 1.0)	9
Kharka	0.8 (0.25 - 2.5)	7
Chiya bari	0.2 (0.05 - 0.7)	3

Maize is the single most important rainfed crop. It is principally grown < 2 000 m. Seed is sown in April and the harvest is in late August. Maize is usually either intercropped with soybeans or relay cropped with millet. Paddy, the preferred crop, is grown in the valley bottoms and on lowland areas wherever the slope permits irrigation. Transplanting is done during the monsoon (June-July) and harvesting occurs in October. Millet is normally transplanted between maize rows during July and harvested in November. Wheat is cultivated in winter after the paddy harvest.

Other crops include potatoes, barley, buckwheat, mustard, grams and pulses and form an important component of the local diet. Cash crops are usually scarce, and include cardamom and tea. A limited range of fruits and vegetables are grown around the homestead, mainly for household consumption.

The diversity of crops grown in the study area is partly explained by the multitude of ecological niches related to elevation that occur in and around villages. Crop diversity is also one of the farmers' strategies for reducing risk in the face of a relatively harsh and highly variable climate (Schroeder, 1985).

3.5.2.3.2 Animal husbandry

Livestock play an important role in the farming systems of Solma. Almost every farm maintained a range of animals, namely cattle, buffaloes, sheep, goats, pigs and poultry. The livestock ownership pattern[8] in the study area is indicated in Table 3.3. Ruminant livestock had the most direct influence on land management. Cattle were the most important group. The main purpose of keeping cattle was to provide draught power for which males were used. Buffaloes were reared mainly for milk production. Organic manuring of fields, arising from animal husbandry, was an essential aspect of subsistence agriculture in the study area as chemical fertiliser was prohibitively expensive and not readily available to most Solma farmers.

Table 3.3 Livestock ownership pattern in Solma.

Livestock type	Mean livestock holding per household (number of animals), range in brackets	% of farmers sampled that owned each livestock type
Cattle	3.0 (1 - 11)	97
Buffalo	1.4 (1 - 3)	65
Goats	4.0 (1 - 12)	85
Sheep	2.3 (1 - 3)	5
Pigs	1.3 (1 - 3)	47

[8] Because of religious reverence (Nepal being a Hindu Kingdom) the law of Nepal forbids the slaughter of cattle and any other form of female animal, which means that a relatively large number of animals are maintained on farms. Because of religious beliefs, Brahamins and Chhetris traditionally do not eat and keep pigs, however, this is no longer strictly observed.

Lack of fodder was considered by farmers as the most important constraint to increasing animal production in the study area. The animals were fed during the monsoon season with grasses and other herbaceous material collected mainly from agricultural land, and during the dry season with crop residues and tree fodder primarily collected from private farmland. Animals were frequently grazed on agricultural land during the fallow period by building temporary stalls so that animal manure was deposited in fields and a fertility benefit for crop production was obtained.

3.5.2.3.3 Farm-forest dependency

As in other parts of rural Nepal, trees in one form or another are of great significance in the farming systems of Solma. Fuelwood was the only component of significant energy source and trees are essential in animal husbandry, not only as fodder but as bedding material, which eventually provides organic fertiliser for agricultural land. Tree products were also used in construction and for agricultural tools and implements.

While many of these products were also produced from public forestland they were rarely available in sufficient quantities from common property resources to satisfy demand because of the generally poor quality of forests in and around Solma. Therefore, mainly private sources of tree products were necessary to satisfy the demand of most farmers. The management and utilisation of public forests in the study area was a shared responsibility and forest products such as fodder, fuelwood, timber and leaf-litter were generally treated as free goods. This, combined with uncontrolled grazing and annual forest fires, has profoundly altered the quality of forests as a resource.

Since access to natural forests in terms of farmer's tree product supply is diminishing, trees on private farmland have become essential in sustaining the farming systems of Solma. Almost every household relied on farmland trees for fodder, fuelwood, timber and a range of minor tree products.

3.6 DISTRIBUTION OF FARMLAND TREES IN THE STUDY AREA

In this section general information is presented on the distribution of farmland tree species in the study area. Based on data derived from the farmland tree inventory and household survey, the distribution of farmland trees in relation to species composition, elevation and land holdings are presented as well as relationships between livestock number owned and number of fodder trees maintained on farms.

3.6.1 Species composition and diversity

The inventory data revealed that a great variety of tree species were managed on farmland in the study area. From the 30 sample households, a total of 129 species were recorded within the altitudinal range 500 to 2 000 m. Of these, 90 species were recorded as fodder, 23 species as non-fodder (mainly fuelwood and timber) and 16 species as fruit trees. Species recorded in the inventory with their local and botanical name, family and uses are presented in Appendix 2.B. A simplified rating of all species for major tree products (fodder, fuelwood, timber including fruit), fodder characteristics, altitudinal range and frequency of occurrence are presented in Appendix 2.C. In all, a total of 7 110 plants were recorded, of which, 6 350 plants (89.3%) were used as fodder in some form. The categorisation of species recorded in the inventory according to their type (3.4.4) revealed that of the 129 species , 106 species (including five species of bamboo) fall under the tree category, 25 species were shrubs and two vines or climbers.

Most species recorded in the inventory have a narrow altitudinal range. It is, therefore, appropriate to consider species assemblages separately according to elevation. Solma farmers recognise three distinct agro-ecological zones locally known as *lekh, kachhad* and *aule.* These terms are equivalent to high, mid and low altitude and roughly correspond to greater that 1 500 m , between 1 000 and 1 500 m and less than 1 000 m in altitude, respectively. However, because of the predominant occurrence of the same species in *lekh* and *kachhad* areas, for the purpose of analyses, data from these two elevations were combined and treated as high altitude species.

3.6.1.1 High altitude species

In total, 83 species were recorded at higher elevations of which 59 were fodder producing. The population of all plants at higher elevations in Solma was dominated by five species: *Alnus nepalensis; Ficus nemoralis; Leucosceptrum canum; Prunus cerasoides;* and *Ficus roxburghii* that accounted for more than 66% of the total number of plants recorded at higher elevations (Figure 3.8). The dominant species found in higher elevations of Solma were not dissimilar to those reported by Rusten (1989) for Salija in the western mid-hills and Carter (1991) for Suri in the central mid-hills at a site lying at similar elevation. With two exceptions (the absence of *Leucosceptrum canum* both in Salija and Suri and the absence of *Ficus roxburghii* in Salija) which were not cultivated as widely in these areas as in Solma, four of the most common species at higher elevations in Solma, *Alnus nepalensis, Ficus nemoralis, Ficus roxburghii* and *Prunus cerasoides* were also the most common in other study areas.

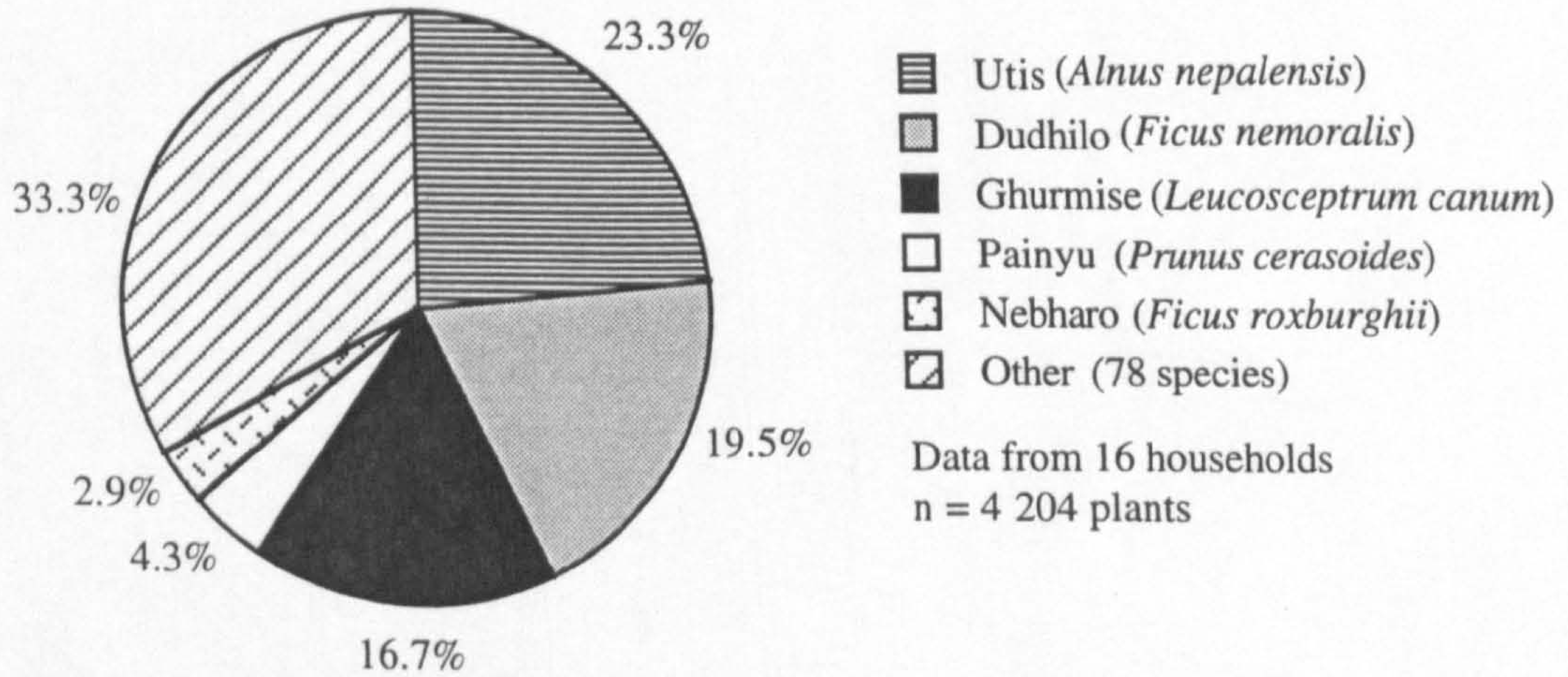


Figure 3.8 High altitude farmland tree species assemblage. Figure refers to density or number of individuals and includes all age classes.

A simplified rating from grade 1 (excellent) to grade 3 (poor) of all species for major tree products (fodder, fuelwood and timber) recorded in the inventory (Appendix 2.C) revealed that five of these dominant species supplied at least two or more important products to the household. Of the five dominant species, three (*Ficus nemoralis, Leucosceptrum canum* and *Ficus roxburghii*) were considered as grade 1 fodder while the other two (*Prunus cerasoides* and *Alnus nepalensis*) were grade 3 fodder. In terms of their fuelwood value, *Ficus nemoralis, Leucosceptrum canum, Prunus cerasoides* and *Alnus nepalensis* were considered as grade 1 while there was disagreement among informants about the fuelwood value of *Ficus roxburghii. Alnus nepalensis* and *Prunus cerasoides* were considered as grade 1 timber while *Ficus nemoralis* was considered as grade 2 timber.

3.6.1.2 Low altitude species

At low elevations, a total of 105 species were recorded of which 72 species were fodder producing, slightly more than at higher elevations. A similar trend in increase in the number of farmland tree species with decrease in altitude has been reported by Carter and Gilmour (1989) in central Nepal. As in the case of higher elevations, the population of all plants at lower elevations was dominated by five species: *Vitex negundo; Bauhinia purpurea; Rhus parviflora; Schima wallichii;* and *Colebrookia oppositifolia.* These five dominant species accounted for almost 45% of the total number of plants recorded in the inventory at low elevations (Figure 3.9).

Of the five dominant species, *Vitex negundo, Rhus parviflora, Colebrookia oppositifolia* and *Bauhinia purpurea* were considered as grade 1 fodder and *Schima wallichii* as grade 3 fodder. The former three species being particularly valued as goat fodder. In terms of their fuelwood value, *Rhus parviflora, Vitex negundo, Colebookia oppositifolia and Schima wallichii* were considered as grade 1 while *Bauhinia purpurea* was considered as grade 2 fuelwood. *Schima wallichii* was considered as grade 1 timber while the wood of *Vitex negundo* and *Bauhinia purpurea* were valued for making agricultural tools and household implements.

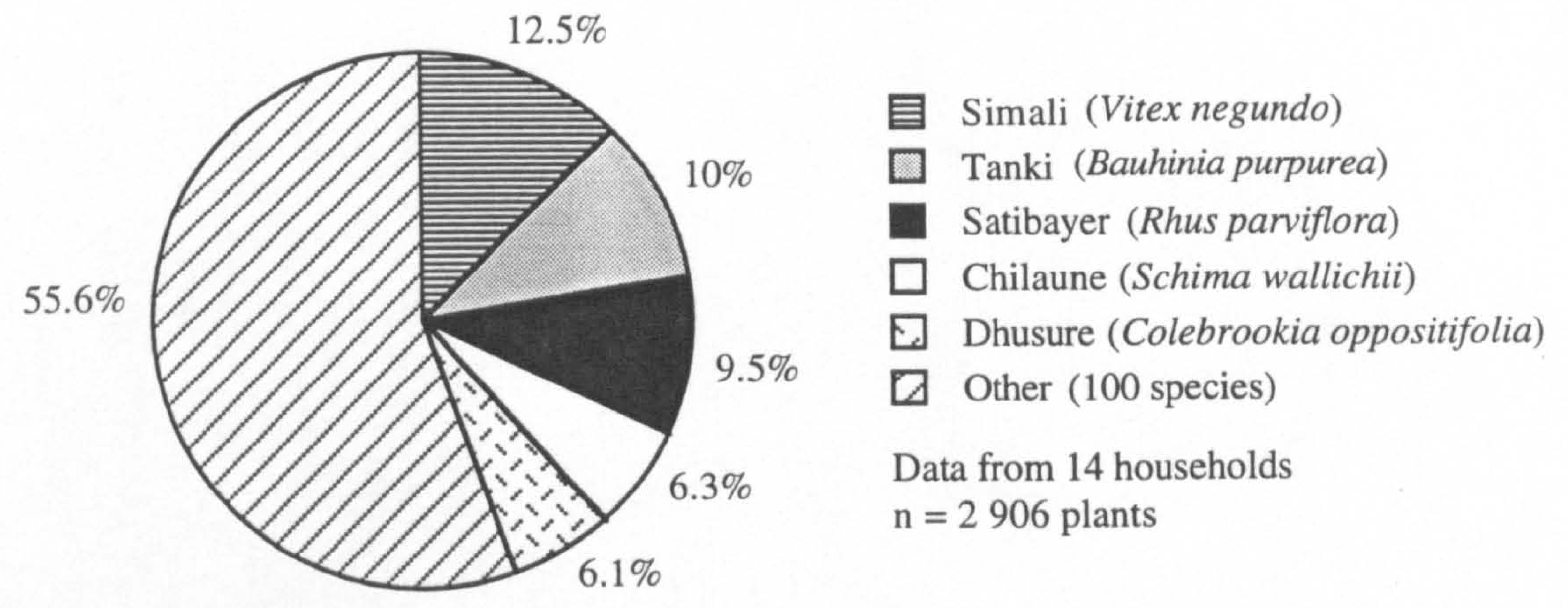


Figure 3.9 Low altitude farmland tree species assemblage. Figure refers to density or number of individuals and includes all age classes.

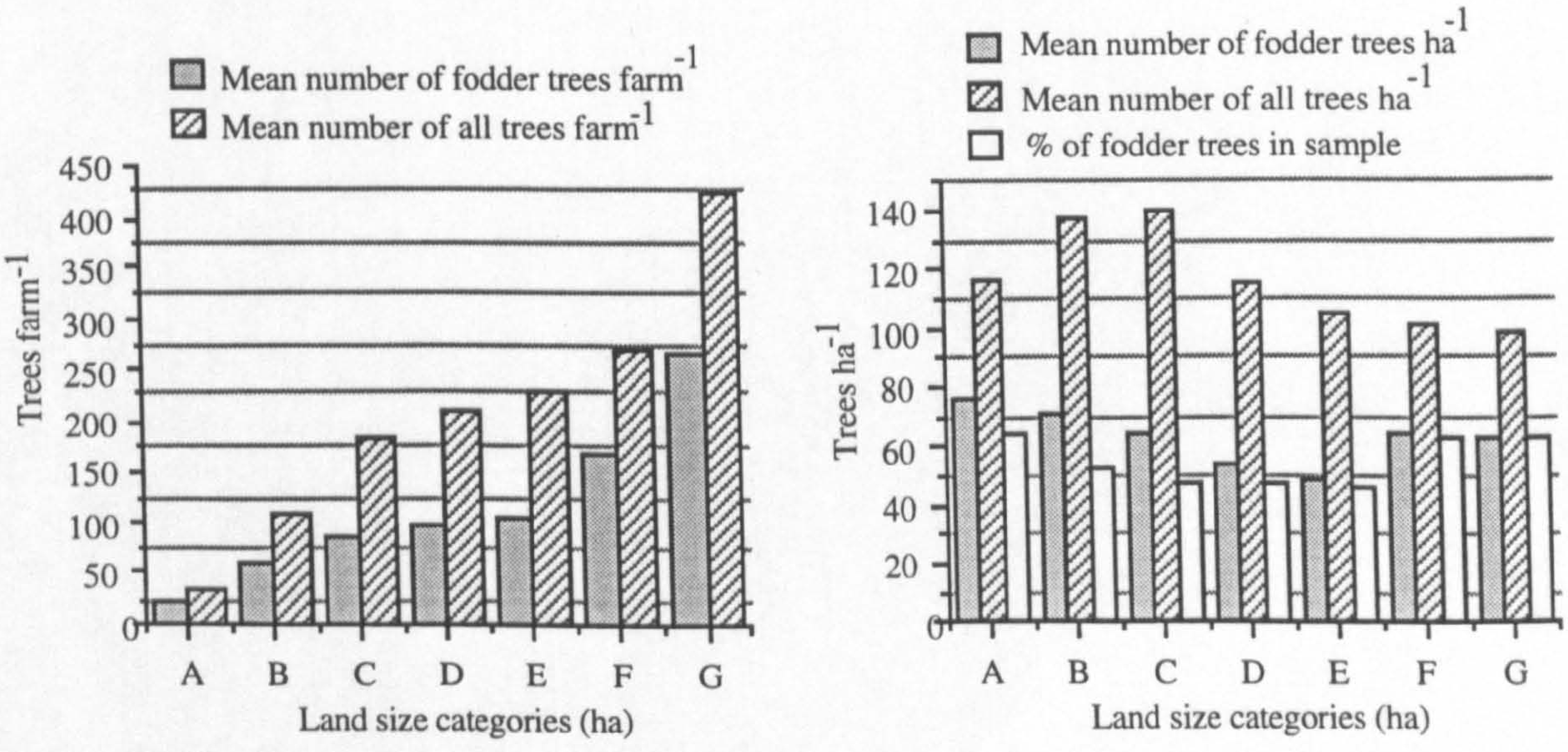
The complex nature of farming systems practised in the study area in which crops, livestock and trees are inextricably interwoven necessarily puts a multiplicity of demands on tree products. This may partly explain the reason for favouring species which supply multiple products to meet farmers' tree product needs.

It is interesting to note that although *Leucosceptrum canum* was extensively managed as a small shrub on crop terrace risers at higher elevations and *Colebrookia oppositifolia, Rhus parviflora* and *Vitex negundo* as live fences along field boundaries (often as boundary markers), around cattlesheds and in areas susceptible to landslips (especially *Vitex negundo*) and are clearly important agroforestry species, there is no previous mention of these species in forestry and agroforestry related research and extension literature in Nepal.

3.6.2 Distribution of trees by farm size

The mean number of all trees and fodder trees per farm and per hectare by land size category are presented in Figure 3.10.a and Figure 3.10.b respectively. Data were collected from all 30 farms who participated in the inventory. While the number of farms in each land size category are too small to merit formal analysis the mean number of trees per farm tended to increase as land holding size increased (Figure 3.10.a). However, the density of trees per unit area of land was higher in land holding sizes < 2 ha than on larger farms, suggesting that it may be the smaller farms who cultivate trees more intensively on their farmland than those with larger farms.

Figure 3.10.b shows how the composition of trees changes as land holding changes. On land holdings of less than 0.05 ha, nearly 65% of all trees are fodder species. These percentage decrease to 52.3%, 46.3%, 46.9% and 45.8% in the next four land size categories while the percentage of other type of trees tend to increase. These data suggest that as land size decreases, farmers focus their tree planting on fodder producing species. However, for land sizes greater than 2.5 ha, this apparent trend changes and fodder species become a greater percentage of total trees maintained on the farm. This change in percentage distribution of fodder trees may be partly the result of the increasing number of livestock that farmers with larger land holdings generally own.



(a) Mean number of all trees and fodder trees per farm by land size category

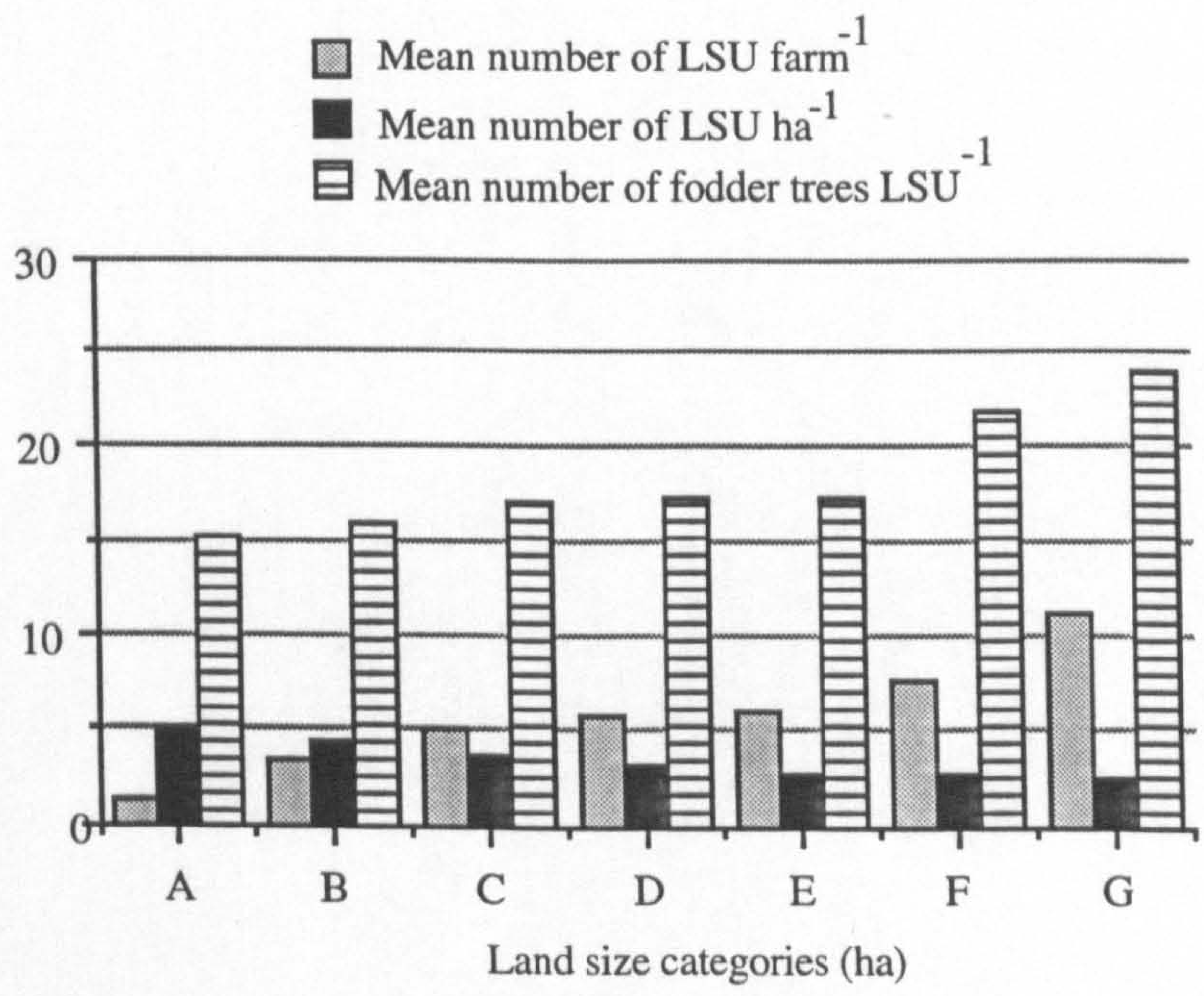
(b) Mean number of all trees and fodder trees per hectare by land size category

A = < 0.49 ha (n = 6 farms); B = 0. 50 - 0.99 ha (n = 5 farms); C = 1.0 - 1.49 ha (n = 3 farms); D = 1.5 - 1.99 ha (n = 4 farms); E = 2.0 - 2.49 ha (n = 3 farms); F = 2.5 - 2.99 ha (n = 3 farms); and G = > 3 ha (n = 6 farms).

Figure 3.10 Mean number of all trees and fodder trees per farm and per hectare by land size category.

3.6.3 Distribution of fodder trees by livestock holding

The mean number of livestock units (LSU)[9] per farm and per hectare and the mean number of fodder trees per LSU by land size category are presented in Figure 3.11. While the mean number of LSU per farm tended to increase with increased land holding size, the density of LSU per hectare tended to decrease as land holding size increased. These data suggest that it is often the smaller farmers who maintain high livestock number per unit area of land which may partly explain why a high percentage of their trees are fodder trees. Livestock density, however, tended to decrease with increased land holding size so that farmers with larger farms had more fodder trees per LSU than those with smaller farms.



A = < 0.49 ha (n = 6 farms); B = 0. 50 - 0.99 ha (n = 5 farms); C = 1.0 - 1.49 ha (n = 3 farms); D = 1.5 - 1.99 ha (n = 4 farms); E = 2.0 - 2.49 ha (n = 3 farms); F = 2.5 - 2.99 ha (n = 3 farms); and G = > 3 ha (n = 6 farms).

Figure 3.11 Mean number of livestock unit per farm, per hectare and the mean number of fodder trees per livestock unit by land size category.

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9 A buffalo is treated as 1.5 LSU; a cow as 1 LSU and a sheep or goats as 0.2 LSU (Dutt, 1979)

The mean number of LSU per farm and the mean number of fodder trees per LSU for the whole study area were calculated as 5.8 and 18.2 respectively. While the number of LSU per farm in Solma is comparable to data reported by Hawkins and Malla (1983) for Dehimando Village Development committee in the western mid-hills (5.9 LSU per farm), the average value of 4.1 fodder trees per LSU reported by Hawkins and Malla (*op. cit.*) differs markedly. These differences may be caused by differences in the survey methods or generally reflect differences in the livestock and tree husbandry in the two areas. Experience has shown that farmers have little or no problem in knowing how many livestock they own but that they may have some difficulty in recalling the number of fodder trees being grown on their farmland. It is also likely that farmers count only mature trees supplying fodder when they are asked to report on the number of fodder trees they own. Unlike Hawkins and Malla's (*op. cit.*) data, which was based on farmer reporting, the number of trees in the present study were individually counted by the enumerators and, therefore, may be a more accurate measure of the number of trees on farms. Additionally, all age classes of trees were counted and this may have resulted the higher number of fodder trees per LSU in the present study than that reported by Hawkins and Malla.

3.7 FARMERS' PERCEPTIONS ABOUT CULTIVATION, MANAGEMENT AND USE OF FARMLAND TREE SPECIES

The basic information required to generate specific research hypotheses about farmers' ecological knowledge to be addressed in the subsequent knowledge acquisition phase are presented in this section. On the basis of the surveys carried out in the study area, preliminary findings relating to farmers' practice and attitudes towards cultivation, management and use of farmland tree resources are presented.

3.7.1 Farmland tree cultivation practices

3.7.1.1 Tree planting activities

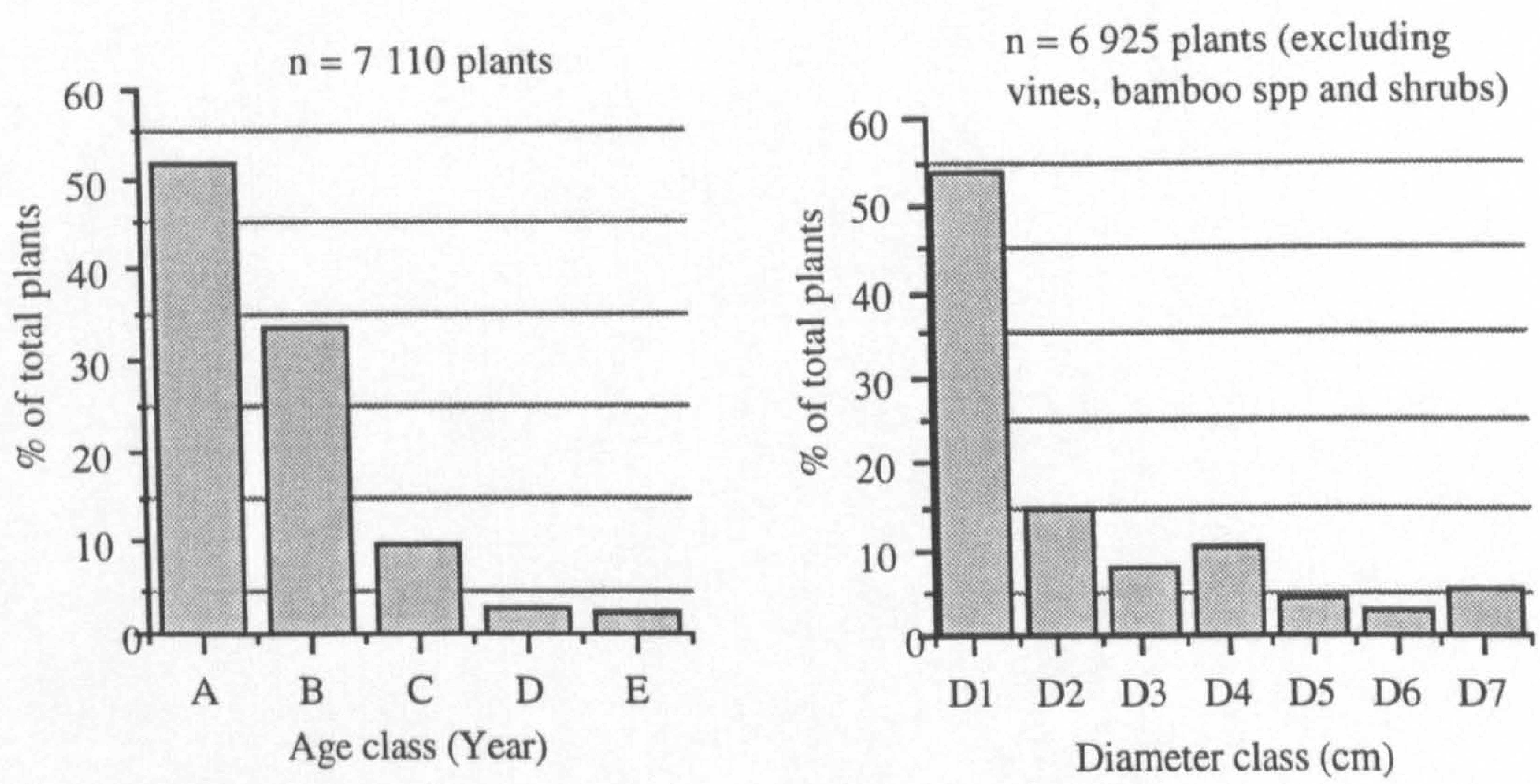
The history of tree cultivation on private farmland is uncertain in Nepal though it has been suggested that most of the trees and shrubs found on farmland were deliberately preserved by farmers when forests were cleared for cultivation (Dutt, 1979). In recent years an increasing number of studies of private tree populations have shown that trees have been promoted or planted on farmland by farmers quite independently of any outside inputs or extension by government agencies (Carter and Gilmour, 1989; Gilmour and Nurse, 1991).

According to Solma farmers, tree planting on farmland was largely a male preserve. All household heads said that whilst both male and female including children, could plant trees, in practice it was always adult males who did so. A similar tendency for men to be responsible for planting trees in other parts of Nepal has been reported (Harrison, 1988; Hobley, 1990; Panday and Yadama, 1990).

Most of the farmers in Solma (except five households who said that they had not planted trees on their farmland, the reasons being either insufficient land or that they had enough trees on their farmland already) claimed to be in the habit of periodically planting at least a few trees on their farmland mainly by transplanting wild seedlings. However, it is not clear how long this has been common practice. Many farmers claimed that they and their neighbours had commenced tree planting only recently, mainly in response to the decline of the forest resource off-farm. An example of a typical explanation elicited from the community during informal discussion is given below.

> In the past we could collect at least three to four *bhari* (loads) of forest fodder in one afternoon because in those days forest fodder was nearby. Therefore, tree planting was not the custom in those days. Now everything (meaning all type of forest products) has become scarce and there is no choice except to plant trees.

An examination of inventory data in terms of plant population structure by age and diameter class strongly supports this statement. Analysis of plant population structure by age class reveals that of the total 7 110 plants recorded in the inventory nearly 52% were less than five years of age (Figure 3.12.a). An analysis of plant population structure by diameter class shows a similar trend, nearly 54% (from a total of 6 925 plants, excluding bamboo species, shrubs and woody vines) were below 5 cm in diameter (Figure 3.12.b). These two parameters can be taken as an indication that young (small) trees vastly outnumber old (large) trees, suggesting that farmers have actively promoted trees in their farmland in recent years.



(a) Plant population structure by age class

(b) Plant population structure by diameter class

Legend for Figure 3.12.a: A = < 5 years; B = ≥ 5 - < 15 years; C = ≥ 15 - < 30 years; D = ≥ 30 - < 50 years; and E = ≥ 50 years.

Legend for Figure 3.12.b: D1 = < 5 cm; D2 = ≥ 5 - < 10 cm; D3 = ≥ 10 - < 15 cm; D4 = ≥ 15 - < 20 cm; D5 = ≥ 20 - < 25 cm; D6 = ≥ 25 - < 30 cm; D7 = ≥ 30 cm

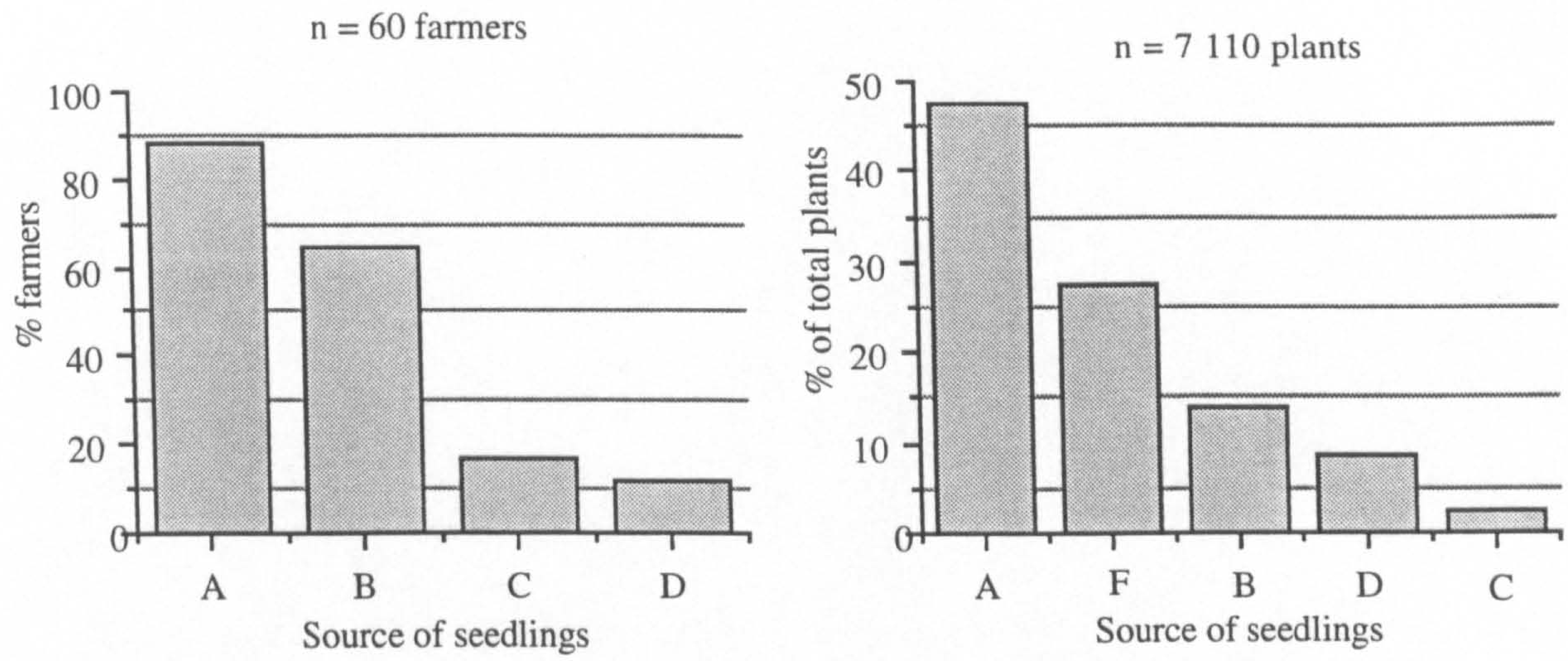
Figure 3.12 Plant population structure by age and diameter class.

Statements made by Solma farmers and the trends indicated by the inventory data match closely with Gilmour's (1990) model of indigenous response to resource availability in Nepal. Gilmour (*op. cit.*) presented three scenarios, the first being where people had ready availability or access to forest products in which case tree planting if it occurred at all was limited to fruit trees. In the second scenario, there was forest within walking distance and farmland was almost devoid of trees. The third scenario was characterised by severe limitation to forest access in which case trees were a common feature of farmland. The situation in Solma may not have been as severe as Gilmour's third scenario but appears to be in a transition phase between the second and third scenarios.

3.7.1.2 Source of seedlings

The variety of sources from which farmers reported obtaining seedlings (Figure 3.13.a) indicates resourcefulness and active involvement of farmers in tree planting in the study area. Four major sources of seedlings were mentioned and, of these, seedlings originating from natural regeneration, were the main source and were either collected as wildings (wild seedlings, 65% of farmers) or protected and managed where they occurred naturally (in-situ managed seedlings, 88% of farmers). When asked about the source of wild seedlings, 90% of farmers said that they collected wildings from their own farmland. Other sources of wildings included gullies or drainage ways (43%) and neighbours farmland (25%). During the inventory 47.6% of plants were recorded as in-situ managed seedlings and 14% as wilding transplants while the source of 27.6% were uncertain (Figure 3.13.b).

It is often assumed that a lack of good quality seedlings and the unavailability of desirable species in most government nurseries are the main reasons for poor uptake (Panday *et al.*, 1991; Forestry Services, 1992; Dutt, 1993). However, despite there having been a well run District Forest nursery for over 10 years stocked with a variety of species, and located at the heart of the study area, only 16.6% of farmers said that they had used the nursery. In the inventory, 160 plants 2.3% of the total number of plants were recorded as having come from the nursery. The reasons for low incidence of the seedlings found on farmers' land originating from nurseries were related partially to: government forest



(a) Percentage of farmers using different sources of seedlings

(b) Proportion of plants originating from different sources of seedlings recorded in the inventory

A = In-situ managed; B = Wildings transplants; C = Government nursery; D = Grown personally; and F = Source uncertain.

Figure 3.13 Source of seedlings.

legislation (because farmers were uncertain over ownership of trees derived from the government nurseries); farmers' preference for planting wildings (because they are well adopted to local environment); and farmers familiarity with indigenous species and their management. Despite the fact that nursery seedlings may have a higher genetic potential than wildings the major species used by farmers have not been the subject of tree improvement work in Nepal.

Robinson and Neupane (1988) have also attributed the low rate of seedling uptake from the nurseries to government forest legislation, while others (Neville, 1987; Yadav, 1992) have attributed farmers ignorance and have emphasised the need to educate farmers about tree cultivation on their farmland.

It is interesting to note that when asked about vegetative methods of propagation, all farmers interviewed recognised that several of their farmland trees could be propagated vegetatively. However, only a small number (11.6%) reported that they were using this method. A total of 603 plants (8.5% of the total number) were recorded as having originated from vegetative propagation in the inventory. Of these, 52% were bamboo species and 36% fruit trees. Fodder species recorded as having originated from vegetative propagation were: *Ficus roxburghii, Ficus lacor, Salix* species, *Saurauia nepaulensis*, and *Erythrina variegata.*

3.7.1.3 Size of seedlings

Several authors (Wilson, 1987; Poudel, 1990; Robinson, 1992) have argued for the need to provide farmers with larger seedlings than those currently available in the nurseries for private planting (in most government nurseries the general aim is to produce seedlings of about 20- 25 cm tall). Solma farmers appeared to confirm this. Although farmers' opinions varied about the best planting size for seedlings (seedling refer here to wildings), a large percentage of the farmers (92%) said that medium sized seedlings (about 60 cm tall)[9] were the most appropriate size for successful planting as opposed to small sized seedlings (7%) and large sized seedlings (1%). The reasons that farmers gave for choosing different sizes of seedling, including advantages and disadvantages of each size as planting material are summarised in Table 3.4.

Planting was normally done during the monsoon season by uprooting wild seedlings with a spade. Large seedlings with a well developed root system were said to be difficult to uproot, resulting in heavy root damage which in turn caused seedlings to wilt and a high rate of mortality. Small wildings, although easier to uproot, were said to be suppressed heavily by ground vegetation. Thus, these problems were overcome by using medium sized wildings.

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[9] Farmers generally categorised seedlings into three size categories: small, medium and large. The measuring units employed by farmers to express seedling size were the *bitta* (tip of thumb to tip of the longest finger) and *hath* (tip of elbow to tip of the longest finger). These local units were converted into centimetres, using the conversion factor one *bitta* equals 20 cm (average physical measurements on a random sample of 25 people). This resulted in sizes of 20, 60 and 140 cm for small, medium and large size seedlings respectively.

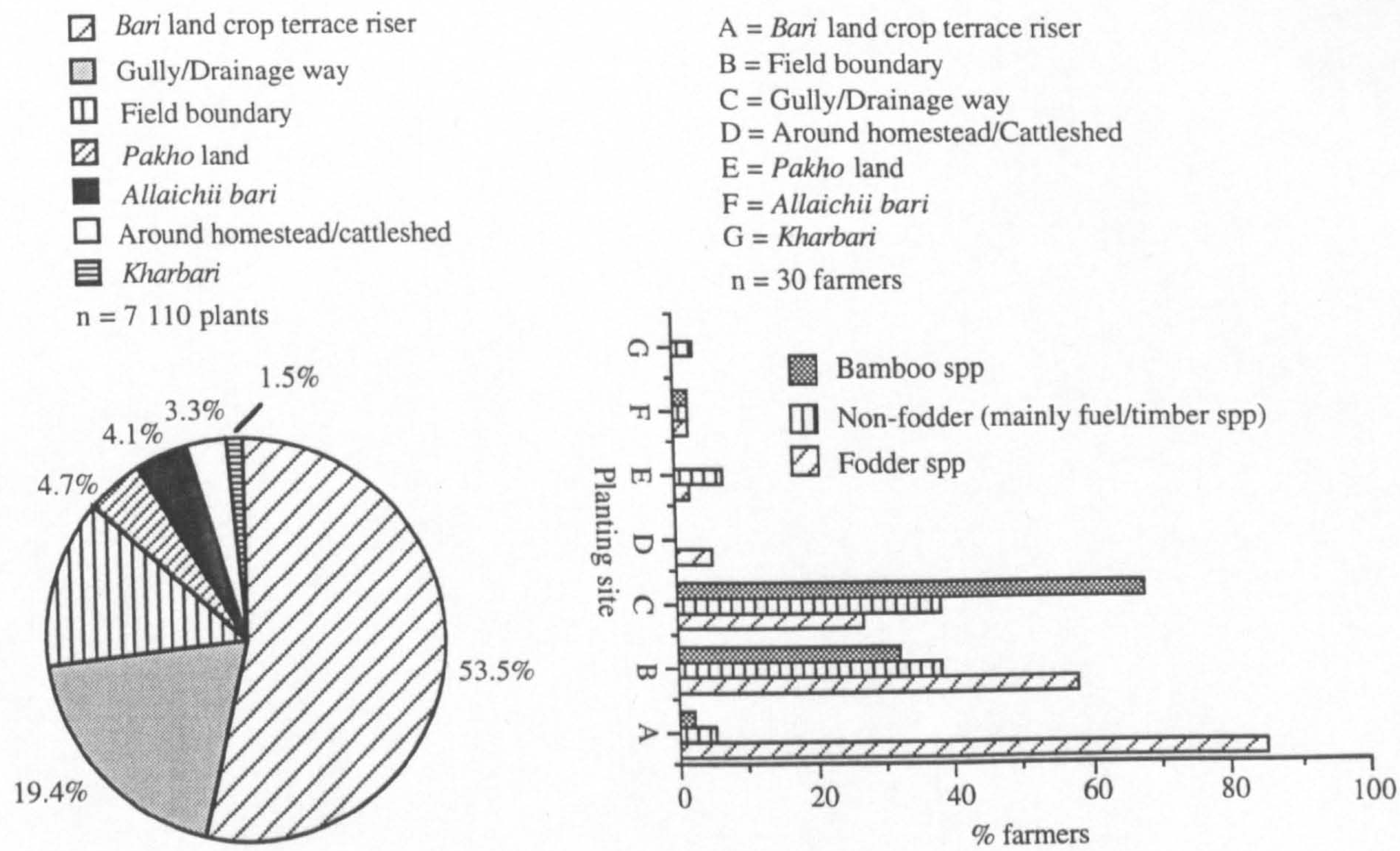
Table 3.4 Farmers' reasons for choosing different sizes of seedlings for transplanting.

Seedlings size	Advantages	Disadvantages
Small (20 cm)	. easy to transplant; . rapid establishment; and . rapid response to fertilisation.	. weed competition extremely high; . growth rate slow; . more labour required for weeding and protection against livestock; and . seedling mortality moderate to high.
Medium (60 cm)	. easy to transplant; . good establishment; . protection cost low; . can withstand long spell of drought; and . seedling mortality minimal.	. slow response to fertilisation; . likelihood of seedlings being damaged during transplanting; and . chances of heavy lodging, breakage and root disturbance by strong wind.
Large (140 cm)	. seedlings out of livestock reach within short period of time; and . protection cost minimal.	. widely spread and matured root system; . heavy root damaged during transplanting; and . seedlings mortality extremely high.

3.7.2 Management of farmland tree species

3.7.2.1 Location of trees on farmland

Altogether seven different site types were recorded as being used by farmers for tree planting on private farmland (Figure 3.14.a). Of these, the most commonly used were: *bari* land terrace risers (the wall between two terraces), gullies or drainage ways and field boundaries. In the inventory 53.5% (from the total of 7 110 plants) were recorded as being grown on *bari* land terrace risers, 19.4% on gullies and 13.5% on field boundaries. Of particular interest was the consistency in the choice made by farmers about where to put particular types of tree species within their farmland. As can be noted in Figure 3.14.b, a large percentage of farmers (85%) used *bari* land terrace risers almost solely for growing tree fodder, field boundaries were used almost equally for fodder, fuelwood, timber and bamboo, while gullies were mainly used for bamboo, although some farmers also used gullies for fuelwood, timber and fodder trees.



(a) Proportion of plants cultivated on different site types recorded in the inventory

(b) Site types used by farmers for growing various types of tree on farmland

Definitions: *Bari* land crop terrace riser is the wall between two terraces and *pakho* land is non-agricultural land usually degraded and not suitable for crop production. Other Nepali terms are defined in Section 3.5.2.3.1.

Figure 3.14 Location of trees on farmland.

It is generally assumed that the small size of land holdings is a major constraint to tree planting in Nepal. However, what emerges from this study is that farmers are very selective and specific in putting particular types of tree species in specific sites within their farmland. This indicates that the availability of particular types of farm site, which farmers think suitable for tree planting, may be more important in determining tree planting than the total size of land holdings.

When asked if there were any particular reasons for planting a particular type of tree on specific farm sites, distinct explanations were given and are summarised in Table 3.5. The patterns that emerge, in terms of tree species location, may be explained according to their primary use, farmers' perceived needs, their perceptions of the value of different tree species and convenience in terms of management and use. For example, one of the main

Table 3.5 Farmers' reasons for cultivating different types of trees on different farm sites.

Planting site	Reasons for choosing particular site for cultivating different types of tree
Bari land terrace riser	. seedling establishment good, survival rate high and growth rate fast; . more convenient for protection and management; . protects terrace risers from landslip; . facilitates agricultural operations; and . minimises tree-crop competition.
Field boundary	. protects terrace edges from landslip; . facilitates agricultural operations; and . minimises tree-crop competition.
Gully/Drainage way	. gully stabilisation; and . to avoid tree-crop competition.
Around homestead/Cattleshed	. windbreak/shelterbelt; and . reserved stock during labour shortage time/emergency.
Allaichii bari	. to shade cardamom; . protection of land from landslip; and . soil improvement.
Pakho land	. protection of land from erosion and landslip; and . soil improvement.
Kharbari	. protection of land from landslip; and . utilisation of available space/land.

reasons given by farmers for cultivating tree fodder on *bari* land terrace risers was one of convenience in terms of proximity to the homestead, protection against theft and livestock outside the cropping season and ease of management and harvest. There was unanimous agreement among farmers that they would not wish to take the risk of growing fodder trees on other sites because such sites were often less fertile and the chance of seedling mortality would be too high. Since *bari* land was fertilised annually with farm yard manure and compost to promote crop production, it was perhaps the most fertile land available for tree growing.

Bamboos were considered by farmers to be *rukho* (meaning that they depress soil fertility). This was cited as a major reason for planting bamboos away from crop terraces, along gullies, to avoid competition with agricultural crops.

Solma farmers appeared to be quite aware of the role that trees can play in farm conservation measures. All 60 farmers interviewed cited landslip control as a reason for planting trees irrespective of the type of site used for tree planting. Authors such as Johnson *et al.* (1982), Malla (1988) and Gurung (1989) have noted farmers planting trees on their farmland to reduce the risk of landslips elsewhere in Nepal.

While some authors have reported that farmers manage trees on *khet* land in other parts of Nepal (Harrison, 1988; Condon, 1990), none of the 30 farms sampled had grown trees on their *khet* land. Rice was considered to be particularly adversely affected by shade and with rice being the most preferred and prestigious crop, *khet* land in Solma was largely dedicated to rice production and kept free of trees. Similar observations have been reported in other parts of the mid-hills (Hawkins and Malla, 1983; Gilmour and Nurse, 1991; Carter, 1991).

3.7.2.2 Tree management for fodder

Nepal is one of the few countries where trees are managed primarily for the fodder they produce. Trees are lopped and carried to stall-fed animals. Leaves and twigs are fed to the animals and the left over branches are used as fuelwood. The seasonal lopping period of some dominant tree fodder species cultivated on farmland in Solma are given in Figure 3.15. Farmers' opinions about the timing of fodder lopping and the frequency at which particular fodder trees were lopped are complex. Several factors were said to influence fodder lopping timing and frequency.

Certain species were reported to be toxic at certain times of the year, for example, *Bridelia retusa* and *Albizia julibrissin* at the flushing stage (locally known as *paulo*) and, if fed, the consequences could be fatal. Others notably, the leaf of *Ficus nemoralis,* were said to stick in animals throats (locally known as *gala lagne*) if fed at the flushing stage. This foliage is, therefore, avoided at that particular time. The rate of regrowth of shoots after lopping in some species was said to be rapid and associated with an ability to withstand frequent lopping (for example, *Grewia oppositifolia, Ficus nemoralis, Coronus oblonga,*

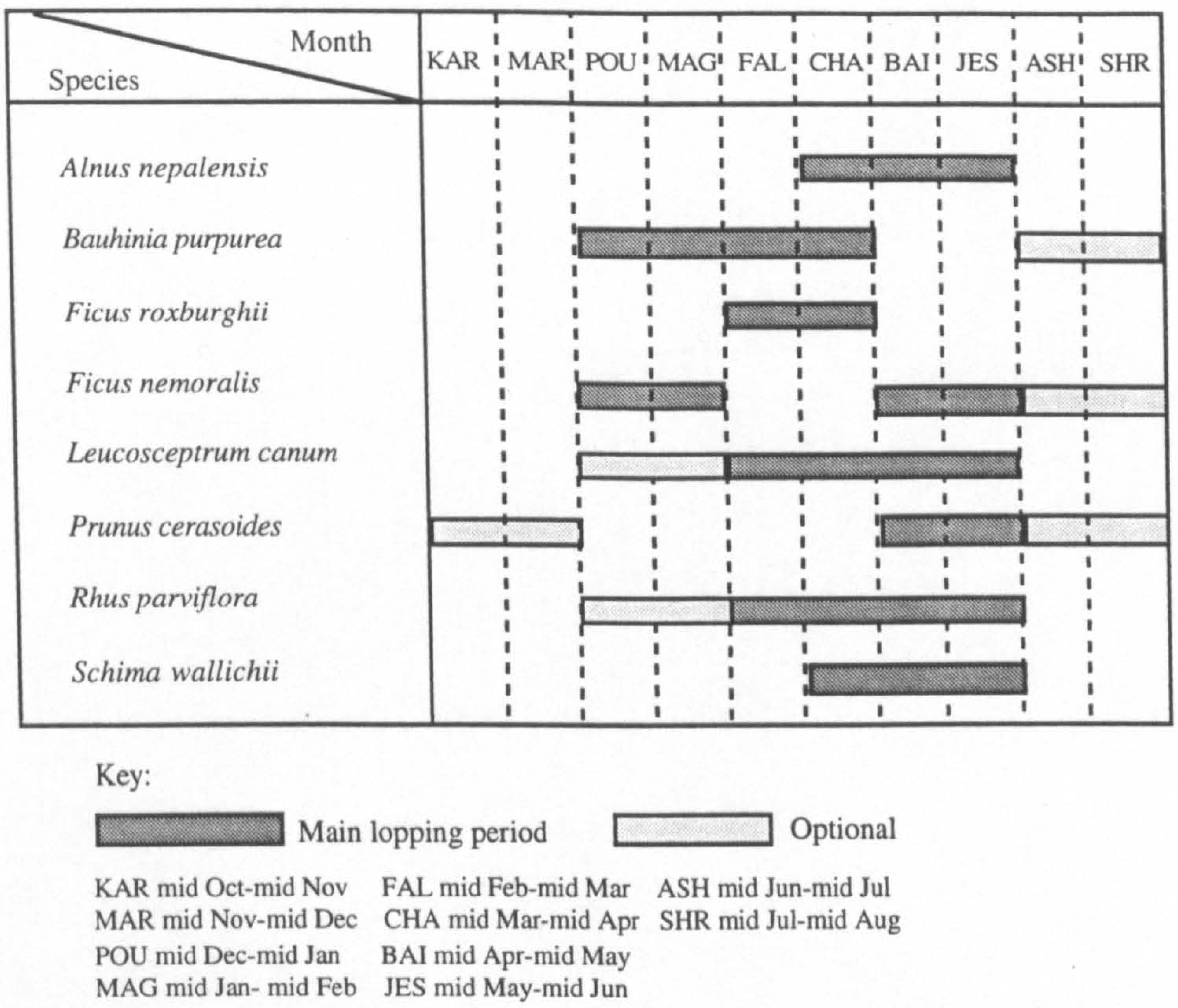


Figure 3.15 Seasonal lopping periods of some dominant tree fodder species cultivated on farmland in Solma.

and *Prunus cerasoides*) and, therefore, they were lopped more than once a year. Other species, for example, *Ficus roxburghii* despite their rapid rate of regrowth of shoots after lopping, were considered susceptible to diseases if frequently lopped and, therefore, were lopped only once a year. Similarly, some species were known to shed their leaves earlier and others to retain their leaves late into the dry season and were lopped accordingly. Some species were said to become less nutritious and unpalatable as the leaves matured (for example, *Leucosceptrum canum* and *Grewia oppositifolia*) but others remained nutritious and palatable (for example, *Artocarpus lakoocha*) and the time of lopping these species was arranged accordingly.

As in the case of tree planting, all the household heads interviewed said that fodder lopping was largely a male preserve because women did not climb trees by tradition and because this was considered too dangerous. It was usual in Solma for men to lop tree fodder and women and children to collect and carry it to stall-fed livestock.

3.7.3 Farmers' perceptions of the effect of farmland trees on crops

3.7.3.1 Tree shade and *tapkan*

An enquiry about the effect of trees on crops revealed that without exception, all farmers interviewed said that trees were detrimental to crops. Previous studies carried out on this topic have cited tree shade as a main factor responsible for causing crop damage (Condon, 1990; Carter, 1991; Robinson, 1992). However, Solma farmers stated that *tapkan* (leaf drip effect causing splash erosion) was also detrimental to crops.

Tree shade was directly correlated by the farmers with the amount of sunlight available to crops. Solma farmers generally agreed that different tree species cast different intensities of shade and were also aware of the fact that the effect of tree shade on crops varies with altitude, aspect, season and the orientation or position of the trees on farmland. It was generally stated that east facing slopes received more sunlight than west facing slopes during the monsoon resulting in a smaller effect of shade on east facing slopes, while north facing slopes were more affected by tree shade during winter months than south facing slopes.

An enquiry into factors influencing different intensities of shade and *tapkan* revealed that farmers' perceptions of the shade and *tapkan* effects on crops was largely based on their understanding of tree phenology and architecture and their variability between tree species. For example, trees with big leaves were considered to be detrimental to crops because large leaves collect a large quantity of water which increases the size of *tapkan* drops so that when they fall they cause more serious splash erosion, which in turn exposes the root systems of the crops, causing heavy crop lodging. *Ficus roxburghii* was the most often cited species falling under this category because of its large size leaves and dense crown. By contrast, *Albizia julibrissin* was widely recognised as a tree species which did not cast either heavy shade or serious *tapkan* effects because of its small size leaves and light crown. Poor crop vigour, poor grain formation and delayed crop maturity all of which ultimately affect crop yield were reported to occur as a result of shade and *tapkan.*

3.7.3.2 *Rukho-malilo* character of trees

According to Solma farmers, different farmland trees affected soil in different ways, some decreasing farmland soil fertility, locally termed as *rukho*, while others increased soil fertility, termed as *malilo*. Tree species that fall under the *rukho* category were those which had shallow or fibrous root systems (locally known as surface feeders) and those with leaves taking a long time to decompose, while the *malilo* type included those species having deep root systems and those with rapid leaf decomposition. *Rukho* trees were said to soak up water and soil nutrients resulting in dry and hard soil underneath the tree crown. Bamboos were classified as *rukho*. Soils around *malilo* trees were reported to be soft, light and loose, and considered fertile by farmers. *Albizia julibrissin* was widely recognised as a *malilo* tree in the study area.

3.7.4 Utilisation of farmland tree species

3.7.4.1 Farmers' perceptions about the value of different farmland trees

The reasons for growing a variety of tree species on farmland and for farmers growing certain species more and others less are complex. According to Solma farmers the value of any given fodder species was said to be influenced by several factors. Certain species were said to be eaten preferentially by some types of livestock that other types of livestock would not eat. For example, *Prunus cerasiodes* and *Pyrus pashia* at higher elevations and *Colebrookia oppositifolia, Vitex negundo, Rhus parviflora* and *Melia azedarach* at lower elevations were considered as poor quality fodder for large ruminants (particularly cattle and buffalo) because they were believed to be less palatable. However, the same species were considered to be palatable and amongst the best fodder for sheep and goats. Similarly, certain species were valued for their high nutritive value (locally known as *posilo* fodder), and were believed to make animals strong and promote milk and *ghee* (milk fat or butter) production, examples being *Leucosceptrum canum, Ficus roxburghii* and

Ficus nemoralis in high altitude areas and *Bauhinia purpurea* and *Artocarpus lakoocha* at lower altitudes. Yet others, for example, *Bridelia retusa* was believed to cause milk production to cease if fed to milking animals and were locally known as *kam posilo* fodder.

Some species were valued for retaining their foliage late into the dry season. For example, *Coronus oblonga* and *Saurauia nepaulensis,* though considered relatively poor quality fodder were maintained on farms because the trees retain foliage late into the dry season and provide much needed green fodder during critical times of the year. The rate of regrowth of shoots after lopping in certain species, for example, *Prunus cerasoides* and *Grewia oppositifolia* (both considered low quality fodder) was said to be very rapid, and hence they were valued because they could be lopped at least two times per year and so produce a large quantity of fodder.

Solma farmers often recognised tree fodder as *chiso* or *obano* and this *chiso-obano* status of tree fodder was said to influence the value of a given species. The term *obano* as understood by Solma farmers meant "dry and warm" and *chiso* "cold and wet". According to Solma farmers, *obano* fodders (for example, *Leucosceptrum canum* and all species of bamboos) tended to be eaten voraciously by animals, often causing constipation if fed in excess, while *chiso* fodders (for example, *Ficus nemoralis and Ficus roxburghii*) were reported to be less palatable, often causing diarrhoea when fed during cold months particularly during the months of *Poush* and *Magh* (mid December to mid February). The common practice reported was to feed a mixture of *chiso* and *obano* fodder to obtain desirable diet mixture.

From the above discussion it is apparent that the question of what constitutes good or poor quality fodder is complex. While some understanding was gained from this initial survey it was not always clear how farmers perceived and evaluated fodder and this remains unclear at this stage.

In the case of fuelwood and timber species, the criteria used by farmers when choosing a particular species were less complex than for fodder. Even here, though several factors were involved, for example, availability as well as burning qualities or timber value. The best fuelwood species were considered to be those which were *kharo* (fiercely burning and heat producing). Durability was the major criterion used in valuing timber. *Alnus nepalensis* at higher elevations was widely used as fuelwood and timber not because it produced wood that was *kharo* or durable but because it was often the only species available for the purpose. At lower altitudes, *Colebrookia oppositifolia, Vitex negundo* and *Rhus parviflora* were preferred fuelwood species not simply because they were available in abundance but because they were explicitly considered to be *kharo.*

3.8 CONCLUSIONS

An overview of the relationships between people and trees, and the farmland tree resource management practices employed by farmers in the study area have been presented. This was subsequently used as a basis for selection of research topics (4.2.1) and to develop specific working hypotheses about the knowledge held by farmers (4.2.3). There is clear indication even at this stage, however, that farmers in the study area had an intimate knowledge about the way in which trees can be incorporated to advantage into their farming systems. Farmers often combined a number of different tree species into their agricultural system and deliberately managed trees on their farmland according to the products they required and the perceived value of the species concerned. The preliminary findings, reported here based largely on formal survey techniques, have, therefore, led to the suggestion that farmers in the study area have a substantial body of knowledge about tree-crop interactions, fodder tree management techniques and the evaluation of fodder quality although much of the detail of this knowledge and how it is used by farmers remains to be elucidated. However, where details were apparent, for example, in relation to effects of *tapkan* or leaf drip (3.7.3.1), farmers' knowledge appeared to have considerable explanatory depth.

CHAPTER 4

KNOWLEDGE ACQUISITION

4.1 INTRODUCTION

Background information on the study area was presented in Chapter 3 together with preliminary findings relating to farmers' perceptions about the cultivation, management and use of farmland tree fodder resources. The research topics worthy of further investigation, having implications for the design of future tree fodder research and development programmes were indicated. The need for a rigorous means of assessing knowledge in order to allow it to be used effectively in a research and development context and methodological requirements and approaches were discussed in Chapter 2. On the basis of these considerations, a knowledge based systems approach, involving the use of artificial intelligence techniques to formally represent and reason with knowledge (under development as part of the broader research programme of which the present study formed a part) was proposed as an appropriate means of achieving the research objectives.

The purposes of the research described in this chapter were to:

- formulate specific research hypotheses on defined topics through consideration of the information derived from the specification fieldwork (Chapter 3);
- use the hypotheses to facilitate the collection of detailed indigenous ecological knowledge from selected groups of people in the study area; and
- create a tree fodder knowledge base containing information about the management and use of farmland tree fodder resources that might be useful in designing future tree fodder research and development programmes.

Sinclair *et al.* (1993) define a knowledge base as an articulated and defined set of knowledge stored in a computer. In the present context, the tree fodder knowledge base may be more specifically defined as an articulated and defined set of knowledge about the management and use of tree fodder resources from a range of known sources, stored in a computer in such a way that the knowledge can be accessed, evaluated and used for a variety of purposes in a research and development context aimed at improving the management of tree fodder resources on farmland.

A number of stages and processes were involved in the creation of the tree fodder knowledge base (Figure 4.1). Broadly they may be divided into two main stages: knowledge elicitation and knowledge representation. Knowledge elicitation and representation together are referred to as knowledge acquisition. The knowledge elicitation phase involved: selection of research topics (4.2.1); selection of key informants (4.2.2); formulation of research hypotheses (4.2.3); interviewing (4.2.5) and recording (4.2.6); and then processing (4.2.6.2.3) and analysing (4.2.6.2.4) the collated knowledge. This was achieved by adopting an iterative fieldwork strategy based on a short interactive fieldwork cycle driven by the use of TEAK (Tools for Eliciting Agroforestry Knowledge; a computer programme for recording, storing and accessing text statements; Haggith *et al.*, 1992) and HyperNet (a graphical tool for representing agroforestry knowledge; Walker *et al.*, 1993).

The knowledge representation involved two stages: intermediate representation of knowledge as natural language statements (4.3.2) and formal representation of knowledge as computer coded statements (4.3.3). The formalisation was achieved through the use of AKT (Agroforestry Knowledge Toolkit), a software toolkit developed in Prolog[1] supporting acquisition, storage, exploration and evaluation of indigenous ecological knowledge (Walker *et al.*, 1994).

[1] An artificial intelligence programming language.

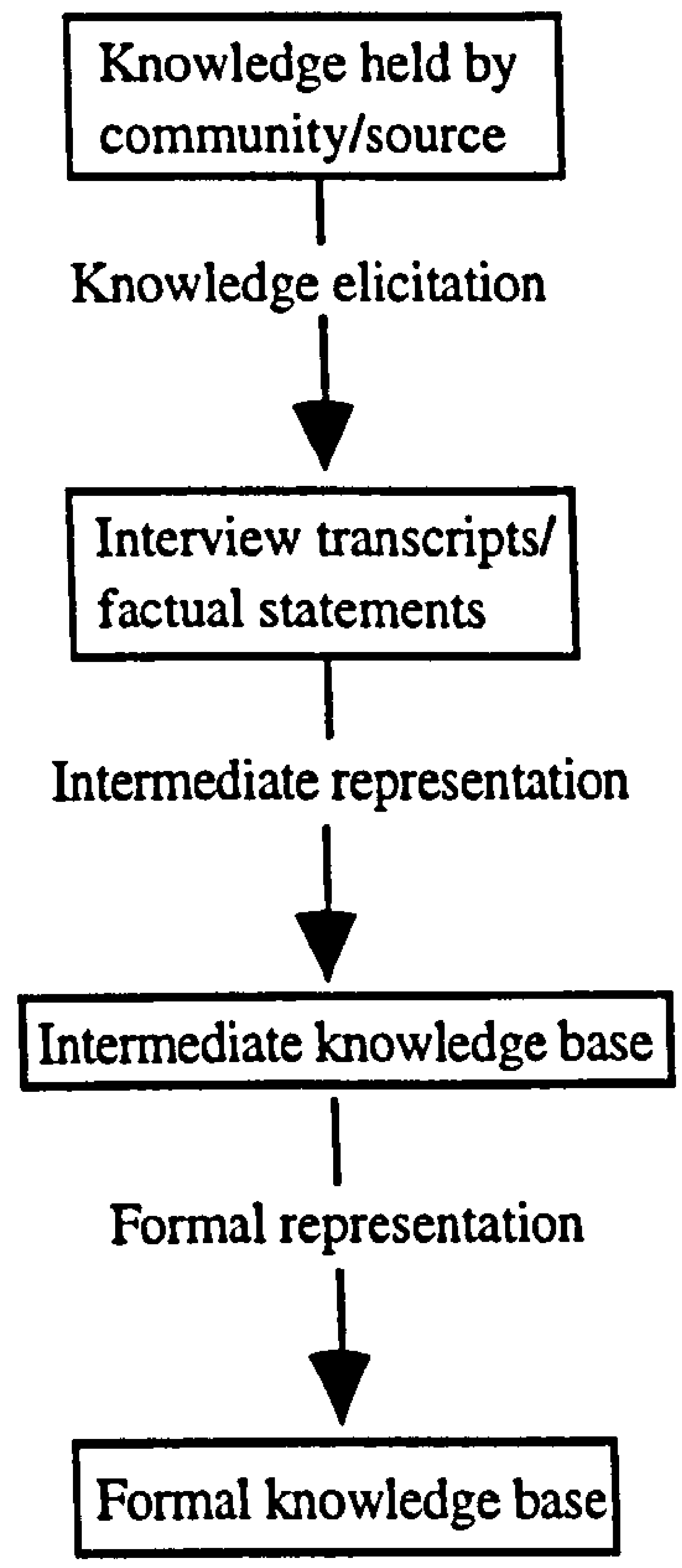


Figure 4.1 Stages and processes involved in the creation of tree fodder knowledge base.

4.2 KNOWLEDGE ELICITATION

4.2.1 Selection of research topics

On the basis of impressions gained from the specification fieldwork (Chapter 3), three specific research topics were selected for detailed investigation: tree-crop interactions; fodder quality evaluation; and tree fodder management techniques. The specification stage of fieldwork indicated that farmers' knowledge surrounding the management of farmland tree fodder resources was largely based on their understanding about the effects of farmland trees on crops and the perceived feeding value of the species concerned (Chapter 3). As systematic research in tree fodder remained in its infancy in Nepal, little was known about the function and purpose of farmland tree fodder resources in the local farming systems, particularly in relation to ecological interactions. This lack of information has been identified as a major constraint in designing and planning appropriate tree fodder research and development intervention strategies in the mid-hills of Nepal (Robinson, 1989; Panday *et al.,* 1990). It was proposed, therefore, that investigation of:

- how farmers perceive interactions occurring in their tree-crop-based farming systems and the underlying knowledge systems used by farmers in managing them;

- how farmers perceive the value of a particular tree fodder species and the underlying knowledge systems used by them in fodder evaluation; and

- the processes by which this type of knowledge is applied in the management of tree fodder on farmland;

would be of considerable value in providing a better understanding of the ecology and management of tree fodder resources on farmland, thereby facilitating the identification of future adaptive tree fodder research and development priorities and strategies.

4.2.2 Selection of key informants and sampling strategy

To collect detailed ecological knowledge from farmers, this study focused upon a limited number of carefully selected individuals referred to as key informants. Kumar (1987a) defines key informants as a selected group of individuals who are likely to provide the needed information, ideas and insights on a particular subject. Purposive sampling can be expected to improve the productivity of fieldwork over random sampling because many randomly selected informants may be unwilling to cooperate or may not be very knowledgeable. However, Kumar (1987b) emphasises that efforts should be made to ensure that key informants are representative of the target population and that an acceptable degree of representativeness can be achieved by classifying the target population on the basis of criteria relevant to the study objectives and by including key informants from each category. This line of approach was followed in the present study.

Previous studies researching other topics in Nepal have indicated that variables such as gender, ethnicity, altitude, wealth and age are likely to influence knowledge held by any particular individual or group of people (Muller-Boker, 1987; Rusten, 1989; Miller, 1990; Smith, 1990; Upton, 1990). However, inclusion of all these variables in the present study would not have been either practically possible or desirable. On the basis of the specification stage of fieldwork (Chapter 3), only those variables which appeared to be of practical significance in the context of farmland tree fodder research and development programmes were considered. These were: altitude (4.2.2.1); ethnicity (4.2.2.2); and gender (4.2.2.3). Given the focus of the study on explanatory ecological knowledge, the study area being a rural area with the population depending almost entirely on subsistence farming, and an indication from the specification stage that it is often the farmers with least land who cultivate trees more intensively on their farmland (3.7.2), variables such as education, wealth and age were not anticipated to vary greatly amongst the target population or to be of immediate significance to knowledge acquisition.

4.2.2.1 Altitude

The results of the specification fieldwork (Chapter 3) show a wide variety of different tree species were grown and managed in the study area in relation to altitude (3.7.1). Similarly, different cropping patterns were practised at different altitudes (3.6.3.1), with a maize/potato cropping pattern common at high altitudes while maize/millet and rice based cropping systems were dominant at low altitudes. This suggested that altitude was an important variable likely to influence knowledge about tree fodder and that its inclusion in the present study would be of value in designing appropriate research and development strategies aimed at generating suitable technologies related to specific altitudinal ranges.

4.2.2.2 Ethnicity

There is little evidence that different agricultural practices are used by members of different ethnic groups in the study area. For example, there are no specifically Brahamin or Limbu farming systems. Instead, the numerous cropping systems found in the mid-hills of Nepal and in the study area tend to reflect environmental diversity. However, the specification fieldwork (Chapter 3) indicated that different ethnic groups in the study area tend to have a particular preference for types of animal (for example, Limbus keep pigs, Brahamins do not, but many Brahamins keep buffalo while few Limbus do) and that farmers often prefer to feed particular types of tree fodder to particular types of animal (3.8.4.2) and, therefore, cultivate and manage specific types of tree fodder on their farmland. There may, therefore, be differences in knowledge related to different cultural inheritance and perceptions. Similar examples where ethnicity has influenced the number and type of livestock, owned by a household, with Brahamins owning more buffalo and cows than other groups, has been reported in other parts of Nepal (Shrestha and Evans, 1984; Tulachan, 1985; Fox, 1987).

4.2.2.3 Gender

The inclusion of gender in the present study was based on the observation that gender related division of work is common in the rural areas of Nepal. Women farmers in rural Nepal contribute more labour to the farming systems than men do and are active in decision making (Kumar and Hotchkiss, 1988; Kennedy *et al.*, 1991). Furthermore, the specification stage of fieldwork indicated that men rather than women lop fodder, but women rather than men collect and feed it to animals (3.8.2.2). On this basis, it was reasonable to assume that there might be gender related domains of knowledge about tree fodder. Significant differences in the preference for tree fodder species between men and women in Salija, western mid-hills of Nepal has previously been reported (Rusten, 1989).

It should be noted that inclusion of these variables in the present study was not intended to test the distribution of knowledge against these variables. They were rather intended to help ensure that the key informants selected were representative of the population in the study area and that farmers knowledge from a range of conditions and sources were sampled.

On the basis of these considerations, male and female farmers who were active (at least 20 years of age), from two ethnic groups, Brahamin and Limbu living at both high ($\geq$ 1 500 m) and low ($\leq$ 1 000 m) altitudes of the study area were sampled. This sampling strategy, with five informants per group resulted in the selection of 40 key informants.

This part of the study was conducted in the second half of the main period of fieldwork and by this time the author had established good rapport within the community and certain people who were informative, interested and, therefore, could be trusted to provide reliable information were known. These individuals were purposively selected as key informants. Thus, a stratified non-random sample was taken.

4.2.3 Working hypotheses

The use of the term working hypotheses in the present study for assertions used as a basis to explore knowledge, should not be confused with formal hypotheses in science which are set up to be confirmed or disproved. In the present study, working hypotheses were established on the basis of the specification stage of fieldwork and used to generate a checklist for the first round of interviews, with the intention of producing more refined hypotheses on the basis of subsequent interview sessions. Therefore, the working hypotheses in the present study were not intended to be strictly tested in the way that they would have been in an analogous experimental trial, rather they were intended to provide a clear focus for each round of interviews on the basis of an assessment of previous interviews.

Based on the impressions gained from the specification stage of fieldwork, the following working hypotheses for each of the research topics were formulated (Table 4.1).

Table 4.1 Research topics and working hypotheses.

Research topic	Working hypothesis
Tree-crop interactions	1. Farmers have an extensive understanding of the way that farmland trees influence crops. 2. The effects of farmland trees on crops include: . shade; . *tapkan;* and . the *rukho-malilo* character of trees. 3. The nature of each of these effects of farmland trees on crops is influenced by tree species and accounted for by factors including: . leaf size; . crow density; . crown size; and . the depth and spread of tree roots. 4. The crop species and variety grown influences the degree of tree effects on crops.
Fodder quality evaluation	1. Farmers have an extensive understanding of the value of different tree fodder species and they deliberately manage them according to the perceived value of the species concerned. 2. The value of any fodder species is influenced by factors including: . the type of animal for which it is intended; . the time of the year it is fed; . the kind of products desired from livestock; . palatability; . the effects of the fodder on animal health; . the availability of fodder from different tree species at different times of the year; and . nutritive value.
Tree fodder management techniques	1. Farmers have an extensive understanding of site characteristics and tree species and the way they influence each other. 2. Farmers have an extensive understanding of the deleterious and beneficial effects of farmland trees on crops. 3. This knowledge is practically applied in making decisions about where to put a particular tree species on farmland. 4. The timing and frequency of fodder lopping is influenced by factors including: . time of leaf shedding; . toxicity of fodder; . effect of lopping on tree health; . leaf maturity; and . the rate of regrowth of shoots after lopping. 5. Farmers integrate this knowledge in making decisions about when and how much fodder to cut from a particular tree species.

4.2.4 Fieldwork strategy, approach and cycle

The fieldwork strategy adopted in the present study (Figure 4.2) was iterative, based on a short fieldwork cycle. The fieldwork consisted of a number of iterative cycles, for example: initial working hypotheses were established from consideration of information derived from the specification fieldwork; a checklist of topics was devised on the basis of these; a first round of interviews was conducted and knowledge was entered into the knowledge base; then the knowledge base was assessed and refined, and as a result, new working hypotheses were established for the next round of interviews, and so on. This involved a 'learning as you go' approach whereby newly collected knowledge helped to set the agenda for the later stages of interviewing, thus moving all the while towards a more complete record of knowledge on the topic in question. Entering new knowledge, and modifying the existing knowledge, in a growing knowledge base on a portable computer[2] provided a powerful means of driving this iterative process. The cycle was repeated until a comprehensive understanding of the topic studied had been gained, identified when new interviewing did not lead to significant alteration of, or addition to, the knowledge base.

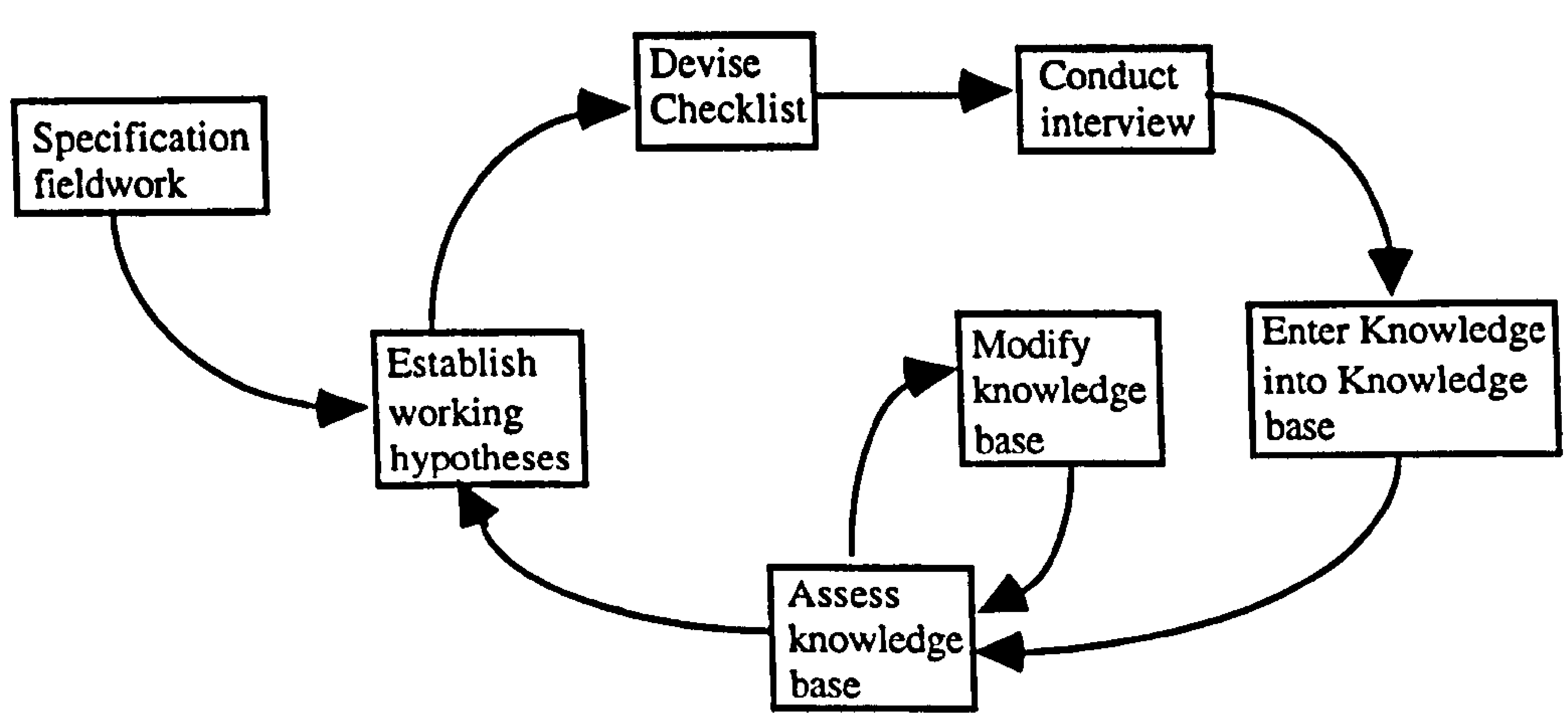


Figure 4.2 Developing the tree fodder knowledge base: an iterative cycle.

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2 Apple Macintosh PowerBook 100 computer was used throughout the period of this study.

4.2.5 Interview strategy, procedure and timing

Given that local people's ideas, understanding and knowledge was the central interest of the study, it was reasonable to suppose that the best way of getting hold of this information was to talk to local people. In recent years, informal (unstructured) interviews have become an increasingly popular tool amongst those working in rural development for gathering information where the emphasis is on qualitative rather than quantitative information (Rhoades, 1984; Dove, 1989). The stated intention of informal interviews is to put farmers at their ease and gain information through the creation and maintenance of a friendly environment conducive to uninhibited disclosure of information. Authors such as Grandstaff and Grandstaff (1987) have emphasised that one of the most important ingredients of successful informal interviews is to have a clear set of objectives stating exactly what the fieldwork is intended to achieve. The informal interview strategy adopted in the present study may be summarised as a set of semi-structured, flexible and open ended conversations with farmers. The interviews were guided by a checklist which was primarily used to ensure that key points of interest, and the same issues, were discussed with each key informant. The intention was to start the conversation with a few key themes and then allow the conversation to flow naturally in the hope that points of interest would be articulated by the informant which the interviewer could then encourage the informant to expand upon.

Interviews were conducted during the second half of the main period of fieldwork from mid December '92 to mid June '93. This period was an agriculturally slack period and it was, therefore, expected that people would have more time for discussion. The key informants were contacted to arrange an appointment a day before the interview. Most of the interviews were conducted at farmers' houses, either in the morning or in the evening. In some cases it was more convenient for farmers to hold discussions in the afternoon while they were engaged in herding animals and the interviews were arranged accordingly. The time spent on each interview was approximately one hour, although in some cases, where farmers were particularly articulate interviews took up to 90 minutes.

Efforts were made to interview key informants separately from other members of the household and this was successfully achieved in most cases. However, in a few instances, other members of the household or neighbours heavily influenced the discussion, in which case the interviews were not recorded but postponed to a later date. The short cyclical nature of the fieldwork required that each interview was processed immediately. For this reason, a maximum of two to three farmers were interviewed per day. Interviews were conducted separately for each of the three topics studied (tree-crop interaction, fodder quality evaluation and tree fodder management techniques). Three to four rounds of interview sessions per topic per informant were required in order to obtain adequate understanding of the topic studied.

4.2.6 Recording knowledge

4.2.6.1 Recording knowledge during the interview

There were two alternatives available for recording information during the interviews: note taking; and tape recording. For the type of detailed information considered in the present study relying on note taking was inadequate. It should be noted that during the interview session, the researcher was required to concentrate on two things at the same time: listening to and interpreting what the informant was saying; and encouraging the informant to expand upon points of interest that arose. For this reason, note taking during the interview neither facilitated open discussion nor allowed the researcher to concentrate on what the informant was saying.

It was found through experience that the most appropriate method was to tape record interviews so that a complete record of the discussion and exactly what the informant had said was retained for future analysis. All the interviews were, therefore, tape recorded in full, using a voice activated microcassettee recorder. However, for reasons discussed earlier (3.3.1), each informant was asked whether recording of the discussion was acceptable to them before being interviewed. All the key informants that were interviewed accepted the prospect of tape recording discussion willingly.

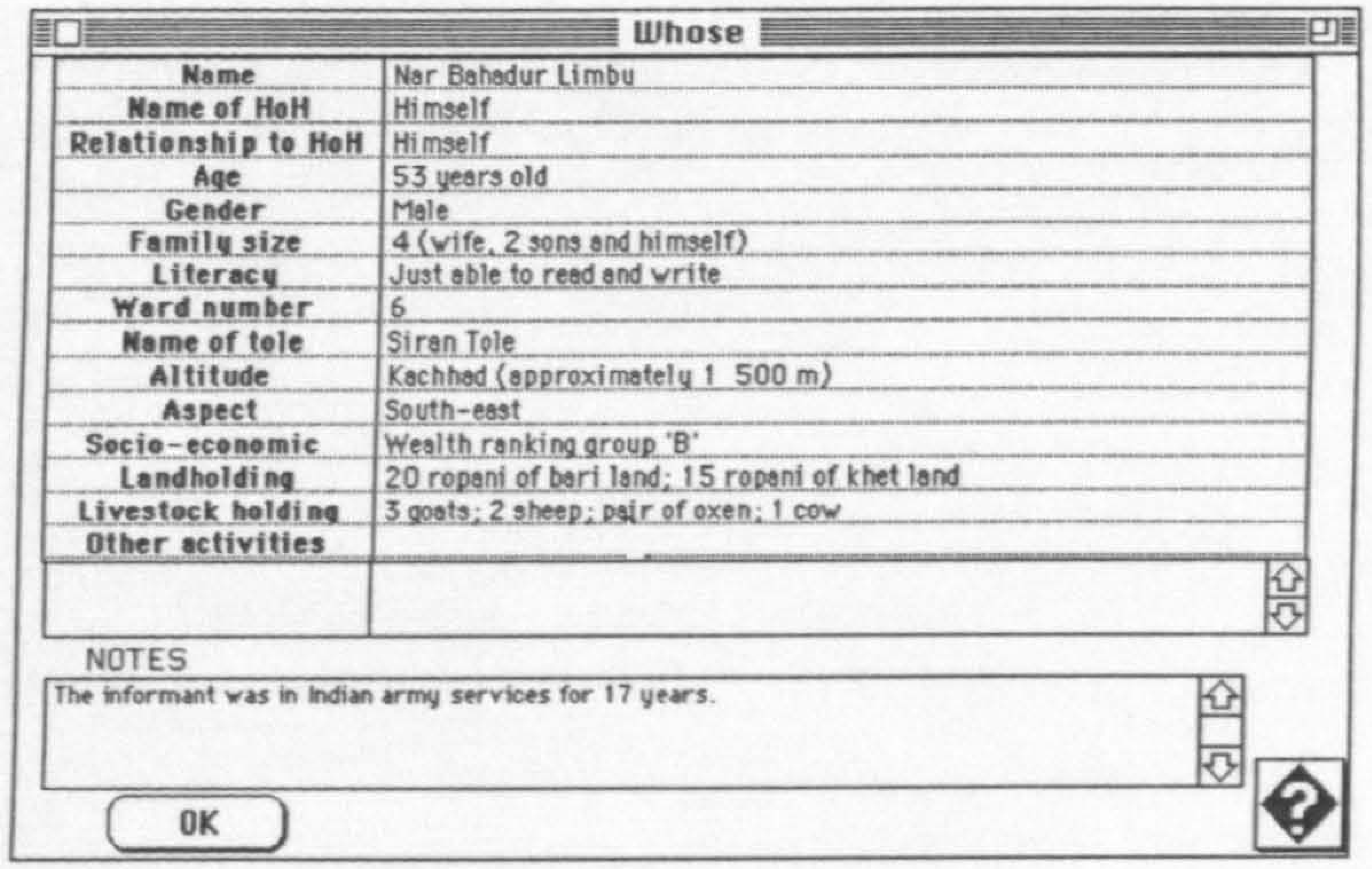
4.2.6.2 Recording knowledge after the interview

Each interview was played back from the tape recording and the relevant ecological knowledge gained from the interview was abstracted and recorded on computer as soon after the interview as possible using TEAK (4.2.6.2.1) and HyperNet (4.2.6.2.2), software toolkits designed primarily for recording the knowledge from interviews but also intended to allow some preliminary analysis of collected knowledge in order to guide further interviewing. The knowledge gained from the interviews was recorded separately for each of the three topics studied. As a result, three separate knowledge bases relating to the three specific topics studied were created. A full description of TEAK and HyperNet can be found in Haggith *et al.* (1992) and Walker *et al.* (1993) respectively.

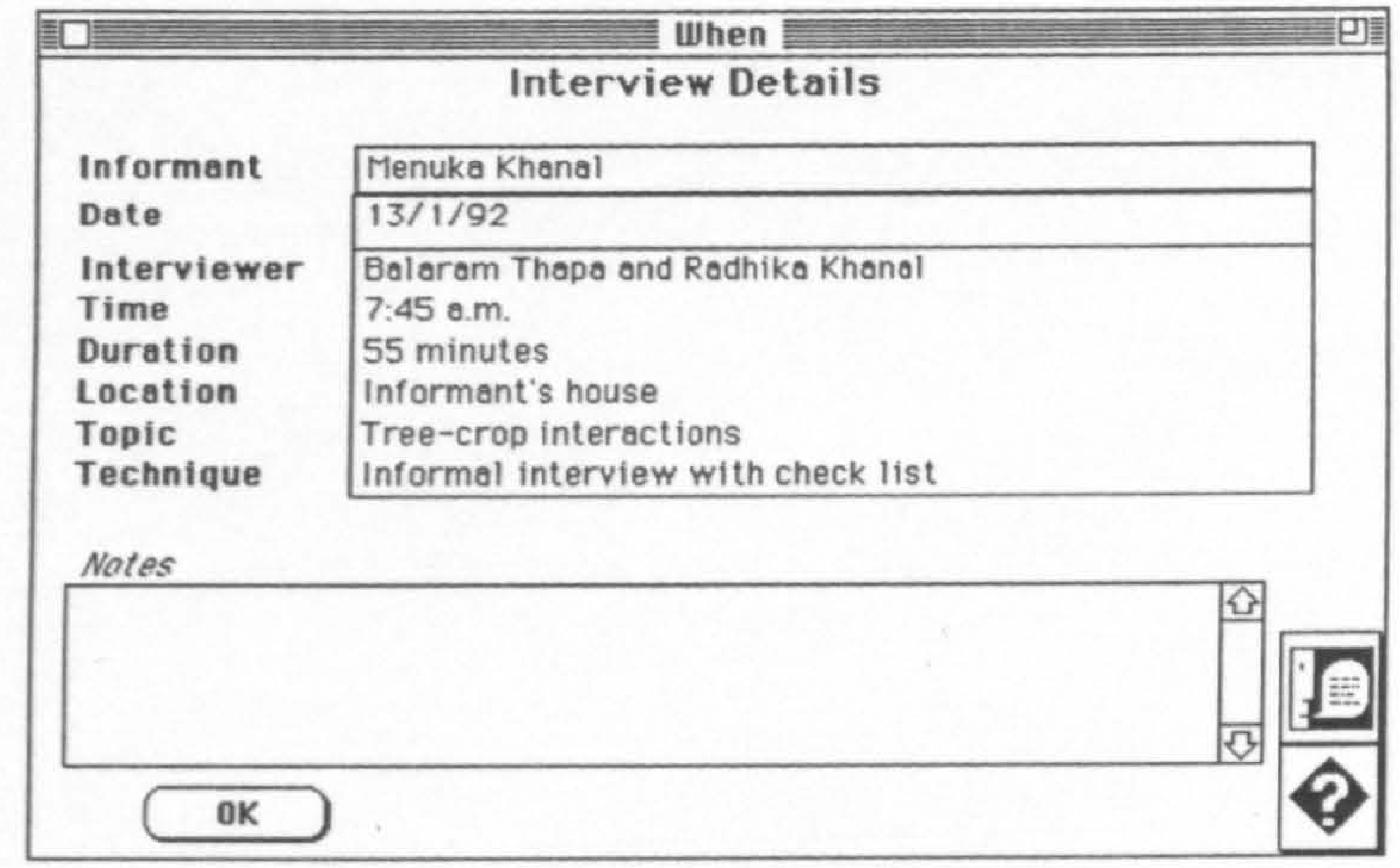
4.2.6.2.1 TEAK (Tools for Eliciting Agroforestry Knowledge)

TEAK is implemented in HyperCard, a software package for Macintosh computers based on a principle of organising information in small chunks called "cards", which are analogous to library catalogues or filing systems. Cards are organised into collections called "stacks". TEAK consists of four stacks: the Whose, When, Sentence and the Keys stacks.

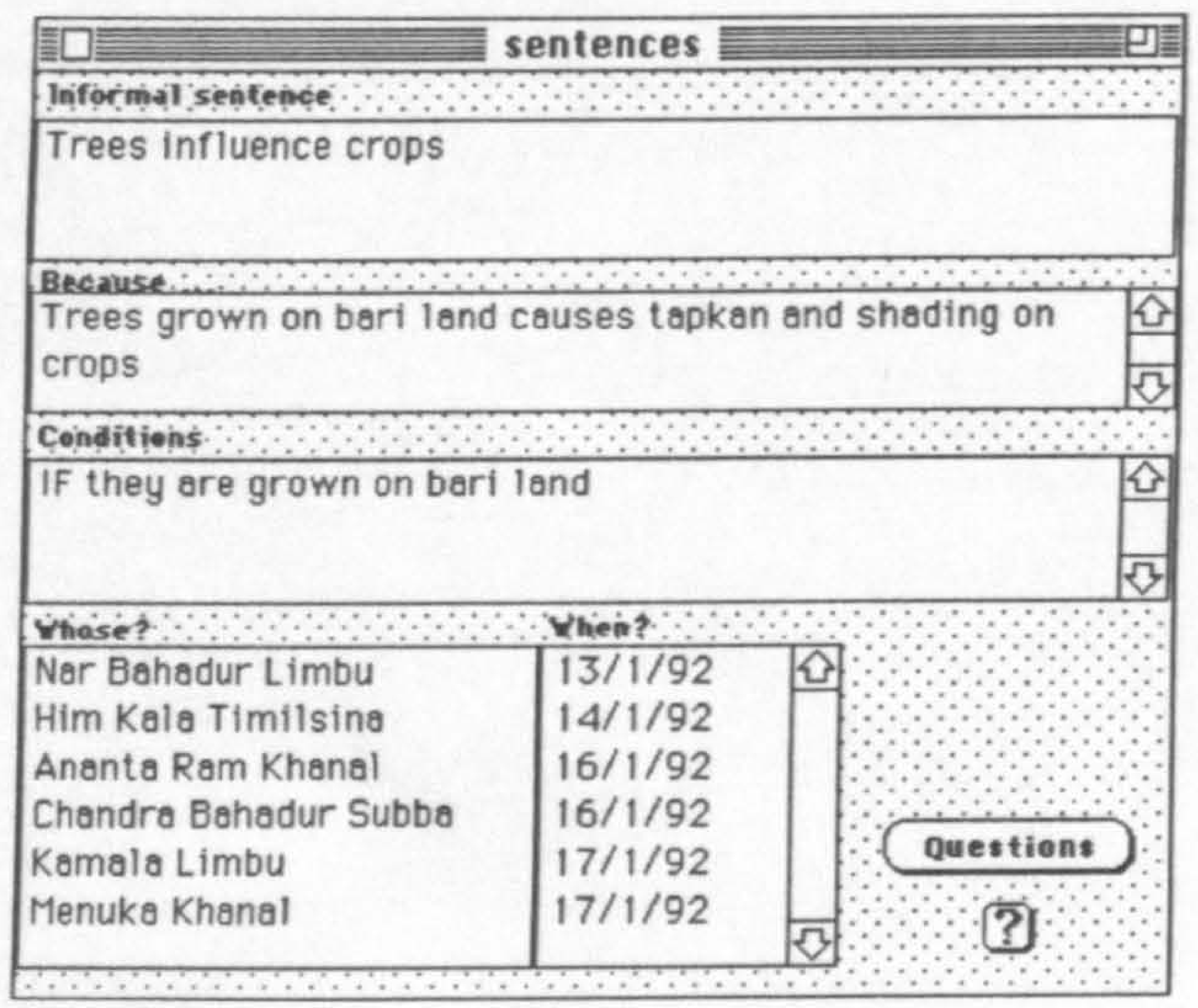
The Whose card contained detailed records of the informant, for example, the informant's name, gender, age, education, location, occupation, land holding and livestock holding (Figure 4.3.a). These categories could be changed according to user needs. The When card contained detailed records of the interview situation, for example, interview date, time, and location (Figure 4.3.b).



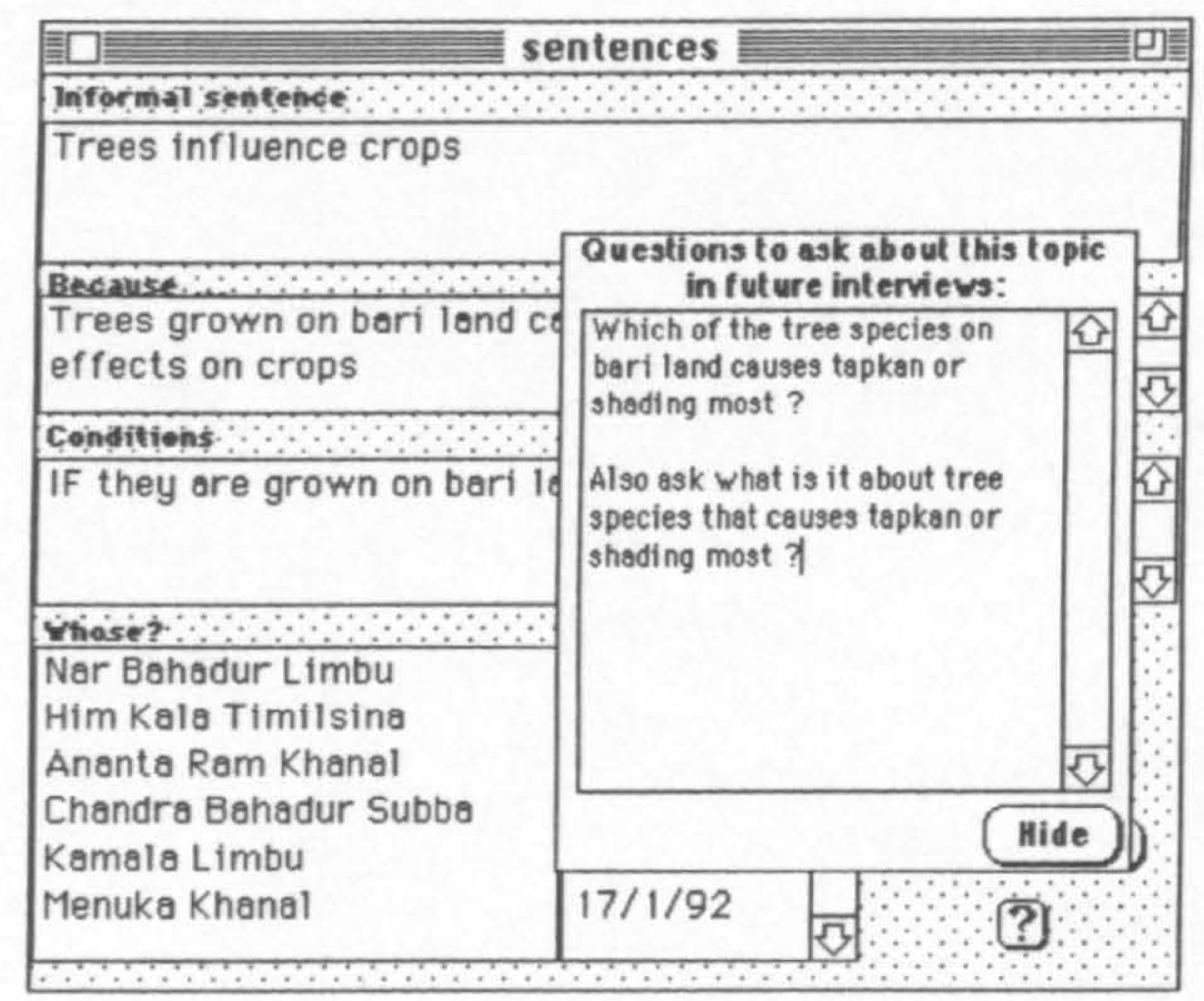
(a) Example of a Whose card



(b) Example of a When card



(c) Example of a Sentence card



(d) The example Sentence card in 4.3c with follow up questions

Figure 4.3 Some features of TEAK: An example of Whose, When and Sentence cards.

The Sentence card consisted of three fields named the Sentence, Because, and Condition fields (Figure 4.3.c). A question button attached to the Sentence card was clicked to record follow up questions for further interviews (Figure 4.3.d). Each set of questions was recorded with the statement it applied to and the name of the informant (s) and interview date (s). The Sentence field contained records of statements extracted from the interview. The source and date of utterance were recorded automatically which allowed the user to add, delete or change any of the listed sources of the current Sentence card. The Because field contained a record of explanation articulated by the source associated with statements and so provided a means of recording linkages between statements. The Condition field contained records of the circumstances under which the source articulated that the statement was valid.

The Keys stack provided a keyword facility. The knowledge base developer identified words within the sentence as keywords which could then form the basis of computerised searches of the knowledge base with combinations of keywords joined by ANDs, ORs or both.

The combination of these features and the ability to connect every single statement with the informant who articulated it, when it was articulated and the circumstances under which the statement was considered valid, together with follow up questions for further interviews, provided a useful means of recording, processing and accessing knowledge. TEAK was used throughout the knowledge elicitation period of fieldwork and all the knowledge gained from the interviews was recorded using it.

4.2.6.2.2 HyperNet

Experience during the early stages of fieldwork demonstrated that a large amount of the ecological knowledge in the present domain was of a causal type essentially consisting of series of cause and effect relationships, and that such knowledge was more fully captured using diagrams. As a result, HyperNet, a graphical tool for recording and representing knowledge was developed (Walker *et al.*, 1993).

Diagrams are widely used and have proved to be a useful means of synthesising and communicating information in ecological science and rapid rural appraisal (Conway, 1989; Lightfoot *et al.*, 1989). HyperNet is based on one widely used type of diagram known as a node and link diagram, in which small pieces of text (nodes) are joined in some meaningful way by lines, usually arrows (links). Because the meaning of links are variable, but explicitly stated, HyperNet diagrams differ fundamentally from other familiar types of node and link diagrams such as flow diagrams and decision trees. In contrast to most published node and link diagrams, HyperNet incorporates defined conventions for developing diagrams which eliminate inconsistency and ambiguity that commonly occur in less rigorously produced node and link diagrams (Walker *et al.*, 1993). The main features of HyperNet that facilitate knowledge synthesis, as used in the present study, are summarised below.

Every node entered into a diagram was classified as either an object (representing objects in the real world, for example, a tree), a process (representing things that happen, for example, splash erosion, germination), or an attribute (representing a particular attribute of an object or process, for example, height of tree, intensity of splash erosion, rate of germination). Links between any two nodes were restricted to a predefined set of link types (the most commonly used of which were: causal, influence, taxonomic and temporal). Restricting links to this set avoided ambiguity forcing the meaning of each node and link to be stated explicitly, which in turn made the resulting diagrams more precise.

A node and link diagram becomes unwieldy if more than a small number of nodes and links are created and, therefore, HyperNet supported the creation of sets of hierarchically structured diagrams. This facility was based on an ability to split any node pair connected by a link into a whole sub-diagram at a lower level in the hierarchy. This meant that each diagram could be kept relatively simple while the total complexity of the information represented in the whole diagram set was much larger. All links could be tagged with conditional information and were tagged with the source of the knowledge providing equivalence with the Whose, When and Condition fields in the Sentence card of TEAK. Once created, diagrams were saved for further exploration and modification.

HyperNet was written in Prolog, and was designed specifically to capture qualitative ecological knowledge about systems. The set of knowledge captured in HyperNet represented a structured argument and was, therefore, particularly useful for capturing, analysing and identifying gaps in knowledge relating to causal information. While, in principle all the knowledge articulated by farmers could be recorded using TEAK, the restricted syntax of diagrams, meant that some knowledge could not be usefully captured in diagrammatic form. Throughout the knowledge elicitation phase of fieldwork, all of the knowledge derived from interviews was recorded in TEAK while HyperNet was used for drawing labelled network diagrams to enhance the researcher's understanding of the subject and to identify gaps in knowledge to guide further fieldwork. An example of how HyperNet and TEAK were used in the present study to facilitate recording, accessing and analysing knowledge during knowledge elicitation is presented in Section 4.2.6.2.4.3.

4.2.6.2.3 Processing and accessing knowledge

The creation of knowledge bases in the present study was premised on the assumption that the knowledge articulated by an informant during interview is a particular combination of information which can be disintegrated into a number of unitary statements that may be useful in more than one context. Unitary statements are used here to refer to the smallest useful units of knowledge abstracted from interviews. In the creation of a knowledge base, a particular combination of information is of less interest than the underlying unitary statements. This is so because unitary statements may be combined in different ways by the informant for different purposes and so recording them along with information about their use provided flexibility for them to be subsequently used as individual building blocks in combination with other unitary statements to create new arguments. In contrast, higher level statements and whole arguments may only be useful in the context in which they were articulated.

4.2.6.2.3.1 Software development

Originally TEAK consisted of two tools: the transcript tool and the template tool. The transcript tool was designed to store transcriptions of interviews along with associated information on the source of the knowledge (the Whose and When card) as well as notes of explanations for reference in later stages of analysis. The template tool consisted of a set of template sentences (Table 4.2) designed to provide a basis for structuring articulated knowledge in a restricted form in order to produce consistent and tractable knowledge bases that would be amenable to computer coding and automatic reasoning. The template tool was based on the hypothesis that the majority of indigenous ecological knowledge could be fitted into a small identifiable set of template sentences. Thus, the rationale behind the transcript and template tool was to transcribe each interview in full and then to recast the key points from the transcript as structured template sentences.

The practical utility of the transcript tool as implemented in TEAK and of the template sentence approach to restricting articulated knowledge were evaluated in the field and found to be impractical. Production of full transcripts of interviews during the early stages of the fieldwork proved extremely time consuming and tedious, taking three to four hours for transcription of a one hour interview despite the researcher being bi-lingual. Other experience reported from Sri Lanka, where a researcher used a translator, resulted in it taking more than eight hours for transcription of a one hour interview (Southern, 1994). Interpreting transcripts as a set of template sentences also proved difficult, often causing distortion of the meaning of what was said by the informants. The initial set of template sentences was found to be inadequate for the variety of statements made by the informants (only about half of the statements articulated by Solma farmers could be captured in the initial set of templates). These experiences with TEAK during the early stages of the fieldwork lead to two major developments of the software and approach. These included:

- extraction of individual factual statements made by the informants directly from a play back of the tape recording rather than forcing all statements into structured templates; and

- development of a new version of TEAK with an appropriate mechanism for recording unitary statements arising from interviews (as outlined above 4.2.6.2.1). The principal components incorporated were the Sentences stack and Keys stack, while the Whose and When stacks which were already available were retained.

Table 4.2 The initial set of template sentence structures used with TEAK. For each statement to be recorded a template was selected and the blank part of sentences (—) were entered by the user.

____ will achieve ____	____ tramples ____
____ will occur as a result of ____	____ conserves ____
____ is a reason for ____	____ produces ____
____ is a way of ____	____ compete with ____
____ is used for ____	____ is defined by characteristics ____ and ____
____ is important for ____	____ is a sort of ____
An increase in ____ causes an increase in ____	____ is a part (component) of ____
A decrease in ____ causes an increase in ____	____ is next to ____
An increase in ____ causes a decrease in ____	____ is close to ____
A decrease in ____ causes a decrease in ____	____ (activity) is done ____ (place)
A change in ____ causes no change in ____	____ is ____ (distance) from ____
A change in ____ causes a change in ____	____ is at ____(place)
____ causes an increase in ____	____ happens ____(place)
____ causes a decrease in ____	____ happens at the same time as ____
____ causes no change in ____	____ happens before ____
____ causes a change in ____	____ happens at time ____
____ is a result of ____	____ happens during ____
____ causes ____	____ takes ____ (duration)
____ influences ____	____ happens ____ (frequency)
____ eats ____	____ is an attribute of ____
____ shades ____	____ (attribute) can range from ____ to ____
____ fertilises ____	____ (attribute) has the value ____
____ protects ____	____ (attribute) is measured in ____ (units)
____ kills ____	____ (attribute) can take possible values ____
____ pollinates ____	____ is ____ than ____
____ compacts ____	____ is preferred to ____
____ erodes ____	The effect of ____ is greater on ____ than on ____

Source: Haggith *et al.* (1992).

Extraction of unitary statements directly from playing back tape recordings was effective in that this process took substantially less time than full transcription, typically from one and a half to two hours for a one hour interview. However, it should be noted that there was a considerable degree of interpretation involved in this process. Recorded statements rarely used the same form of words that the informant had originally articulated (see example in Section 4.2.6.2.3.2). This was because the intention was to capture the sense of what was meant by the informant where as the actual spoken dialogue was specific to the idiosyncratic circumstances of each interview. Statements are factual in the sense that they are perceived by the source to be true rather than being scientifically verified. Care was taken to minimise distortion.

4.2.6.2.3.2 Extracting statements from tape recorded interviews

An example is given below to illustrate the process of recording factual statements directly from tape recorded interviews (Table 4.3). The short extract in Table 4.3 was taken from the first round of interviews with Nidhi Nath Khanal (one of the male Brahamin key informant living at high altitude in the study area) about effects of farmland trees on crops. A large amount of the verbal dialogue has been omitted in the example, so that only the dialogue relevant to the research is included. The Nepali has been translated into English (Nepali terms, identified in italic font, are defined elsewhere in this thesis).

Table 4.3 Interview extract: An example

Question: What trees do you grow on your farmland ? Nidhi Nath Khanal: There are different types, but the most important are fodder trees, like *nebharo, dudhilo, chamlayo, rato siris, painyu.* I also have a few *utis* trees in my farmland, but *utis* is not a good fodder. It is not very palatable to animals. Question: Do you think that these farmland trees influence crops ? Nidhi Nath Khanal: Yes. But it depends where trees are grown on the farmland. Some trees are grown on *pakho* land. Some trees are grown along gullies, like *bans. Bans* must never be planted on *bari* land. They are very *rukho.* Trees grown along gullies and *pakho* land do not affect crops because they are away from *bari* land. Fodder trees are mainly grown on bari land. Crops around these trees do not grow well because the trees cause shading and *tapkan* on crops. Question: Which trees on your *bari* land do you think influence crops most ? Nidhi Nath Khanal: Every tree on *bari* land influences crops. The most notorious one is *nebharo. Nebharo* causes heavy shading and *tapkan on* crops. The only tree I know is *rato siris* which neither causes heavy shading nor heavy *tapkan.* Question: Can you explain what is it about *nebharo* trees that causes heavy shading or *tapkan* ? And what is it about *rato siris* that does not cause heavy shading or *tapkan* ? Nidhi Nath Khanal: *Nebharo* has very big leaves. You might have noticed that they have very dense crowns as well. That is why they cause heavy shading and *tapkan. Rato siris* has very small leaves and a sparse crown, therefore, they do not cause heavy shade or *tapkan* on crops in a way that *nebharo* does.

While this is a very short extract of an interview at a fairly general level, close examination shows that it actually contains quite a lot of information requiring careful interpretation in order to generate concise set of meaningful unitary statements. After the interview session the tape was played back and statements were abstracted and written on paper before entering into TEAK. To illustrate this, from the text:

```
"... but the most important are fodder trees, like nebharo, dudhilo,
chamlayo, rato siris, painyu"
```

the following statements were extracted and source appended:

```
Nebharo is a type of fodder tree (Nidhi Nath Khanal, 23.12.92)
Dudhilo is a type of fodder tree (Nidhi Nath Khanal, 23.12.92)
Chamlayo is a type of fodder tree (Nidhi Nath Khanal, 23.12.92)
Painyu is a type of fodder tree (Nidhi Nath Khanal, 23.12.92)
Utis is a type of fodder tree (Nidhi Nath Khanal, 23.12.92)
```

Note that there is an element of interpretation here, it is not a direct translation of the informant's words. The name and date after the sentence give the informant and the date on which the interview took place which allows cross referencing with further information about the informant and the particular topic discussed in the interview. Other text from the extract in Table 4.3 such as:

```
"... Utis is not a good fodder. It is not very palatable to animals"
```

generated useful factual statements on other topics:

```
Utis is not a good fodder (Nidhi Nath Khanal, 23.12.92)

Utis fodder is not very palatable to animals (Nidhi Nath Khanal,
23.12.92)
```

Interviews were conducted separately for each of the three topics studied and because the topic of this interview was tree-crop interactions, information on fodder value was not of immediate relevance, but was useful for the fodder evaluation topic. Such odd pieces of relevant information occurred throughout the course of fieldwork and were recorded in TEAK as part of the fodder evaluation knowledge base and kept separately from the emerging tree-crop interactions knowledge base.

Part of the extract from Table 4.3 could be recorded in more than one way, for example:

```
"... it depends where trees are grown on the farmland. Some trees are
grown on pakho land. Some trees are grown along gullies, like bans.
Bans must never be grown on bari land. They are very rukho. Trees grown
along gullies and pakho land do not affect crops because they are away
from the bari land. Fodder trees are mainly grown on bari land. Crops
around these trees do not grow well because the trees cause shading and
tapkan on crops"
```

Initially, because the text contained statements linked with explanation it was thought prudent to record it so that explanation remained linked to the statement with which it was associated. As a result, a mechanism for recording linkages between statements through the use of BECAUSE was introduced to TEAK by incorporating a Because field in the Sentence card (Figure 4.3.c). On this basis, the following statements were constructed from the text extract above:

```
Trees do not influence crops IF they are grown along gullies OR pakho
land BECAUSE gully AND pakho land are located away from bari land (Nidhi
Nath Khanal, 23.12.92)

Trees influence crops IF they are grown on bari land BECAUSE they cause
shading AND tapkan on crops (Nidhi Nath Khanal, 23.12.92)

Bans is not grown on bari land (Nidhi Nath Khanal, 23.12.92)

Bans is grown along gullies (Nidhi Nath Khanal, 23.12.92)

Bans is rukho (Nidhi Nath Khanal, 23.12.92)
```

Note that the first two statements were recorded as conditional statements on the basis that there was an implication that *pakho* land and *bari* land were alternatives to gully land.

Further consideration revealed a number of deficiencies in the initial structure of statements like these in respect of the basic concepts of rigorous representation of knowledge discussed earlier (Section 2.3). Some of these statements were too long and such statements were found to be unwieldy to search for using keywords. Some statements contained more than one fact so that they could be further broken down into smaller statements without loss of meaning. For example, the statement `'Trees influence crops IF they are grown on bari land BECAUSE they cause shading AND` tapkan on crops' contained two facts relating to 'shading' and 'tapkan' which could be broken down into two separate unitary statements as follows:

Trees influence crops IF they are grown on bari land BECAUSE they cause shading on crops (Nidhi Nath Khanal, 23.12.92)

Trees influence crops IF they are grown on bari land BECAUSE they cause tapkan on crops (Nidhi Nath Khanal, 23.12.92)

It also became evident that where a BECAUSE link was used as a means of recording linkages between statements, these links themselves could more appropriately be represented as unitary statements. For example, the statements 'Trees influence crops IF they are grown on bari land BECAUSE they cause shading on crops' and 'Trees influence crops IF they are grown on bari land BECAUSE they cause tapkan on crops' could be more appropriately represented as:

Trees cause shading on crops IF they are grown on bari land (Nidhi Nath Khanal, 23.12.92)

Shading influences crops (Nidhi Nath Khanal, 23.12.92)

Trees cause tapkan on crops IF they are grown on bari land (Nidhi Nath Khanal, 23.12.92)

Tapkan influences crops (Nidhi Nath Khanal, 23.12.92)

As a result, the use of the BECAUSE link was discontinued and all the contents of Because fields were transferred to new Sentence cards. These experiences led to the conclusion that certain conventions could be usefully adopted while constructing unitary statements generated by an interview. These included:

- that unitary statements should contain a single unit of information which cannot be broken down meaningfully into two or more statements; and

- that unitary statements should contain knowledge that is useful without reference to other statements.

Using these conventions the following unitary statements were finally constructed from the last two paragraphs in Table 4.3.

```
Nebharo causes heavy shading on crops (Nidhi Nath Khanal, 23.12.92)

Nebharo causes heavy tapkan on crops (Nidhi Nath Khanal, 23.12.92)

Rato siris does not cause heavy shading on crops (Nidhi Nath Khanal,
23.12.92)

Rato siris does not cause heavy tapkan on crops (Nidhi Nath Khanal,
23.12.92)

Trees cause heavy shading on crops IF they have big leaves AND a dense
crown (Nidhi Nath Khanal, 23.12.92)

Trees cause heavy tapkan on crops IF they have big leaves AND a dense
crown (Nidhi Nath Khanal, 23.12.92)

Trees do not cause heavy shading on crops IF they have small leaves AND
a light crown (Nidhi Nath Khanal, 23.12.92)

Trees do not cause heavy tapkan on crops IF they have small leaves AND a
light crown (Nidhi Nath Khanal, 23.12.92)

Nebharo has big leaves (Nidhi Nath Khanal, 23.12.92)

Nebharo has dense crown (Nidhi Nath Khanal, 23.12.92)

Rato siris has small leaves (Nidhi Nath Khanal, 23.12.92)

Rato siris has light crown (Nidhi Nath Khanal, 23.12.92)
```

This extract also generated a number of questions that needed to be asked in the follow up interviews for clarification. For example, are *rukho* trees always planted along gullies and not on *bari* land ? What does *rukho* mean ? Are there trees other than *bans* which farmers recognise as *rukho* ? Do farmers recognise trees as being anything other than *rukho* ? Do all big leaved trees cause heavy *tapkan* or shading ? These questions were recorded in TEAK using the question button. In summary, the outcome of this early experience led to knowledge representation as:

- sets of unitary statements containing a single unit of information which could not be broken down meaningfully into two or more statements but made sense without reference to other statements;

- each statement was tagged with its source (s) (who the information came from and when) so that the circumstances under which the information was recorded were known;

- each statement had any known conditions limiting its application specified; and

- a set of questions were attached to each statement, requiring further clarification in follow up interviews.

4.2.6.2.4 Analysing knowledge

This section concentrates on the analysis of knowledge during the iterative fieldwork phase rather than on the analysis of the content of complete knowledge bases, which is considered in Chapter 5. While maintaining a degree of spontaneity and the opportunity to incorporate the unexpected, it was important that the fieldwork as a whole moved steadily towards answering particular questions. This was achieved largely by assessing what had already been discovered and deciding on that basis what else must be sought. The objective was to fill gaps in the emerging knowledge base, eliminate distortions caused by partial or incorrect interpretation of what had been articulated and to resolve conflicts in the knowledge base where possible. Achieving these objectives required working systematically through the knowledge base invoking a range of techniques as follows: identifying associated sets of statements; identifying the conditional status of statements; identifying complete chains of reasoning; identifying and resolving conflicting statements; and capturing the degree of certainty associated with statements. Each of these are discussed and examples are given in the following sections.

4.2.6.2.4.1 Identifying associated sets of statements

This involved exploring knowledge that was possibly associated with each unitary statement. For example, for the statement `'Bans is rukho'` in the previous example it was necessary to investigate whether or not there were *rukho* tree species other than *bans*, what the informant actually meant by *rukho* and whether the informant recognised other types of tree than *rukho* trees. A follow up interview based on these questions revealed that:

- three other tree species (*mayal, shyalfusro and nigalo*) were also recognised as *rukho* by the informant;
- *rukho* trees were thought to cause crop yield to decrease ; and
- trees were also recognised as *malilo* by the informant, two tree species (*rato siris* and *utis*) were recognised as *malilo* and that *malilo* trees were thought to cause crop yield to increase.

On the basis of this information, the statement `'Bans is rukho'` was edited and new information incorporated into the knowledge base (Table 4.4).

Table 4.4 New information incorporated into the knowledge base following evaluation and a follow up interview based on the initial extract in Table 4.3. See text for explanation of the process of evaluation.

```
Bans is a type of rukho tree
Mayal is a type of rukho tree
Shyalfusro is a type of rukho tree
Rukho tree causes a decrease in crop yield
Rato siris is a type of malilo tree
Utis is a type of malilo tree
Malilo tree causes an increase in crop yield
```

Such evaluation provided information which served four different purposes:

- clarification of old information and editing where necessary (for example `'Bans is a type of rukho tree'` on the basis that there were other *rukho* trees);

- generation of new information (for example, the *rukho-malilo* status of trees);

- generation of further questions for the next round of interviews. For example, what is it about *bans* (and *shyalfusro* ...) that causes a decrease in crop yield and what is it about *rato siris* (and *utis*) that causes an increase in crop yield; and

- gradual development in the understanding on the part of the researcher about the topic studied, for example, trees cause *rukho-malilo* effects on crops and on the basis of this understanding farmers tend to classify trees using *rukho* and *malilo* categories.

In order to confirm that all the relevant knowledge associated with the above statements had been covered, a full set of statements were then formulated as in Table 4.4 and presented to the informant for comment. Informants were essentially asked to confirm or contradict each of the statements.

4.2.6.2.4.2 Identifying the conditional status of statements

This involved ensuring that the conditions under which statements applied had been identified and that any existing alternative statements relevant to other conditions had been covered. For example, the knowledge base contained the statement that `'Trees cause heavy tapkan on crops IF they have big leaves AND a dense crown'`. Further fieldwork revealed that the condition under which the statement applied was not entirely correct. It was found that an additional condition `'AND the amount of rainfall is high'` needed to be attached to this statement, implying that despite big leaves and a dense crown, trees would not cause heavy *tapkan* if the amount of rainfall was low.

Consequently the statement was simply restructured as:

```
Trees cause heavy tapkan on crops IF they have big leaves AND a dense
crown AND the amount of rainfall is high
```

Similarly, as in the case of associated knowledge previously, in order to check that any existing alternatives based on other conditions had been covered, a set of statements were formulated and presented to the informant for discussion. For example, in this case:

```
Trees cause heavy tapkan IF they have big leaves AND a dense crown
Trees cause heavy tapkan IF they have big leaves AND a light crown
Trees cause heavy tapkan IF they have small leaves AND a dense crown
Trees cause heavy tapkan IF they have small leaves AND a light crown
```

Certain statements were unconditional and once this feature was confirmed, it was recorded by setting the condition 'ALWAYS'. For example, `'Bans is a type of rukho tree. ALWAYS'`.

4.2.6.2.4.3 Identifying complete chains of reasoning

This involved identifying causal links between events and expanding these links to obtain a more detailed explanation of relationships. This was achieved through the application of node and link diagramming using HyperNet as discussed earlier (4.2.6.2.2). For illustrative purposes, the knowledge collected from the first round of interviews about the shading effect of trees on crops is presented (Figure 4.4).

After completing the first round of interviews, the causal knowledge recorded in TEAK was selected and used to develop HyperNet diagrams. While doing so, three levels of knowledge were identified. The first level consisted of very basic knowledge indicating general influences (upper section of Figure 4.4). This was expanded in the second level (middle section of Figure 4.4) where some causal linkages were identified. The third level was a further expansion of the second level including greater detail (lower section of Figure 4.4).

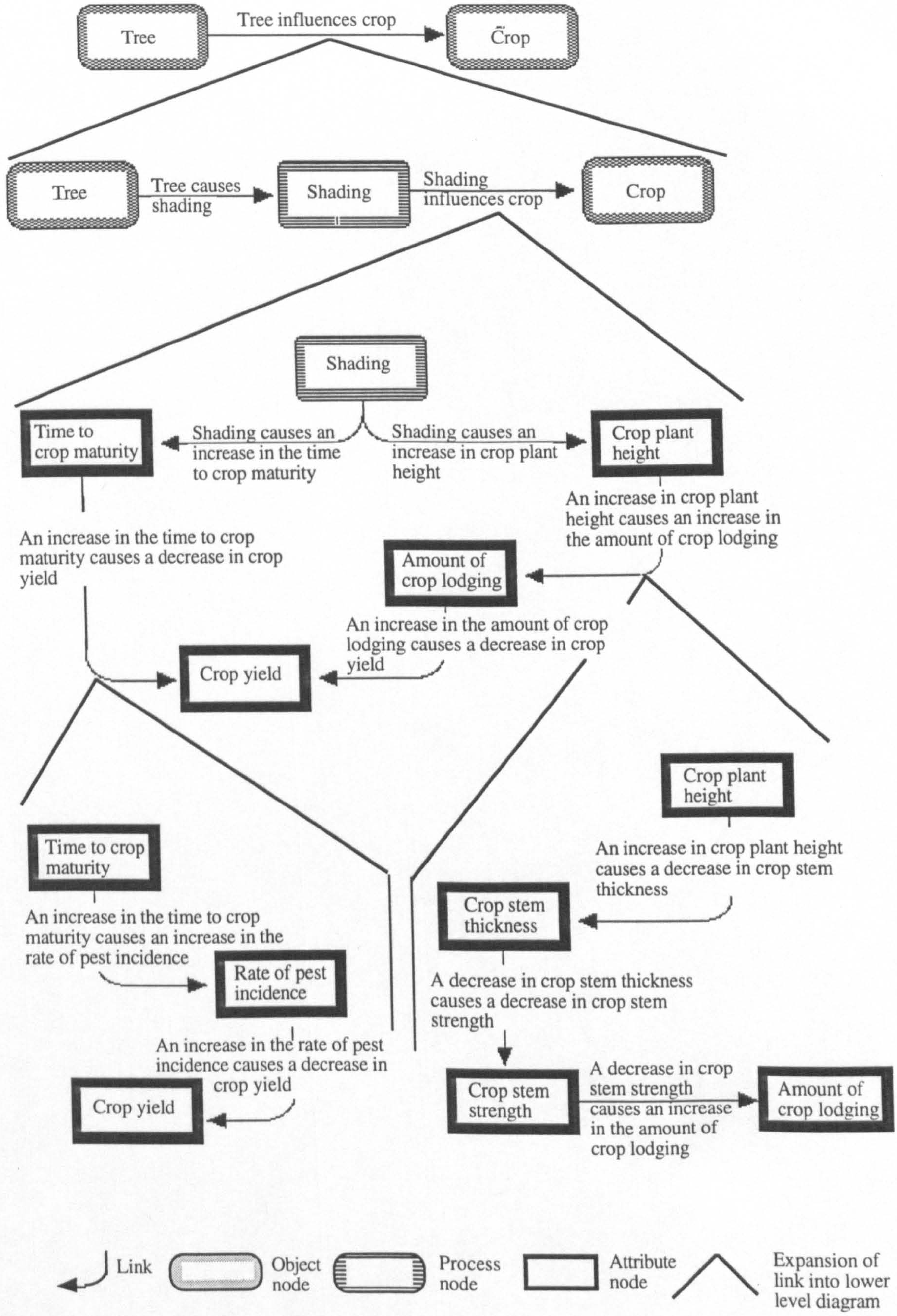


Figure 4.4 A portion of the knowledge base about the effects of tree shading on crops synthesised into a set of hierarchically linked diagrams using HyperNet (the lower diagrams are expansions of a single link in the diagram above).

While structuring the knowledge in HyperNet, first the meaning of each of the links had to be carefully considered as a feature of the entire procedure. Subsequently, the completeness of the diagram as a whole was assessed. Following this procedure, it rapidly became clear that several linkages had not been explicitly stated by the informants. For example, in the present example there was no explanation as to how an increase in crop plant height resulting from shading influenced crop lodging. Similarly, there was no statement explicitly indicating link between crop maturity and crop yield.

The gaps in knowledge identified through the use of HyperNet were used as a basis for generating a checklist of questions for future interviews (for example, how does an increase in crop plant height resulting from shading influence crop lodging ? How does a delay in the time to crop maturity resulting from shading cause a decrease in crop yield ?). An example of information obtained from a follow up interview based on such a checklist is given in Table 4.5.

Table 4.5 New information obtained from a follow up interview based on checklist generated by HyperNet diagram in Figure 4.4.

```
An increase in crop plant height causes a decrease in crop stem
thickness

A decrease in crop stem thickness causes a decrease in crop stem
strength

A decrease in crop stem strength causes an increase in crop lodging

Delay in the time to crop maturity causes an increase in the rate of
pest incidence

An increase in the rate of pest incidence causes a decrease in crop
yield
```

The new information derived from follow up interviews was again incorporated into the diagram which was then re-assessed and once again any gaps in knowledge identified for investigation in further interviews. This process was repeated until a comprehensive understanding of the topic had been gained as determined by not being able to identify further logical omissions. The use of HyperNet diagrams thus provided a rapid means of developing a clear understanding of the topic studied and in identifying important issues to be dealt with in further interviews which had not been readily apparent from consideration of the unitary statements in a textual form. A combination of HyperNet, TEAK and the use of the question button proved to be a powerful means of driving fieldwork.

4.2.6.2.4.4 Identifying and resolving conflicting statements

Over the course of knowledge elicitation, it became apparent that the knowledge base contained several conflicting statements. Such conflicting statements and the reasons for them were considered in order that they could either be resolved or retained as unresolved alternatives in the knowledge base. Careful consideration revealed different types of conflict, for example, conflicts in statements by the same informant as opposed to conflicts in statements amongst different informants. Conflict occurred sometimes because the researcher misunderstood the information provided by the informant and sometimes because the question asked was too vague, but certain conflicts remained unexplained. A brief example follows.

Discussion about which farmland fodder trees cause most *tapkan* produced conflicting statements by two different informants as follows:

```
Dudhilo causes heavy tapkan (Ananta Ram Khanal, 23.2.93)
Dudhilo causes light tapkan (Purna Dhoj Limbu, 21.2.93)
```

Further consideration of the above statements in a follow up interview lead to a new discovery that farmers recognised two different varieties of *dudhilo* (*thulo pate dudhilo* and *sano pate dudhilo*). Thus, the original statements were not actually conflicting, but the two informants were referring to two different varieties of the same species which had different implications for *tapkan*. This process of conflict resolution thus generated a number of important questions to be dealt with in further fieldwork.

- What are the characteristics of the two varieties of *dudhilo* ?
- Are there other tree species for which farmers recognise more than one variety ?
- Are the two varieties of *dudhilo* reported by farmers recognisably and consistently different by objective criteria ?

The follow up interviews revealed that the leaf size was larger and crown density higher for *thulo pate dudhilo* than for sano pate dudhilo and, therefore, *thulo pate dudhilo* was thought to cause heavy *tapkan* and *sano pate dudhilo* to cause light *tapkan*. On the basis of this information, a number of new statements were constructed (Table 4.6).

Table 4.6 New information generated through the process of conflict resolution (An example of conflicts in statements amongst different informants, a case of two varieties of *dudhilo* (*thulo pate dudhilo* and *sano pate dudhilo*).

```
Thulo pate dudhilo causes heavy tapkan
Sano pate dudhilo causes light tapkan
Thulo pate dudhilo has big leaves
Thulo pate dudhilo has dense crown
Sano pate dudhilo has small leaves
Sano pate dudhilo has light crow
Thulo pate dudhilo causes heavier tapkan than sano pate dudhilo
```

Similarly, the knowledge base also contained conflicting statements by the same informant. For example, discussion about the fodder value of farmland tree species produced conflicting statements by the same informants as follows:

```
Bakaino is a posilo (nutritious) type of fodder (Guru Pradad Luitel, 9.3.93)

Bakaino is a kam posilo (less nutritious) type of fodder (Guru Pradad Luitel, 9.3.93)
```

Further fieldwork showed that these were not in fact conflicting statements but that the informant was referring to the fodder value of *bakaino* for two different classes of animals. It was revealed that farmers often classified tree fodder as either goat-sheep fodder or cattle-buffalo fodder and that any fodder considered as *posilo* to cattle and buffalo was also considered *posilo* to goats and sheep, but that all goat-sheep fodder was considered *kam posilo* to cattle and buffalo. *Bakaino* was considered *posilo* fodder for goats and sheep, while *kam posilo* for cattle and buffalo. So, the statements were restructured as in Table 4.7.

Table 4.7 New information generated through the process of conflict resolution (An example of conflicts in statements by the same informants, a case of *bakaino*).

```
Bakaino is a type of goat-sheep fodder
Bakaino fodder is posilo to goats (and sheep)
Bakaino fodder is kam posilo to cattle (and buffalo)
Goat-sheep fodder is kam posilo to cattle (and buffalo)
Cattle-buffalo fodder is posilo to goats (and sheep)
```

4.2.6.2.4.5 Capturing the degree of certainty associated with statements

Certainty refers here to the confidence with which statements were considered to be true or known. Efforts were made to elicit a certainty rating based on a simplified scale, for example, 0 (known never to occur) to 3 (known always to occur) for each statement. However, this proved to be impractical because informants were uncomfortable with this concept and either would not articulate or were not confident in stating a degree of certainty associated with a statement. Because of this, attempts to record the certainty of statements was discontinued after a short trial.

In summary, an iterative fieldwork strategy based on a short fieldwork cycle supported by software packages (TEAK and HyperNet) proved to be an effective means of recording, processing and analysing knowledge during knowledge elicitation. This iterative process was applied sequentially for each of the three topics studied. The cycle was repeated until the subject studied was comprehensively covered, which was considered to have occurred when informants started repeating facts they had already stated and added no further knowledge to that already recorded. While the processes described above could, in principle, have been undertaken on paper, it would not have been possible to amass such a large and coherent set of knowledge on paper in an equivalent time period because the collation and analysis of knowledge demanded and enabled by the use of the computer software is what ensured the coherence of the elicitation strategy.

4.3 KNOWLEDGE REPRESENTATION

By definition, a knowledge based systems approach involves the development and use of a formal knowledge base. The creation of knowledge bases was premised on the assumption that computer based reasoning could assist in exploring, evaluating and using knowledge.

The creation of the tree fodder knowledge base involved two stages of knowledge representation: intermediate representation defined here as, the process of recording knowledge as unitary statements in natural language preceded formal representation, which is defined as, the process of coding knowledge in a restricted format that can be used for automatic reasoning. The intermediate and formal representation was achieved through the application of AKT (Agroforestry Knowledge Toolkit), a software toolkit under development as part of a broader research programme of which the present study formed an integral part.

The methodological approaches and the techniques of representing knowledge in the knowledge base as intermediate and formal representations and how they were achieved through the application of the AKT toolkit are discussed in this section.

4.3.1 AKT (Agroforestry Knowledge Toolkit)

AKT was under development during the research and this development process was influenced by the experiences gained through attempting to apply the software in the present study. AKT was implemented in Prolog for use on Apple Macintosh computers and combined the functionality of the two previous software packages TEAK and HyperNet. The software comprised seven sets of interfaces: the sentence interface; the diagram interface; the source interface; the keyword interface; the selection interface; the statement of fact interface; and the formalisation interface. Furthermore, reasoning tools were available within AKT facilitating automatic reasoning. A full description of AKT functionality can be found in Walker *et al.* (1994) and a brief description of each of the interfaces including the reasoning tools and how they were implemented at the time they were used in the present study are presented where appropriate in this thesis with examples.

4.3.2 Intermediate representation

The objective of creating an intermediate knowledge base was to produce a succinct and explicit record of current knowledge which could then be formally represented. Thus, in principal the intermediate representation was transient. However, since formal representation is inherently less expressive than intermediate representation, it may not fully capture the meaning of intermediate statements. Therefore, the maintenance of intermediate statements together with their formal equivalents retained more of the original knowledge articulated while enabling automated reasoning with the formalised knowledge.

In the process of intermediate representation, efforts were made to synthesise and compact the knowledge base by minimising repetition, ensuring that the terms used were consistent and that the content of the knowledge was as unambiguous as possible. A range of different techniques were used to synthesise the knowledge base and these are discussed in the following section.

4.3.2.1 Minimising repetition

TEAK was developed in HyperCard (and its associated scripting language HyperTalk) and since HyperCard could not provide sufficiently flexible manipulation of knowledge that was possible with Prolog (Walker *et al.,* 1994), the knowledge bases created and stored using TEAK were subsequently transferred to AKT. Originally, separate knowledge bases for each of the three topics studied were created to ensure that each topic was covered comprehensively. While this strategy proved effective during elicitation, it was apparent that there were considerable repetitions of statements amongst the knowledge bases. Therefore, the three knowledge bases were merged to form a single unified tree fodder knowledge base. The tree fodder knowledge base contained 3 265 statements at this juncture.

Once the knowledge bases were merged, repetitive statements in the knowledge base were located and removed. The result was a significant compaction of the knowledge base reducing the number of statements by about 38%.

4.3.2.2 Explicit record of knowledge

Experience in the present study has shown that allowing statements to be recorded in natural language can lead to ambiguous intermediate representation. While, natural language is robust in its use and interpretation, to be useful as a precursor of formal representation, statements in the knowledge base were required to be as unambiguous as possible and exactly specified.

In the process of intermediate representation, the knowledge base was found to contain several statements which either contained implicit meaning or were ambiguous. Similarly, the terms used were often found to be inconsistent. For example,

```
Fodder trees are lopped more than one time per year IF they coppice
rapidly

Badahar fodder causes an increase in milk production
```

An increase in crown density causes an increase in the intensity of tapkan

Note that the meaning of the above statements were not explicitly represented although meaning was implied, for example, 'Badahar fodder causes an increase in milk production', by implication this was through feeding badahar fodder to a lactating animal. The use of the term 'intensity of tapkan' was ambiguous in that it contained two different meanings, for example, 'duration of tapkan' and 'the number of tapkan drops' which together constituted 'intensity of tapkan'. Similarly, the term 'coppice' could be more explicitly stated as 'the rate of regrowth of shoots after lopping'.

Throughout the process of intermediate representation, statements containing ambiguity and implicit meaning in the knowledge base, such as those outlined above, were identified and made explicit. So, the statements above were restructured as:

The lopping frequency of tree fodder is greater than one time per year IF the rate of regrowth of shoots after lopping is rapid

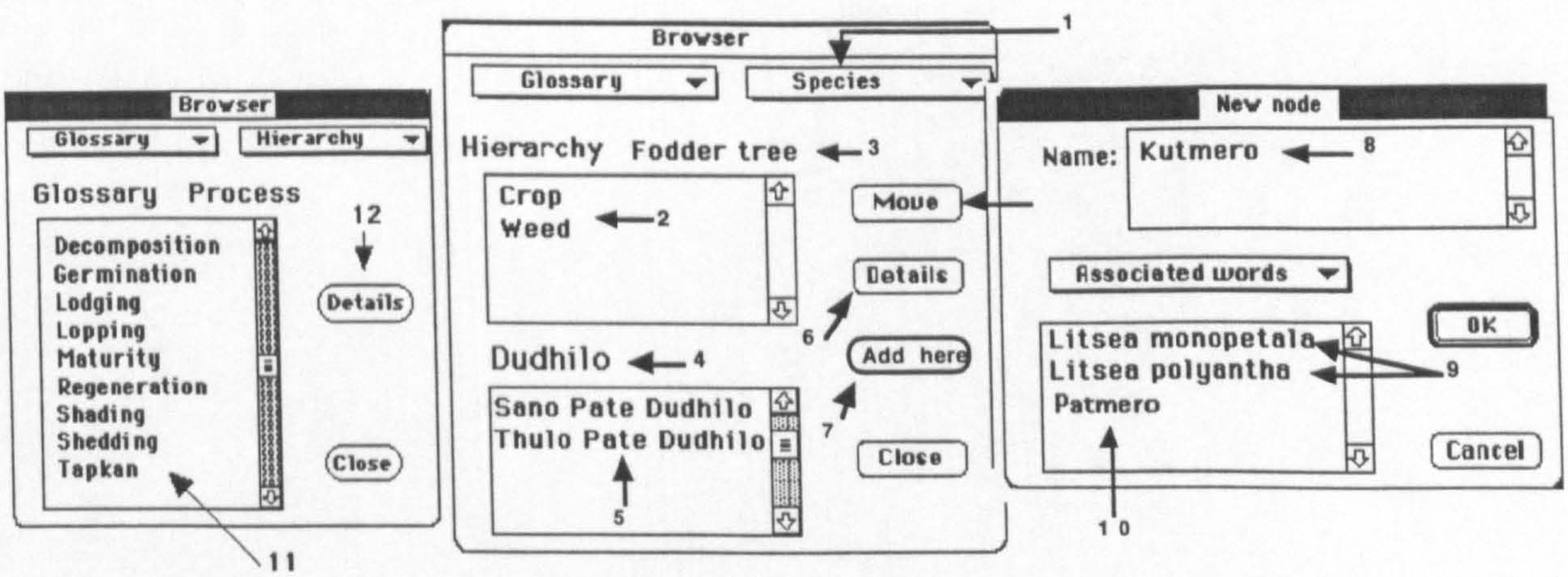
An increase in crown density causes an increase in the number of tapkan drops

An increase in crown density causes an increase in the duration of tapkan

Feeding badahar fodder to lactating animals causes an increase in milk production

Inconsistent use of terms was a significant source of ambiguity. Although not apparent during elicitation, it was subsequently found that different terms were often used to capture the same meaning and that single terms were used to capture different meanings. For example, 'intensity of tapkan' was used to mean both 'the duration of tapkan' and 'number of tapkan drops' and 'coppice' to refer to the 'rate of regrowth of shoots after lopping'. Consistent use of terms was encouraged by the use of glossaries of keywords, a facility available in the keyword interface within AKT which could be continuously updated (Figure 4.5). Every time a new intermediate statement was created, terms within that statement that were already defined within the identified automatically, terms not already in the glossary were manually identified and entered into an appropriate glossary.

In the process of intermediate representation, four fundamental types of terms were encountered. These included: objects (representing objects in the real world), processes (representing things that happen), attributes (which refer to a particular attribute of an object or process) and values (which refer to a value of a particular attribute of an object or process). For example, in a statement `'An increase in crown density causes an increase in the number of tapkan drops'`, `'crown'` was identified as an object or more accurately part of an object `'tree'`, `'density'` as an attribute of an object `'crown'`, `'increase'` as a value of the attribute `'density'`, `'tapkan'` was identified as a process, `'number of drops'` as an attribute of the process `'tapkan'` and `'increase'` as a value of the attribute `'number of tapkan drops'`. Because these terms have different meanings they were stored separately in appropriate glossaries each comprising a list of terms.



1. The name of current hierarchy, selecting the arrow generates a list of all the hierarchies
2. A list of 'parent' nodes of the current hierarchy
3. 'Parent' node of the current node
4. The current node
5. A list of 'children' of the current node
6. Provides further information about the current node
7. Places the new node in the current hierarchy (in this case in the list of 'children' of the current node)
8. The name of the new node about to be added in the current hierarchy
9. Binomial synonymous for 8
10. Nepali synonymous for 8
11. Process glossary containing a list of of terms identified as process
12. Provides further information about terms listed in the process glossary

Figure 4.5 The keyword interface.

The object glossary contained a list of terms identified as objects in intermediate statements, the process glossary contained a list of all terms identified as processes and the attribute glossary contained a list of terms identified as particular attributes of processes or objects. The glossaries contained 208 objects, 43 processes and 162 attributes.

The keyword interface also provided a mechanism for recording the definition of terms listed in the glossary. An example of some of the terms encountered and captured in the glossaries during the creation of the intermediate knowledge base are presented in Table 4.8.

Table 4.8 Examples of terms captured in keyword glossaries during the creation of the intermediate knowledge base.

Object	Process	Attribute	Attribute-value
Tree		Height	Tall, short
Crown		Size Density	Large, small Dense, light
Leaf		Size Texture	Small, big Stiff, coarse, soft
Stem		Thickness Strength	Increase, decrease Increase, decrease
Root		Depth Spread	Shallow, deep Horizontal, vertical
	Lodging	Amount	Increase, decrease
	Decomposition	Rate	Rapid, slow
	Shedding	Time	Early dry season, late dry season
	Tapkan	Number Duration Velocity	Increase, decrease Increase, decrease Increase, decrease
	Splash erosion	intensity	Increase, decrease
	Lopping	Rate of regrowth of shoots Frequency Timing	Rapid, slow Greater than, less than Early dry season, late dry season

Synonymous terms were frequently encountered in the creation of the intermediate knowledge base. The most common synonyms were sets of names for the same tree species or crop varieties, for example, *painyu,* wild cherry and *Prunus cerasoides,* the Nepali, English and binomial names for the same species respectively. However, synonymous terms also frequently occurred in the same language, for example, *kutmero* or *patmero* which are equivalent Nepali name for the species *Litsea monopetala.* It is interesting to note that some ethnic groups, particularly Limbus tended to have names for different tree species in their local dialect. Examples include *phasrel* and *rodingo* in Limbu for which the equivalent Nepali names are *gogun* and *faledo* and the equivalent binomial names are *Saurauia nepaulensis* and *Erythrina variegata* respectively. The keyword interface was introduced to AKT to provide a structure in which synonymous terms could be identified and captured efficiently in the keyword hierarchy (Figure 4.5). Before this facility was available, such synonymous information was recorded as a list of statements of equivalence as follows:

```
Rodingo is a Limbu name for faledo
Erythrina variegata is a binomial name of faledo
Patmero is synonymous to kutmero
Litsea monopetala is a binomial name for patmero
```

Provision of the synonym facility in the keyword interface within AKT, therefore, allowed significant compaction of the knowledge base.

These techniques were applied throughout the process of intermediate representation. The result of the process was the development of a more compact knowledge base with a more consistent use of terms and, therefore, a more explicit statement of knowledge.

4.3.2.3 Imposing hierarchical structure

The imposition of hierarchical structure was based on the assumption that much indigenous ecological knowledge is inherently hierarchical in nature because the description and explanation of ecosystems tends to be hierarchical. The most common example of a hierarchical structure of ecological knowledge is the taxonomic classification of relationships between plant species. Hierarchical classification is widely used in ethnographic research (Werner and Schoepfle, 1987a; 1987b), for example, in deriving species taxonomies (Berlin, 1973) and soil taxonomies (Benfer and Furbee, 1990).

In the process of intermediate representation, hierarchical information was captured using the facilities available in the keyword interface within AKT by identifying a parent-child relationship between two objects (Figure 4.5) in which each link in the hierarchy has the meaning `'is a type of'`. The purpose for creating object keyword hierarchies in the current knowledge base were twofold:

- facilitating the development of a compact knowledge base; and
- facilitating hierarchically structured exploration of the knowledge base (Chapter 5).

Initially, the knowledge base contained a large amount of information particularly related to plant species. For example,

```
Thulo pate dudhilo is a type of dudhilo
Sano pate dudhilo is a type of dudhilo
Dudhilo is a type of fodder tree
Udase is a type of weed
Illame is a type of weed
Sano seti  is a type of maize
Thulo seti is a type of maize
Maize is a type of crop
Mudke is a type of millet
Millet is a type of crop
Badahar is a type of fodder tree ...
```
and so on.

Using the keyword interface such information was more easily captured in a hierarchical structure by creating a plant species hierarchy (Figure 4.6) and the separate statements made redundant since they were deducible from the hierarchy.

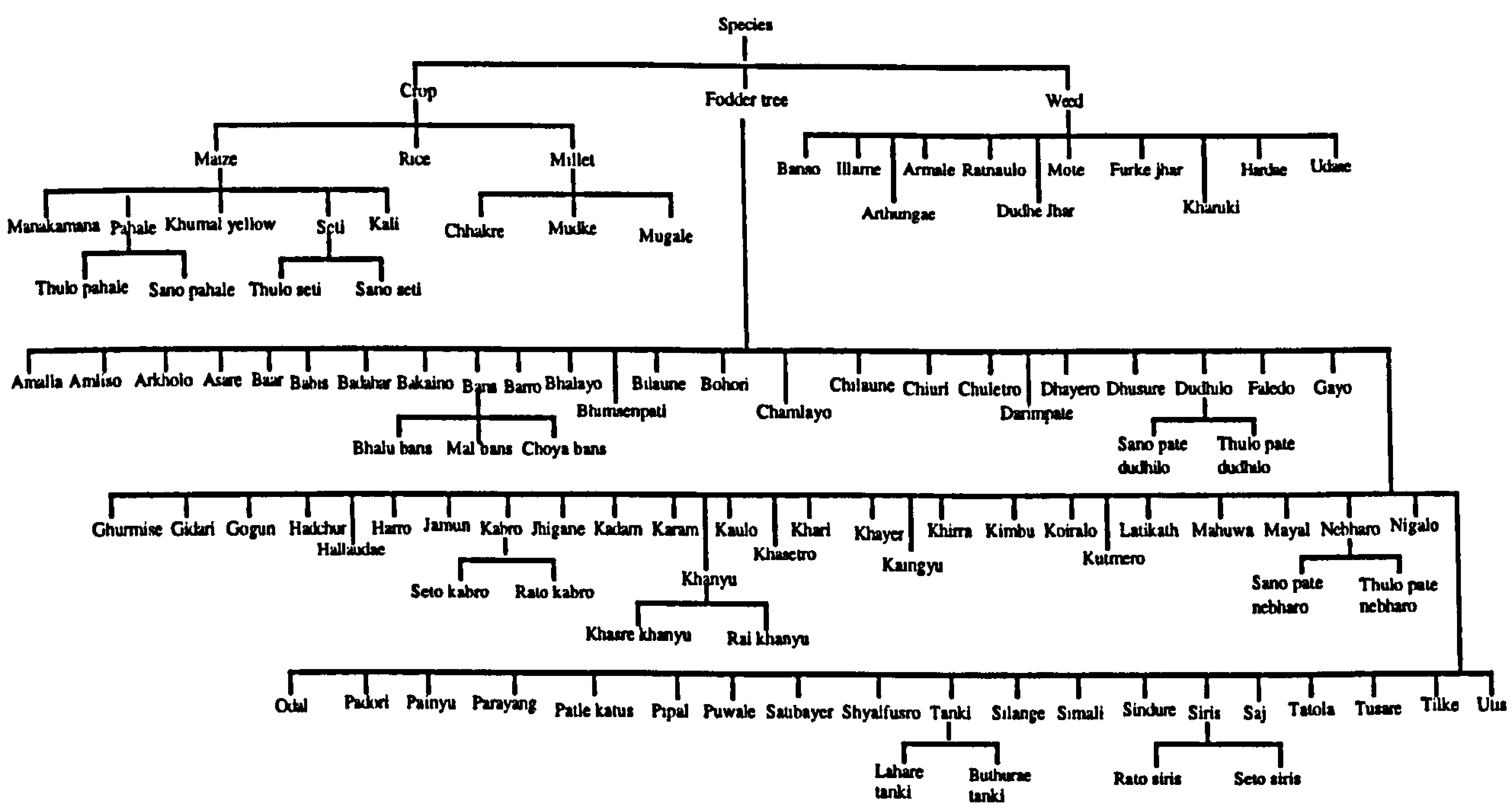


Figure 4.6 Plant species hierarchy (an example of an object keyword hierarchy).

The intermediate knowledge base contained six keyword hierarchies: species; *rukho-malilo* fodder tree (Figure 4.7); *posilo-kam posilo* fodder tree (Figure 5.6.a); *chiso-obano* fodder tree (Figure 5.6.c); type of goat-sheep and cattle-buffalo fodder (Figure 5.6.b); and type of tree planting site created directly in relation to the content of the knowledge base. Some object keywords appeared in more than one hierarchy, for example, the object *rato siris* appeared both in the *posilo-kam posilo* and the *rukho-malilo* hierarchies because *rato siris* was considered by the farmers to be *posilo* as well as to be a *malilo* fodder tree. Certain keywords identified in the intermediate statements as objects could not be structured hierarchically. Such object keywords were captured in a miscellaneous flat list. The outcome of the imposition of hierarchical relationships was a significant compaction of the knowledge base and producing an end result that could be more flexibly accessed and explored (Chapter 5).

4.3.2.4 Deductive reasoning

Deductive reasoning may be described as the process of deriving general principles from a set of instances which can both compact the content of the knowledge base and illuminate interesting properties of a set of knowledge. In the process of intermediate representation, in some instances, it was possible to apply deductive reasoning across the knowledge base. The knowledge base contained information about the characteristics of a number of tree species in regular use including whether they were considered to be *rukho* or *malilo, posilo* or *kam posilo, chiso* or *obano* and goat-sheep or cattle-buffalo fodder. Furthermore, the knowledge base contained a set of statements about *rukho-malilo, posilo-kam posilo, chiso-obano* and goat-sheep or cattle-buffalo fodder which together constituted definitions for these terms. For example,

```
Bans is a type of rukho fodder tree
Shyalfusro is a type of rukho fodder tree
Bans has shallow roots
Shyalfusro has shallow roots
Bans roots compete heavily with crops for soil nutrients
Bans roots compete heavily with crops for soil moisture
Shyalfusro roots compete heavily with crops for soil nutrients
Shyalfusro roots compete heavily with crops for soil moisture
Rato siris is a type of malilo fodder tree
Tatola is a type of malilo tree
Rato siris has deep roots
Tatola has deep roots
Rato siris roots do not compete heavily with crops for soil nutrients
Rato siris roots do not compete heavily with crops for soil moisture
Tatola roots do not compete heavily with crops for soil nutrients
Tatola roots do not compete heavily with crops for soil nutrients
```

```
Badahar is a type of posilo fodder
Mal bans is a type of posilo of fodder
Feeding badahar fodder to lactating animals causes an increase in milk
(and ghee) production
Feeding mal bans fodder lactating animals causes an increase in milk
(and ghee) production
Badahar fodder is palatable to animals
Mal bans fodder is palatable to animals
Painyu is a kam posilo type of fodder
Gogun is a kam posilo type of fodder
Feeding painyu fodder to lactating animal does not causes an increase in
milk (and ghee) production
Painyu fodder is not very palatable to animals
Feeding gogun fodder to lactating animals does not causes an increase in
milk (and ghee) production
Gogun fodder is not very palatable to animals
```

Dudhilo is a type of chiso fodder
Nebharo is a type of chiso fodder
Dudhilo fodder causes animals to produce watery dung IF fed during cold months
Nebharo fodder causes animals to produce watery dung IF fed during cold months
Bans is a type of obano fodder
Ghurmise is a type of obano fodder
Bans fodder causes animals to produce firm dung
Ghurmise fodder causes animals to produce firm (dry) dung

Bakaino is a type of goat-sheep fodder
Bakaino fodder is posilo to goats (and sheep)
Bakaino fodder is palatable to goats (and sheep)
Bakaino fodder is kam posilo to cattle (and buffalo)
Bakaino fodder is not very palatable to cattle (and buffalo)
Badahar is a type of cattle-buffalo fodder
Badahar fodder is posilo to cattle (and buffalo)
Badahar fodder is palatable to cattle (and buffalo)
Badahar fodder is posilo to goats (and sheep)
Badahar fodder is palatable to goats (and sheep)... and so on.

Deductive reasoning across this knowledge led to the following conclusions:

The depth of rukho tree roots is shallow
Trees compete heavily with crops for soil nutrients (and soil moisture) IF the depth of tree roots is shallow
The depth of malilo tree roots is deep
Trees do not compete heavily with crops for soil nutrients (and soil moisture) IF the depth of tree roots is deep
Feeding posilo fodder to lactating animals causes an increase in milk (and ghee) production
The palatability of posilo tree fodder leaf is palatable to animals
Feeding kam posilo fodder to lactating animals does not causes an increase in milk (and ghee) production
The palatability of kam posilo tree fodder leaf is not very palatable to animals

Feeding chiso fodder causes animals to produce watery dung IF the feeding timing OR season is a cold month
Feeding obano fodder causes animals to produce firm (dry) dung

Goat-sheep fodder is posilo to goats (and sheep)
Goat-sheep fodder is palatable to goats (and sheep)
Goat-sheep fodder is kam posilo to cattle (and buffalo)
Goat-sheep fodder is not very palatable to cattle (and buffalo)
Cattle-buffalo fodder is posilo to cattle (and buffalo)
Cattle-buffalo fodder is palatable to cattle (and buffalo)
Cattle-buffalo fodder is posilo to goats (and sheep)
cattle-buffalo fodder is palatable to goats (and sheep)

This deduction was further checked and found to be widely accepted by key informants. Using the hierarchical approach described above (4.3.2.3.), all the species information (for example, `'Bans is a type of rukho fodder tree'` `'Badahar is a type of posilo fodder'` `'Dudhilo is a type of chiso fodder'` and `'Bakaino is a type of goat-sheep fodder'`) were captured by creating *rukho-malilo, posilo-kam posilo, chiso-obano* and goat-sheep and cattle-buffalo fodder hierarchies in the knowledge base. Only the deduced information (for example, `'The depth of rukho tree roots is shallow'` `'Feeding posilo fodder to lactating animals causes an increase in milk production'` `'Feeding chiso fodder causes animals to produce watery dung...'`) were represented as statements in the intermediate knowledge base. An example of *rukho-malilo* fodder tree hierarchy created by the application of deductive reasoning is presented in Figure 4.7. The result of this exercise was a significant compaction of the content of the knowledge base. The hierarchies created through deductive reasoning also demonstrate how this hierarchical approach can be usefully extended to generic concepts.

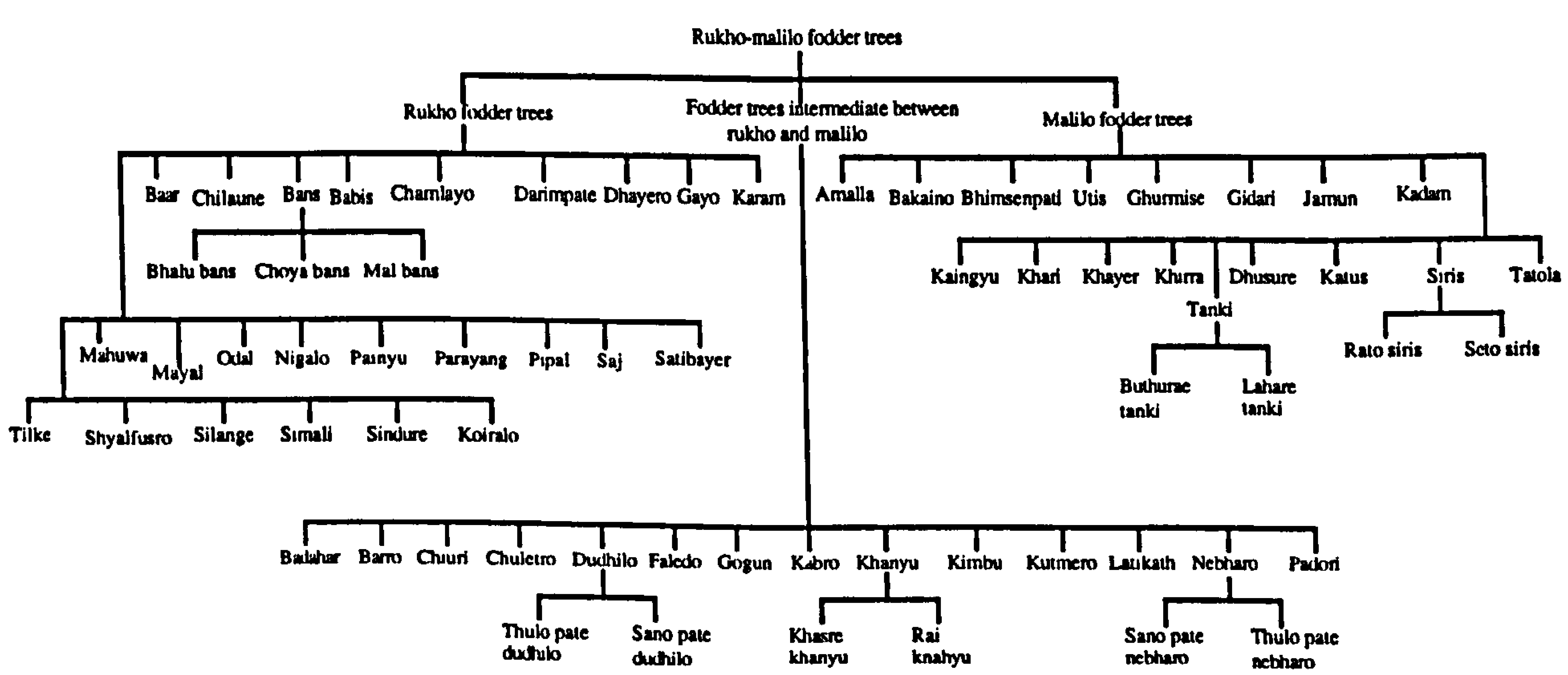


Figure 4.7 The *rukho-malilo* tree hierarchy, an example of an object keyword hierarchy incorporating *rukho-malilo* concepts related to effects of trees on crops.

Deductive reasoning was also used in other ways. The knowledge base contained information about the attributes of tree species influencing the degree of *tapkan* and shading effects on crops, timing and frequency of fodder lopping and fodder palatability. Originally the knowledge base contained a large number of statements each being repeated for individual tree species which could be easily compacted through deductive reasoning. For example,

```
Nebharo causes heavy tapkan on crops
Chuletro causes heavy tapkan on crops
Rai khanyu cause heavy tapkan on crops
Badahar causes heavy tapkan on crops
Thulo pate dudhilo causes heavy tapkan on crops
Rato siris causes light tapkan on crops
Sano pate dudhilo causes light tapkan on crops
Amalla causes light tapkan on crops
Nebharo has big leaves
Nebharo has dense crown
Rai khanyu has big leaves
Rai khanyu has dense crown
Thulo pate dudhilo has big leaves
Sano pate dudhilo has dense crown
Rato siris has small leaves
Rato siris has light crown
Sano pate dudhilo has small leaves
Sano pate dudhilo has light crown
Amalla has small leaves
Amalla has light crown
```

Deductive reasoning across this knowledge revealed that `'Trees cause heavy tapkan on crops IF they have big leaves AND dense crowns` and `'Trees cause light tapkan on crops IF they have small leaves AND sparse crowns`. Once this deduction was confirmed, the knowledge base was compacted without loosing meaning. For example, instead of repeatedly writing species X, Y, Z causes heavy *tapkan* each time, this knowledge was represented as follows:

```
Trees cause heavy tapkan on crops IF the size of leaf is big AND the
density of the crown is dense
Trees cause light tapkan on crops IF the size of leaf is small AND the
density of the crown is sparse
Nebharo has big leaves
Nebharo has dense crown
Rai khanyu has big leaves
Rai khanyu has dense crown
Thulo pate dudhilo has big leaves
Sano pate dudhilo has dense crown
Rato siris has small leaves
```

```
Rato siris has light crown
Sano pate dudhilo has small leaves
Sano pate dudhilo has light crown
Amalla has small leaves
Amalla has light crown
```

4.3.2.5 Representing linked sets of statements

The intermediate tree fodder knowledge base in this chapter resulted in a set of unitary statements. Disintegration of knowledge into unitary statements was justified on the basis that an individual unitary statement may be combined in a variety of ways with other statements for different purposes so that the maximum flexibility is achieved in terms of utility by representing knowledge in its smallest meaningful units (4.2.6.2.3). However, individual statements are of limited use on their own. Their value lies in their combination with other statements and the degree to which the deducible linkages between statements are captured. These deducible linkages between statements are also important for use in automated reasoning (Chapter 5).

In the process of intermediate representation, the deduction of linkages between statements was achieved by matching the 'tail' of one statement to the 'head' of another statement. The head of the statement is referred here to as that part of the statement that occurs before the term that defines the relationship, for example, 'causes' and the tail of the statement as that part of the statement that occurs after the defining term. Two types of examples, the first relating to binary attribute-value statements and the second relating to conditional attribute-value statements are given below.

Linkages between binary attribute-value statements:

```
An increase in the diameter of fodder tree branch causes an increase in
the frequency of lopping strokes

An increase in the frequency of lopping strokes causes an increase in
the amount of splitting up of branch wood

An increase in the amount of splitting up of branch wood causes an
increase in the rate of drying up of fodder tree branches
```

An increase in the rate of drying up of fodder tree branches causes a decrease in the number of regrowth of shoots after lopping

A decrease in the number of regrowth of shoots after lopping causes a decrease in the amount of foliage biomass production

In the first example, the text 'increase in the diameter of fodder tree branches' before 'causes' is the head and the text 'increase in the frequency of lopping strokes' after 'causes' is the tail. The tail of the first statement clearly provides a linkage with the second statement: An increase in the frequency of lopping strokes causes an increase in the amount of splitting up of branch wood and so on.

Linkages between conditional attribute-value statement:

Fodder tree causes heavy tapkan on crops IF the size of leaves are big

Nebharo tree has big leaves

In this example, the condition 'IF the size of leaves are big' is the tail which provides a linkage with the second statement 'Nebharo has big leaves'. This occurs because in the object keyword hierarchy (Figure 4.6), 'nebharo' is recognised as a 'fodder tree', through the object keyword hierarchy link 'is a type of' (4.3.2.3), the linkages between the two statements in this example result in the deducible interpretation that 'Nebharo causes heavy tapkan on crops'.

The AKT toolkit provided a mechanism by which linked sets of statements could be represented in the knowledge base either through a text based approach or through a diagrammatic representation. Although representation through the construction of diagrams was useful in critically assessing the linkages between the statements, for reasons already discussed (4.2.6.2.2), not all linked sets of statements could be represented as node and link diagrams. Therefore, all the statements in the present study was represented using the text based approach.

4.3.2.6 Structure and content of the intermediate knowledge base

On the basis of the foregoing discussion, this section summarises the structure and content of the knowledge in the intermediate knowledge base (Figure 4.8). The end product of intermediate representation was a significant compaction of the content of the knowledge base which finally consisted of 986 intermediate statements (compacted from the original 3 265 statements) and the development of a succinct statement of intermediate knowledge comprising the following components:

- unitary statements as the basic units of knowledge;
- a set of intermediate unitary statements (wherever appropriate compacted by deducible linkages) tagged with keywords, source and conditions;
- detailed information about each source (for example, who contributed the knowledge and when was it recorded);
- a set of keyword glossaries containing at least one reference to every keyword in the knowledge base;
- definitions associated with keywords in glossaries (where necessary);
- synonymous terms identified for each keyword; and
- information about how object keywords were hierarchically related.

4.3.3 Formal representation

The creation of formal knowledge bases was premised on the assumption that the development and use of computer based reasoning with knowledge could facilitate an efficient and effective means of evaluation and use of knowledge in a research and development context. The intermediate statements created in the previous section provided a

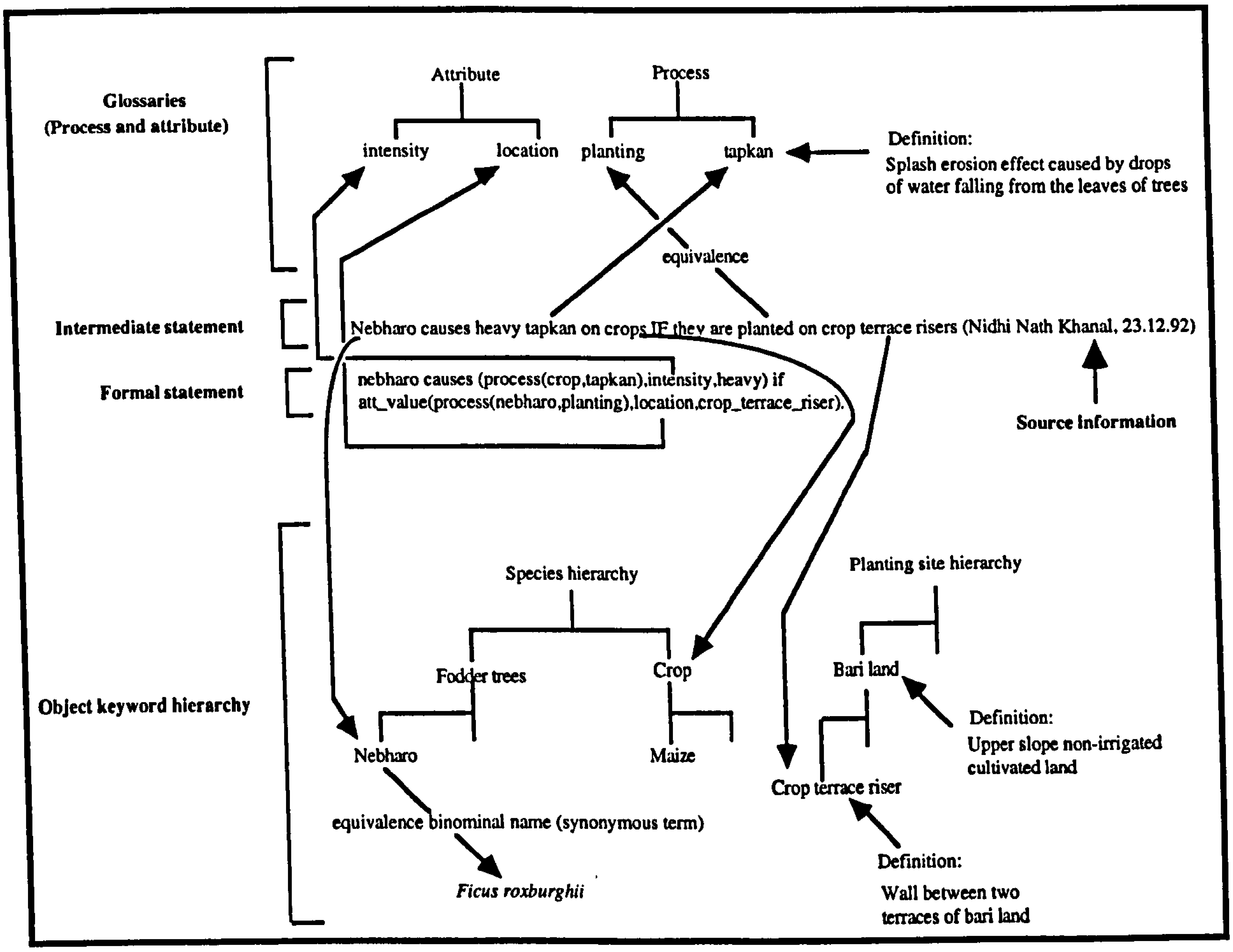


Figure 4.8 A summary of the structure of the intermediate knowledge base. A single statement (including corresponding formal representation) and the information associated with that statement are shown.

computer based representation of knowledge but not in a form in which it could be used for automatic reasoning. Therefore, these intermediate statements required formalisation. The purposes of formalisation were twofold:

- to facilitate automatic reasoning with knowledge; and
- to force explicit and unambiguous representation of knowledge.

The intermediate statements described earlier (4.3.2) were formalised through the application of a defiant clause grammar developed on the basis of considering intermediate statements acquired from a range of field sites in four countries including the present research in Nepal (Walker *et al.*, 1994). The formal grammar comprised four fundamental types of statement: attribute-value statements, comparison statements, causal statements and link statements. These statement types linked four fundamental categories of term: objects, processes, attributes and values. The formal grammar restricted knowledge representation to a specified syntax, therefore, requiring the user to decide how best to represent the meaning of the natural language statement within constraints imposed by the grammar, which is analogous to translation between two natural languages.

This section introduces the formal grammar and describes the procedure for formalising intermediate statements using it.

4.3.3.1 The formal grammar

The formal grammar (Table 4.9) defined the range of forms that a formal statement could take. Formal statements consisted of a set of terms linked by and ordered in relation to other special terms that form part of the formal language. This linkage and ordering provided information on the way in which the elements of the statement were related. All the terms in the formal statement relate to the two fundamental elements: objects (which represent and describe physical items in the real world, for example, tree, crop, animal) and processes (which describe fluxes or events in the real world, for example, leaf decomposition, germination and natural regeneration).

In the formal language, objects were represented as atoms (essentially the name of the object, for example, tree, cow, buffalo or the name of a class of objects, for example, trees, cows or buffaloes). All objects appeared in the sort hierarchy, that is, the object keyword hierarchy described in 4.3.2.3.1.

Processes were also represented as atoms (that is, the name of the process, for example, lodging, lopping, splash erosion) with their name appearing in the process glossary.

Like objects and processes, attributes and values of objects or processes were represented as atoms (for example, the attribute 'height' of the object tree may have the value 'tall' or the attribute 'rate' of the process decomposition may have the value 'rapid')

Table 4.9 The formal grammar explained in text.

Sentence ==> Statement **if** Conditions
Sentence ==> Statement
Statement ==> Causal_statement
Statement ==> Attribute_statement
Statement ==> Negative_attribute_statement
Statement ==> Link_statement
Statement ==> Comparison_statement
Negative_attribute_statement ==> **not**(Attribute_statement)
Link_statement ==> **link**(Link_type, Object, Object)
Link_statement ==> **link(influence, Thing, Thing)**
Thing ==> Process
Thing ==> Object
Comparison_statement ==> **comparison**(Attribute, Object1, Comparison_type, Object2)
Comparison_statement ==> **comparison**(Attribute, Process1, Comparison_type, Process2)
Conditions ==> Attribute_statement
Conditions ==> Negative_attribute_statement
Conditions ==> Link_statement
Conditions ==> Comparison_statement
Conditions ==> Conditions **or** Conditions
Conditions ==> Conditions **and** Conditions
Attribute_statement ==> **att_value**(Object, Attribute, Value)
Attribute_statement ==> **att_value**(Process, Attribute, Value)
Attribute ==> X *{atom appearing in Attribute glossary}*
Value ==> **increase | decrease | change | no_change**
Value ==> **range**(X,Y) *{ X and Y are atoms }*
Value ==> > | < | = | <= | >= X *{ constant or variable appearing elsewhere in statement }*
Value ==> X { atom }
{Note: Quantities and Values can be subdivided into type such as Nominal and Ordinal etc., and Attribute_statements should have matching types, but this is not something that the parser[3] can check.}
Comparison_type ==> **greater_than | less_than | same_as**
Causal_statement ==> Cause **causes** Attribute_statement
Cause ==> Attribute_statement
Cause ==> Process
Cause ==> Object
Process ==> **process**(X) *{X is an atom - the name of a process }*
Process ==> **process**(Object,X) *{X is an atom and name of a process }*
Process ==> **process**(Object,X,Object2) *{X is an atom and name of a process }*
Object ==> X *{X is a variable appearing in the sort specifications}*
Object ==> **part**(Object.Part) *{May not want to allow part(part(part(twig,leaf),branch),oak) etc.}*

Key:

The symbol '==>' means 'can take the form'. Structures on the left hand side of the '==>' symbol can be developed by creating the structure on the right hand side of the symbol. Capitalised words are defined elsewhere in the grammar, words in bold are reserved terms that form part of the language and can only be used for the purpose for which they are used in the grammar, X and Y represent atoms which are defined by the user.

Source: Walker *et al.* (1994)

[3] A parser is code that disassembles a statement into its component parts and checks the relationships between those parts, thereby ascertaining whether that statement conforms to a particular grammar.

with their names appearing in an attribute glossary. Values could be represented by the special terms 'increase' 'decrease' 'change' 'no_change' and 'range' to capture special meaning of a particular statement. Comparison types of statement were required to include one of the values: 'greater_than' 'less_than' or 'same_as' enabling the comparison of the values of attributes for two objects or processes.

The term 'causes' enabled the causal relationship between objects and processes to be captured. The terms 'if' 'and' and 'or' allowed conditionality and multiple conditions to be captured. The term 'part' allowed a particular object to be disintegrated (for example, leaf, branch or roots were represented as part of tree). The term 'not' was used to capture negation (for example, `Bans is not a malilo tree`). The term 'link' allowed the user to define relationships between objects or process (other than the causal or comparative links) already catered for (for example, cows eat grass, where 'eat' is a link between two objects 'cow' and 'grass').

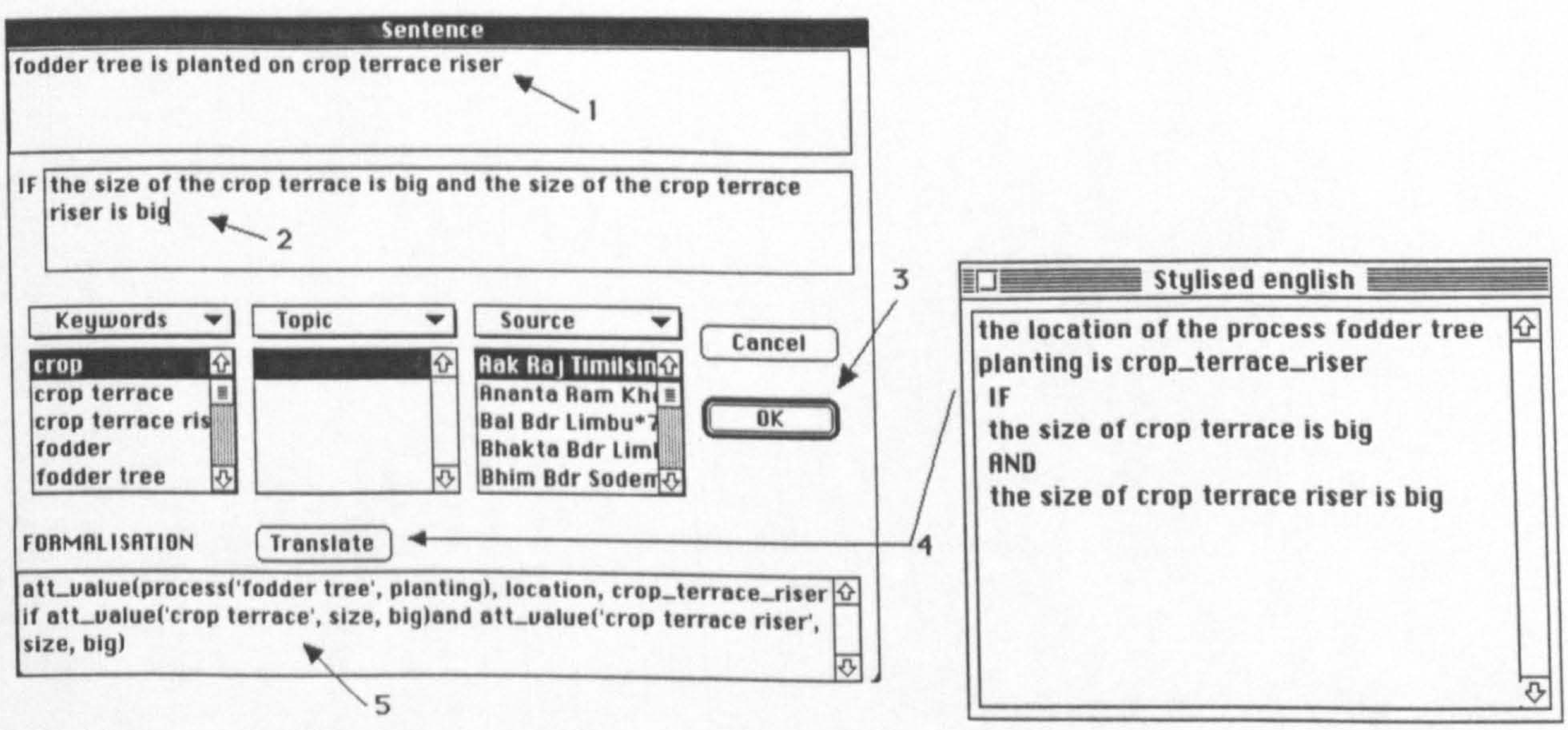
The combination of the four fundamental elements (object, process, attribute and value) with a set of special terms ('causes', 'if', 'and', 'or', 'comparison' and 'link') in the formal grammar provided the basis for the formal representation of knowledge. A parser checked that the syntax of each formal statement conformed to the grammar. The parser also checked that objects within each formal statement were identified within the sort hierarchy and that a list of terms identified as processes and attributes occurred in an appropriate glossary, thereby ensuring a consistent use of terms. Terms not already in the glossary were identified and manually entered into an appropriate glossary during formalisation.

4.3.3.2 The process of formalisation

The intermediate statements were formalised using the formal grammar described above . The process of formalisation involved four steps: reassessment of the intermediate statement; identifying the elements in the statement; identifying the statement type; and writing the formal statement. Each of these are described in this section.

4.3.3.2.1 Reassessment of the intermediate statement

This was carried out to ensure that the statements in the intermediate knowledge base were unambiguous, unitary, complete and accurate. Since some degree of interpretation of the intermediate statement was necessary during formalisation and since the intermediate statement and formal statements remain linked (Figure 4.9) in the knowledge base, no major editing of the intermediate statements were carried out except in cases where the original statement was found to be either repetitive, incomplete or ambiguous. It was found that the majority (71%) of the statements in the intermediate knowledge base were sufficiently explicit to allow formalisation as they stood. The remaining 29% of statements were mostly repetitive in nature and consideration rendered them redundant.



1. Intermediate statement
2. Condition
3. Clicking OK button provides detailed information about the statement set
4. Clicking "Translate" button provides an equivalent English translation of the formal statement (as in the right hand box)
5. Formal statement

Figure 4.9 An overview of sentence interface, illustrating the process of formalisation.

4.3.3.2.2 Identifying the elements in the statement

Elements were identified by deciding what words in the statement were objects (and parts of objects), processes, attributes and attribute values. These elements were explicit in most of the intermediate statements but in a few cases they were implicit in which case some interpretation was required. Example of identification of elements in intermediate statements are given in Table 4.10.

Table 4.10 Identification of the fundamental elements of intermediate statements.

Intermediate statement	Elements
A decrease in crop stem strength causes an increase in the amount of crop lodging	'crop' and 'stem' are both objects, 'stem' is a part of the object 'crop', 'strength' is an attribute of the object 'stem', 'lodging' is a process and 'amount' is an attribute of the process 'lodging'. In this case the attribute 'strength' takes the special value 'decrease' while 'amount' takes the value 'increase'.
Utis is a tall tree	'*utis*' and 'tree' are both objects, but the attribute of the object '*utis*' or 'tree' is implicit, however, the value 'tall' can reasonably be supposed to be referring to an attribute 'height'.
The rate of regrowth of shoots after lopping is slow if the atmospheric temperature is low	'regrowth shoots' is the object and 'lopping' is a process, 'slow' is the value of an attribute 'rate' and 'low' is the value of an attribute 'temperature'. There is, however, no explicit object or process to which the attribute 'temperature' is attached because it refers to an environmental variable. To capture such global variables in the formal representation an object 'system' was created to which the attribute was attached. This device was used for all global variables.

4.3.3.2.3 Identifying the statement type

The next step in the formalisation process was to decide which type of formal statement most appropriately captured the meaning of the intermediate statement. Formal statements were of one of four types: causal; comparison; user-specified link; or attribute-value (which could take a negative form). Any of the statement types could be made conditional. Each are briefly discussed below.

4.3.3.2.3.1 Causal statements

Identifying causal statements was often straight forward. Any statement with the word 'causes' or 'results in' was likely to be a causal statement. In a generic sense causal statements were recognised as statements in which the value of an attribute was changed. Causal statements had the general structure: `X causes Y.` `X` was always a change in the value of an attribute whereas `Y` could also be a change in the value of an attribute captured by using one of the special values 'increase' 'decrease' 'change' or 'no_change'. Therefore, causal statements took one of the following three forms (Table 4.11).

Table 4.11 Forms of causal statements.

General form of statement	Examples
Change in an attribute-value causes a change in an attribute-value	An increase in leaf maturity causes an increase in leaf coarseness.
	An increase in crop plant height causes a decrease in crop stem thickness.
Process causes a change in an attribute-value	Lopping causes a decrease in tree height.
	Shading causes an increase in crop plant height.
Object causes a change in an attribute-value	Trees causes an increase in the intensity of shading IF they are planted on crop terrace.

The terms 'causes2way' and 'causes1way' have been used in the formal version of causal statements (see Table 4.16 for an example). This distinction is important for two reasons: to avoid repetitions where two intermediate statements have effectively the same meaning; and to ensure that the causal relationships between the statements are explicit. For example, because an increase is the opposite of a decrease, the statement: `'A decrease in crop stem strength causes an increase in the amount of crop lodging'` and `'An increase in crop stem strength causes a decrease in the amount of crop lodging'` have effectively the same meaning and, therefore, the term 'causes2way' has been used to capture this reversibility and represent both intermediate statements by a single formal statement. However, the two-way nature of the causal mechanism was not always valid, for example, age of leaf cannot decrease and so leaf maturity cannot be reversed. In such cases, the term 'causes1way' was used (Table 4.16). Of the total of 700 formal statements, 36% were of the causal type.

4.3.3.2.3.2 Comparison statements

Comparison statements were used to compare the relative value of either a pair of objects or a pair of processes (Table 4.12). Only 12% of the formal statements were of the comparison type.

Table 4.12 Forms of comparison statements.

General form of statement	Examples
Comparison of the relative value of a pair of objects	*Sano pate dudhilo* fodder is more *chiso* than *thulo pate* dudhilo.
	Sano pate dudhilo sheds leaves earlier in the dry season than *thulo pate dudhilo*
	Badahar fodder is more palatable than *gogun* fodder.
Comparison of the relative value of a pair of processes	No statement was recorded that compared the relative value of a pair of processes in the knowledge base.

4.3.3.2.3.3 User-specified link statements

Intermediate statements containing two objects but no information about attributes or values were generally captured as link statements. The grammar includes a special type of link statement in which the link type is 'influence'. Influences were used to link any combination of objects or processes, where there was no information specified about attributes or values. Thus, link statements took one of two forms with either a user-defined link type or the special link type 'influence' (Table 4.13). Of the four types of formal statements, link statements occurred least frequently constituting less than 8% of the total.

Table 4.13 Form of link statements.

General form of statement	Examples
User-specified link statement	Bakaino fodder is palatable to goats Rato siris fodder is toxic to animals
Special link statement in which the link type is 'influence'.	Tapkan influences crops Shading influences crops

4.3.3.2.3.4 Attribute-value statements

Virtually all of the intermediate statements could be captured as attribute-value statements (Table 4.14) where the statement consists of an object or process and information about its attributes and values. Attribute-value statements were by far the most frequent in the knowledge base consisting nearly 45% of the formal statements. Intermediate statements could also be captured as negative attribute-value statements.

Table 4.14 Example of intermediate statements which could be captured as either positive or negative attribute-value statements.

Positive attribute-value statement	Negative attribute-value statement
Rato siris causes light *tapkan.*	*Rato siris* does not cause heavy *tapkan.*
Feeding *badahar* fodder to lactating animals causes an increase in milk production.	Feeding *badahar* fodder to lactating animals does not cause a decrease in milk production.
Nebharo tree has big leaves	*Nebharo* tree does not have small leaves

4.3.3.2.3.5 Conditional statements

Any statement type could be made conditional by appending conditions and multiple conditions could be linked using 'and' or 'or' conjunction, or a series of both (Table 4.15).

Table 4.15 Examples of conditional statements.

Form of statement	Examples
Causal statement	*Dudhilo* fodder causes diarrhoea to animals IF they are fed as a sole fodder AND the feeding season is cold months.
Comparison statement	Trees with big leaves cause less *tapkan* effects on crops than trees with small leaves IF the intensity of rainfall is low
Link statement	Trees influence crops IF they are planted on crop terrace

4.3.3.2.4 Writing the formal statements

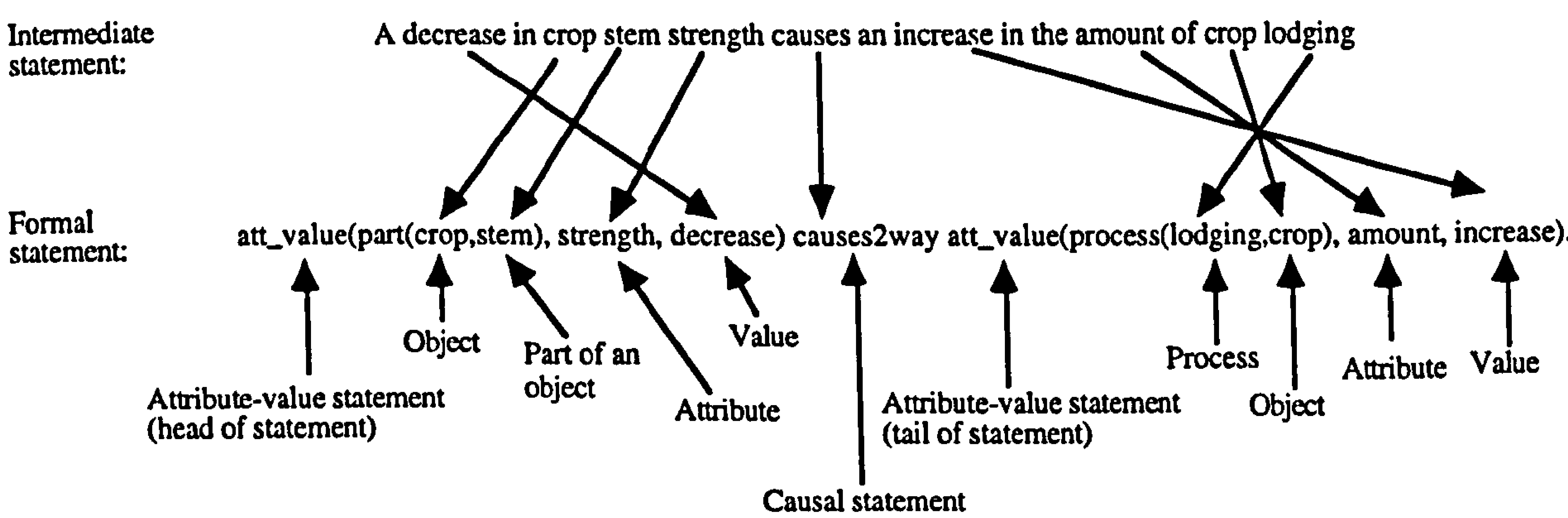
The processes described above of identifying elements in intermediate statements and an appropriate formal statement structure were applied to individual intermediate statements before they were formalised. The formal statement was then required to correspond precisely to the structures defined in the grammar. These included the following restrictions:

- there should not be any terms in the formal statement with a capital letter;
- there should not be a space after predicate name or reserved terms except 'causes', 'and', 'or' or 'if';
- arguments within a clause should be followed by a comma and space;

- all compound terms (for example, fodder tree) should be joined by an underscore or enclosed in inverted commas (fodder_tree or 'fodder tree'); and

- each formal statement should be followed by a full stop.

Using the formal grammar and the conventions outlined above, the majority of the knowledge (94% of statements) was formalised rapidly while a few difficult statements (6%) which were predominantly socio-economic in nature rather than ecological required careful consideration and interpretation but were eventually formalised. An example of the translation between intermediate and formal statement is given in Figure 4.10.



An equivalent English translation (the stylised English) of this formal statement automatically generated by the parser would be something like: `'A decrease in the strength of the part stem of the crop causes an increase in the amount of the process crop lodging'.`

Figure 4. 10 An example of the translation between intermediate and formal statement

Examples of the formal representation of some of the intermediate statements previously discussed are presented in Table 4.16.

Table 4.16 Some example of intermediate statements and corresponding formal representations.

Intermediate statement	Formal statement
A decrease in crop stem strength causes an increase in the amount of crop lodging	att_value(part(crop, stem),strength, decrease) causes2way att_value(process(crop, lodging), amount, increase).
Utis is a tall tree	att_value(Utis, height, tall).
Lopping causes a decrease in tree height	process(lopping) causes2way att_value(tree, height, decrease).
Tree causes an increase in the amount of shading if they are planted on crop terrace	Tree causes2way att_value(process(shading),amount, increase)if att_value(process(tree,planting),location, crop_terrace).
An increase in leaf maturity causes a decrease in fodder palatability	att_value(leaf,maturity,increase) causes1way att_value(fodder,palatability,decrease).
The gowth rate of regrowth shoots after lopping is slow if the atmospheric temperature is low	att_value(process(regrowth_shoot,lopping), growth_rate, slow) if att_value(system, temperature, low).
Rato siris fodder is toxic to animals	link(toxic_to, rato_siris_fodder, animal).
Badahar fodder is more palatable than *gogun* fodder	comparison(palatability, badahar_fodder, greater_than, gogun_fodder).
Shading influences crops	link(influence,shading,crop).
Nebharo has big leaves	att_value(part(nebharo, leaf),size, big).
Nebharo does not have small leaves	not(att_value(part(nebharo, leaf),size, small)).

4.4 CONCLUSIONS

The process of creating a formal tree fodder knowledge base described in this chapter resulted in a set of 700 unitary formal statements. A standard but flexible knowledge acquisition strategy was used involving an iterative cycle of knowledge elicitation, representation and evaluation in respect of ambiguity, consistency in the use of terms and completeness of the knowledge base as a whole. The study moved through a set of increasingly restrictive methods of recording knowledge. The experience suggests that the iterative evaluation of knowledge bases as they were created and a restrictive approach to knowledge representation led to a coherent, consistent and comprehensive and, therefore, useful record of knowledge.

This study has demonstrated that farmers' ecological knowledge relating to tree fodder resources in Solma could be fully recorded as unitary statements in natural language and represented in a computer coded form amenable to automatic reasoning defined by the restricted syntax of a formal grammar. Experience during the course of this study suggested that the structure proposed in the formal grammar allowed representation of farmers' ecological knowledge without undue distortion. However, it should be noted that there was a considerable amount of interpretation involved in the process of generating statements from the original interview dialogue. The restrictions imposed by the formal grammar during formalisation may have misrepresented some of the meaning intended by the informants. Further evaluation of the knowledge base in terms of the extent to which knowledge in the knowledge base represents a valid abstraction of the knowledge held by the source (s) from which it was elicited is reported in Chapter 6. Being able to record knowledge using Nepali script rather than having to translate into English might reduce the extent of interpretation required in the recording process.

The formal grammar was less expressive than natural language and was not designed to represent socio-economic as opposed to ecological knowledge. Such information required considerable interpretation before it could be formalised. Extension of the structure of the formal grammar to include socio-economic and management factors would have made it easier to capture some of the knowledge articulated by farmers and make it possible to identify management actions and their ecological consequences.

The process of formalisation proved to be useful in two ways. Firstly, the restricted nature of the formal grammar encouraged precise representation of knowledge. Secondly, the rigorous and consistent representation demanded by formalisation helped to significantly improve the quality of the knowledge base as a whole by forcing re-evaluation of implicit meaning in statements and more accurate definition and use of terms. This is reflected in the fact that the process of formalisation resulted in considerable clarification and compaction of the intermediate knowledge base from 986 to 700 statements. The final

700 statements were stored in both formal and intermediate forms which could be flexibly explored using either automatic reasoning techniques or the database type search facilities (Chapter 5). This makes it possible to view the knowledge in a variety of ways and to construct a variety of arguments about the ecology of farmland tree fodder management practices by combining unitary statements in different ways. Thus, a record of the knowledge of Solma farmers, largely independent of the researcher's interpretation was created in sharp contrast to the discursive approaches familiar from ethnographic accounts of local knowledge systems (Brokensha, 1980; Richards, 1985).

CHAPTER 5

EVALUATION OF KNOWLEDGE

5.1 INTRODUCTION

The detailed processes involved in the creation of the tree fodder knowledge base through the application of a knowledge based systems approach, and the structure of the resulting tree fodder knowledge base were presented in Chapter 4. In this chapter the underlying knowledge system articulated by farmers about the management and use of tree fodder resources on their farmland is investigated using a range of analytical approaches. Firstly, the methods used are described with examples (5.2) and then the results of applying these methods across the entire knowledge base are presented (5.3).

5.2 METHODS OF ACCESSING, EXPLORING AND ANALYSING THE CONTENT OF THE KNOWLEDGE BASE

The AKT software provided a range of mechanisms by which the content of the knowledge base could be accessed, explored and analysed, in different ways, for a variety of purposes. These included: searching and extracting procedures (5.2.1); and automatic reasoning procedures (5.2.2). The process of knowledge analysis involved:

- deciding on which specific topics to select from the tree fodder knowledge base for detailed knowledge analysis;
- generation of extracts of knowledge on the selected topic through the use of search facilities involving appropriate combination of keywords from the glossaries and/or object keyword hierarchies;

- manual evaluation of knowledge extracts; and
- the use of automatic reasoning procedures.

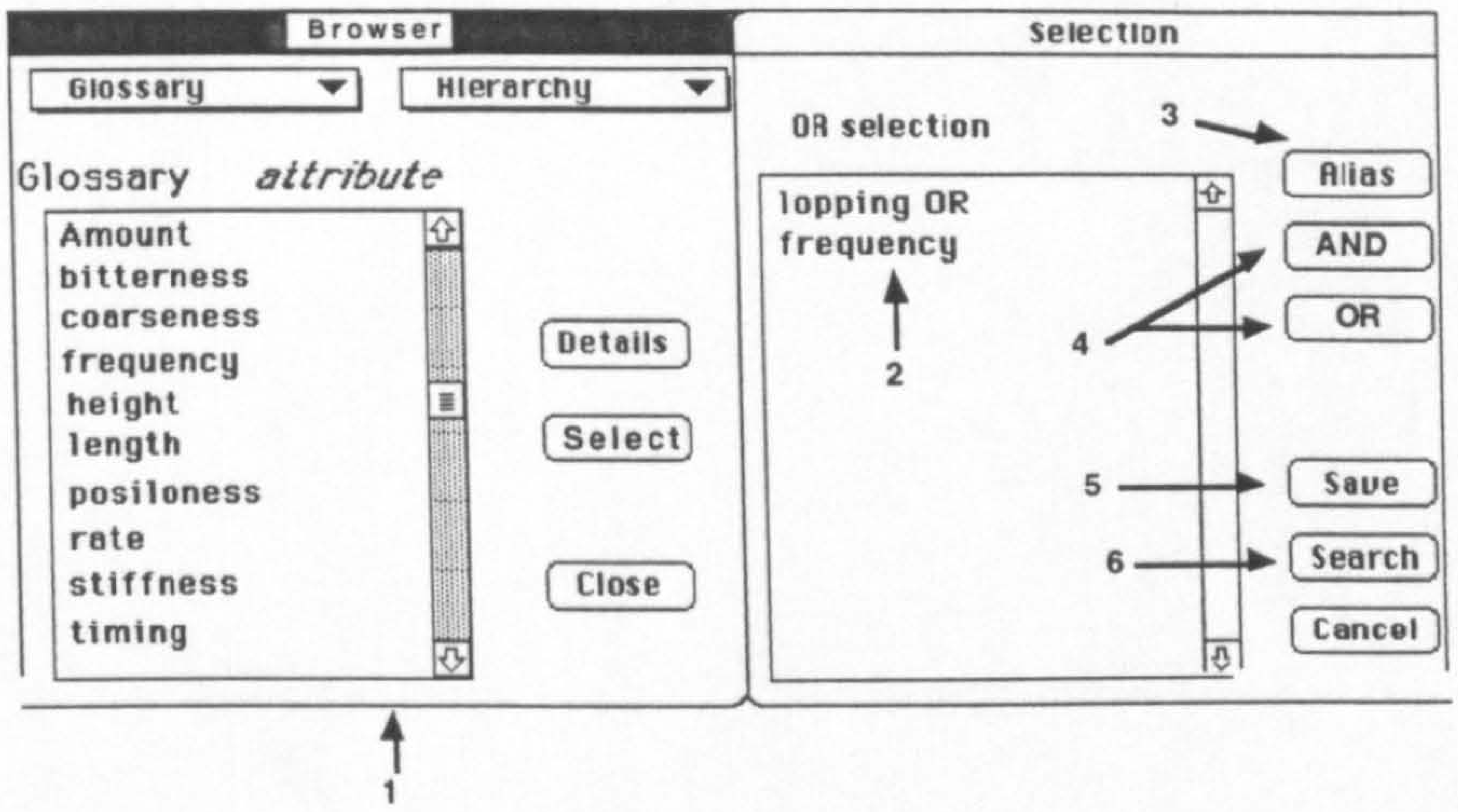
The facilities available within the AKT software including their functionality and how they were used in analysing the content of the tree fodder knowledge base in the present study, which represents their first application, are reported in this section.

5.2.1 Searching and extracting procedures

The tree fodder knowledge base in the present study was created from interviews with 40 key informants on three separate topics, which resulted in a large and complex knowledge base containing 700 statements. Accessing specific statements about particular topics or sub topics was, therefore, a daunting but fundamental task in analysing the content of the knowledge base. The searching procedures enabled the abstraction of subsets of knowledge on specific topics which could then be either manually evaluated or used as a basis for automated reasoning.

5.2.1.1 Selecting subsets of the knowledge base

Analysis of knowledge was based upon detailed consideration of the knowledge available about particular topics. Such an approach requires abstraction of subsets of knowledge according to specified criteria. The glossaries and object keyword hierarchies in the AKT software (4.3.2.2) provided a framework for selecting sets of statements by searching either on intermediate or formal statements. Search criteria were generated by selecting a set of keywords from the appropriate keyword hierarchies and glossaries and by specifying the relationships between them using either AND or OR linkages. More complex selection criteria were generated using an 'alias' facility that stored combinations of keywords and linkages (Figure 5.1).



1. The selection interface makes use of the glossary and keyword dialogue which allows the user to build up a selection with the 'select' button.
2. The selection as specified by the user
3. Saves specification as an alias
4. Operator which allows the user to specify selection criteria
5. Saves a search specification
6. Initiates a search (in this example all the statements containing the term 'lopping' or 'frequency' will be searched and displayed on the computer screen)

Figure 5.1 The selection interface.

A choice of three search modes was available: 'Node only'; 'Node and descendants'; and 'Node and family'. Node only selected only those statements that contained the specified keyword. Node and descendants selected all statements which contained the specified keyword and statements that contained keywords below the specified keyword in the hierarchy. Node and family selected all statements that contained the specified keyword and statements that contained keywords above and below the specified keyword in the hierarchy. For example, by selecting the keyword 'fodder tree' from the object keyword hierarchy in Figure 4.6 (4.3.2.3.1), the Node only mode generated a total of 109 statements, while the Node and descendants mode selected 262 statements, and the Node and family selected 370 statements. The results of searches were saved for detailed analysis.

An example of an extract of statements containing the terms 'lopping' and 'frequency' is presented in Table 5.1. The extract contains information articulated by farmers about frequency of fodder lopping. It provides, to some extent, insights into the possible implications of increased or decreased frequency of fodder lopping.

Table 5.1 Example of an extract of all intermediate and formal statements containing the terms lopping, or, frequency, from the tree fodder knowledge base.

A decrease in the frequency of lopping causes an increase in the number of regrowth shoots after lopping att_value(process(lopping), frequency, decrease) causes2way att_value(process(regrowth_shoots,lopping), number,increase).
A decrease in the frequency of lopping causes an increase in the growth rate of regrowth shoots after lopping att_value(process(lopping), frequency, decrease) causes2way att_value(process(regrowth_shoots,lopping), growth_rate, increase).
An increase in the growth_rate of regrowth shoots after lopping causes an increase in the diameter of the fodder tree branch att_value(process(regrowth_shoots,lopping), growth_rate, increase) causes2way att_value(part(fodder_tree,branch), diameter, increase).
An increase in the growth_rate of regrowth shoots after lopping causes an increase in the length of the fodder tree branch att_value(process(regrowth_shoots,lopping), growth_rate, increase) causes2way att_value(part(fodder_tree,branch), length, increase).
An increase in the number of regrowth shoots after lopping causes an increase in density of the fodder tree crown att_value(process(regrowth_shoots,lopping), number, increase) causes2way att_value(part(fodder_tree,crown), density, increase).
An increase in the number of regrowth shoots after lopping causes an increase in foliage biomass att_value(process(regrowth_shoots,lopping), number, increase) causes2way att_value(foliage, biomass, increase).
An increase in the frequency of lopping strokes causes an increase in the amount of splitting up of branch wood att_value(process(lopping), frequency_of_stroke, increase) causes2way att_value(branch_wood, amount_of_splitting, increase).
A decrease in the sharpness of the cutting knife causes an increase in the frequency of lopping strokes att_value(knife, sharpness, decrease) causes2way att_value(process(lopping), frequency_of_stroke, increase).
An increase in the diameter of fodder tree branch causes an increase in the frequency of lopping strokes att_value(part(fodder_tree,branch), diameter, increase) causes2way att_value(process(lopping), frequency_of_stroke, increase).

It is possible to draw conclusions from consideration of the extract in Table 5.1. For example, it is possible to state that:

```
a decrease in the frequency of fodder lopping leads to an
increase in the density of the tree crown
```

This is so because it is known that a decrease in the frequency of lopping causes an increase in the number of shoots that regrow after lopping, and that an increase in the number of regrowing shoots after lopping causes an increase in the density (leaf area density) of the tree crown. Also since foliage biomass is directly related to the density of the tree crown, it is reasonable to assume that because an increase in the number of regrowing shoots after lopping causes an increase in the amount of foliage biomass that will also cause an increase in the density of the tree crown.

While the creation of extracts on specific topics using the search facility provided a useful means of accessing and exploring the knowledge which otherwise would have been time consuming if undertaken manually, it is apparent from the example extract and the type of conclusions that can be drawn from it, that detailed analysis of the knowledge was not achievable through this process. For example, although the extract provided information on what people had articulated about the possible downstream implications of changing the frequency of fodder lopping, it did not assist in determining the impact of, for example, changing the crown density of fodder trees either in terms of upstream consequences (that is; whether the stated effects of changing the frequency of fodder lopping are influenced by the initial density of the tree crown) or in terms of further downstream consequences (that is; what the effects are of the changes in crown density that has resulted from the change in the frequency of fodder lopping). However, the procedure clearly provided a firm basis on which to base further knowledge analysis by identifying areas requiring further consideration. In this way, the searching and extracting procedures were used as the first stage in the process of analysing the content of the tree fodder knowledge base.

5.2.2 Automated reasoning with the knowledge base

Two automated reasoning tools were implemented in the AKT software: the query tool; and the navigation tool. While the search and extracting procedures could be applied to both intermediate and formal statements, the use of automatic reasoning tools was restricted to formal statements. Because each reasoning tool used certain aspects of the formal grammar, choice in how knowledge was formalised affected the subsequent automatic reasoning that was possible. For, example, the navigation tool (5.2.2.2) explores cause and effect relationships in the knowledge base, and, therefore, only works with statements formally coded using the causal statement type.

5.2.2.1 Query tool

The query tool (Figure 5.2) was used to investigate whether the knowledge base contained certain specific items of knowledge. Queries were made in the form of attribute-value statements and were used to identify statements in the knowledge base containing attributes and values of particular objects or processes. For example, the query procedure:

```
att_value(fodder,X,Y)
```

where X and Y are variables, returns the set of all the statements in the knowledge base containing attributes and values of fodder.

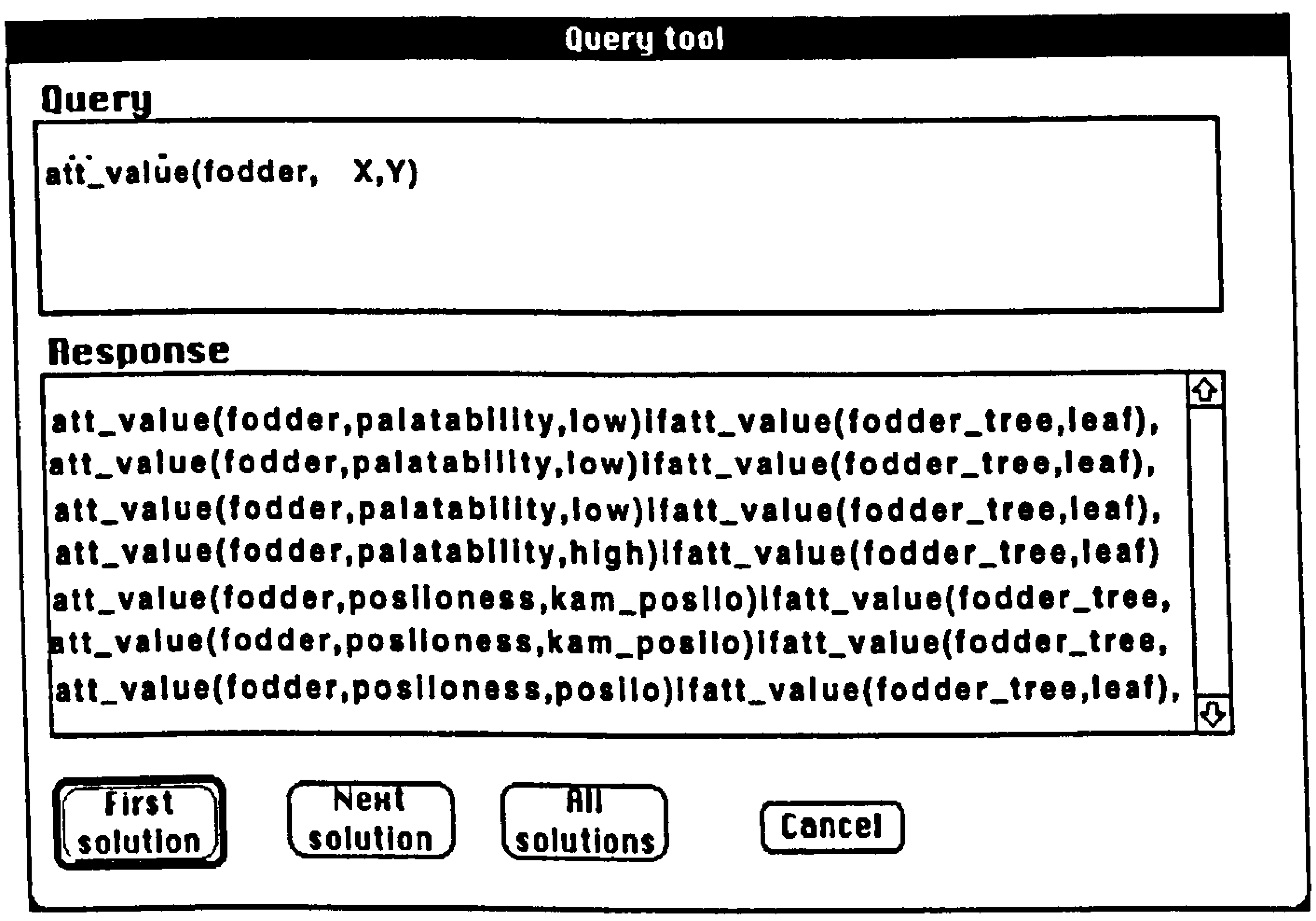


Figure 5.2 The query tool interface. The upper box represents the query. The lower box displays the response. Clicking one of the three solution buttons initiates the processing. Any statements in the response with conditions attached results in the system asking the user to confirm whether the condition is valid in order to continue processing the query. As there are often several statements that satisfy a query one or more solutions may be selected by clicking on one of the three solution buttons.

The responses generated by the above query are presented in Table 5.2. The query also generated information about 50 different fodder tree species in terms of their *posiloness*, of which, 32 were *posilo*, 15 *kam posilo* and 13 intermediate (this species-specific information is not shown in Table 5.2). This is because the query tool uses hierarchical links in the object keyword hierarchy to recognise that, for example, `badahar is a type of posilo fodder` and that `posilo fodder is a type of fodder.`

Table 5.2 Information about attributes of fodder generated using the query procedure. The query used to generate this information was: `att_value(fodder,X,Y)`. See text for explanation of the operation of the query procedure.

The palatability of fodder is low if the texture of fodder tree leaf is coarse
att_value(fodder,palatability,low) if att_value(part(fodder_tree,leaf),texture,coarse)

The palatability of fodder is high if the texture of fodder tree leaf is soft
att_value(fodder,palatability,high) if att_value(part(fodder_tree,leaf),texture,soft)

The palatability of fodder is low if the texture of fodder leaf is stiff
att_value(fodder,palatability,low) if att_value(part(fodder_tree,leaf),texture,stiff)

The palatability of fodder is low if the bitterness of fodder tree leaf is bitter
att_value(fodder,palatability,low) if att_value(part(fodder_tree,leaf),bitterness,bitter)

The palatability of fodder is low if the maturity of fodder tree leaf is over-ripe
att_value(fodder,palatability,low) if att_value(part(fodder_tree,leaf),maturity,over_ripe)

The palatability of fodder is intermediate if the maturity of fodder tree leaf is unripe
att_value(fodder,palatability,intermediate) if att_value(part(fodder_tree,leaf),maturity,unripe)

The palatability of fodder is high if the maturity of fodder tree leaf is ripe
att_value(fodder,palatability,high) if att_value(part(fodder_tree,leaf),maturity,ripe)

The posiloness of fodder is posilo if the texture of fodder tree leaf is soft att_value(fodder,posiloness,posilo) if att_value(part(fodder_tree,leaf),texture,soft)

The posiloness of fodder is kam posilo if the texture of fodder tree leaf is coarse
att_value(fodder,posiloness,kam_posilo) if att_value(part(fodder_tree,leaf),texture,coarse)

The posiloness of fodder is kam posilo if the texture of fodder tree leaf is stiff
att_value(fodder,posiloness,kam_posilo) if att_value(part(fodder_tree,leaf),texture,stiff)

The posiloness of fodder is kam posilo if the bitterness of fodder tree leaf is bitter
att_value(fodder,posiloness,kam_posilo) if att_value(part(fodder_tree,leaf),bitterness,bitter)

The posiloness of fodder is posilo if the maturity of fodder tree leaf is ripe
att_value(fodder,posiloness,posilo) if att_value(part(part(fodder_tree,leaf),maturity,ripe)

The posiloness of fodder is kam posilo if the maturity of fodder tree leaf is over-ripe
att_value(fodder,posiloness,posilo) if att_value(part(fodder_tree,leaf),maturity,over_ripe)

The posiloness of fodder is intermediate if the maturity of fodder tree leaf is unripe
att_value(fodder,posiloness,intermediate) if att_value(part(fodder_tree,leaf),maturity,unripe)

The information generated by the query was then used to examine what attributes and values farmers had articulated about fodder. Examples of conclusions possible from the information in Table 5.2 are summarised below.

- Two attributes of fodder: palatability and *posiloness* (nutritive value) were recognised by farmers.
- Palatability of a given fodder could be high, low or intermediate between the two.
- *Posiloness* of a given fodder could be *posilo* (nutritious), *kam posilo* (less nutritious) or intermediate between *posilo* and *kam posilo.*
- Two attributes of leaves: leaf texture and leaf maturity were known to influence palatability and *posiloness.*
- Three types of leaf texture : coarse, stiff and soft were recognised by the farmers, and these were known to influence palatability so that, for example, a leaf that was soft was more palatable than a leaf that was coarse and/or stiff.
- Leaf maturity was described in terms of ripeness. Three categories of ripeness were recognised: unripe, ripe and over-ripe (senescing), and these were known to influence nutritive value, for example, a leaf that was ripe was more *posilo* and palatable than a leaf that was unripe and/or over-ripe and a leaf that was unripe was more *posilo* and palatable than a leaf that was over-ripe.

On the basis of the conclusions drawn from Table 5.2, further queries were made to explore more specific knowledge about each of the fodder attributes, for example, what information was available about the leaf texture of individual fodder tree species. This was achieved through the use of query procedure:

```
att_value (fodder_tree,leaf),texture, Y)
```

which requested the system to return all the attribute-value statements about the 'leaf' part of the object 'fodder tree' with an attribute 'texture' having any value. The responses generated by this query are shown in Table 5.3. The information in Table 5.3 showed that at least seven fodder tree species were recognised by farmers as having coarse leaves, five species with soft leaves and two species with stiff leaves.

Table 5.3 An example of information about fodder tree species having different leaf texture generated by the query procedure. The query used to generate this information was: `att_value(fodder_tree,leaf),texture,Y).`

The texture of bakaino tree fodder leaf is soft
att_value(part(bakaino,leaf),texture,soft)

The texture of buthure tanki tree fodder leaf is coarse
att_value(part(buthure_tanki,leaf),texture,coarse)

The texture of ghurmise tree fodder leaf is soft
att_value(part(ghurmise,leaf),texture,soft)

The texture of gogun tree fodder leaf is coarse
att_value(part(gogun,leaf),texture,coarse)

The texture of jamun tree fodder leaf is soft
att_value(jamun,leaf),texture,soft)

The texture of koiralo tree fodder leaf is stiff
att_value(part(koiralo,leaf),texture,stiff)

The texture of lahare tanki tree fodder leaf is soft
att_value(part(lahare_tanki,leaf),texture,soft)

The texture of nigalo tree fodder leaf is coarse
att_value(part(nigalo,leaf),texture,coarse)

The texture of padori tree fodder leaf is stiff
att_value(part(padori,leaf),texture,stiff)

The texture of parayang tree fodder leaf is coarse
att_value(part(parayang,leaf),texture,coarse)

The texture of rato siris tree fodder leaf is soft
att_value(part(rato_siris,leaf),texture,soft)

The texture of sano pate nebharo tree fodder leaf is soft
att_value(part(sano_pate_nebharo,leaf),texture,soft)

The texture of kimbu tree fodder leaf is soft
att_value(part(kimbu,leaf),texture,soft)

The texture of thulo pate nebharo tree fodder leaf is coarse
att_value(part(thulo_pate_nebharo,leaf),texture,coarse)

The texture of mahuwa tree fodder leaf is stiff
att_value(part(mahuwa,leaf),texture,stiff)

In this way throughout the process of knowledge analysis queries were made at various scales ranging from generic to very specific queries. The query tool was helpful in identifying specific items of knowledge contained in the knowledge base. The tool as it was implemented, however, was restricted in that only a single statement could be used as a query, therefore, in order to explore knowledge fully about the topic the tool had to be repeatedly used.

5.2.2.2 Navigation tool

The navigation tool (Figure 5.3) was used to explore cause and effect relationships. Unlike the query tool, it allowed navigation across linked sets of statements recorded in the knowledge base. The navigation proceeded one step at a time from cause to effect (downstream) or from effect back to its possible causes (upstream). Thus, the navigation tool provided a means of exploring and analysing knowledge about the known causes of and the implications of particular events.

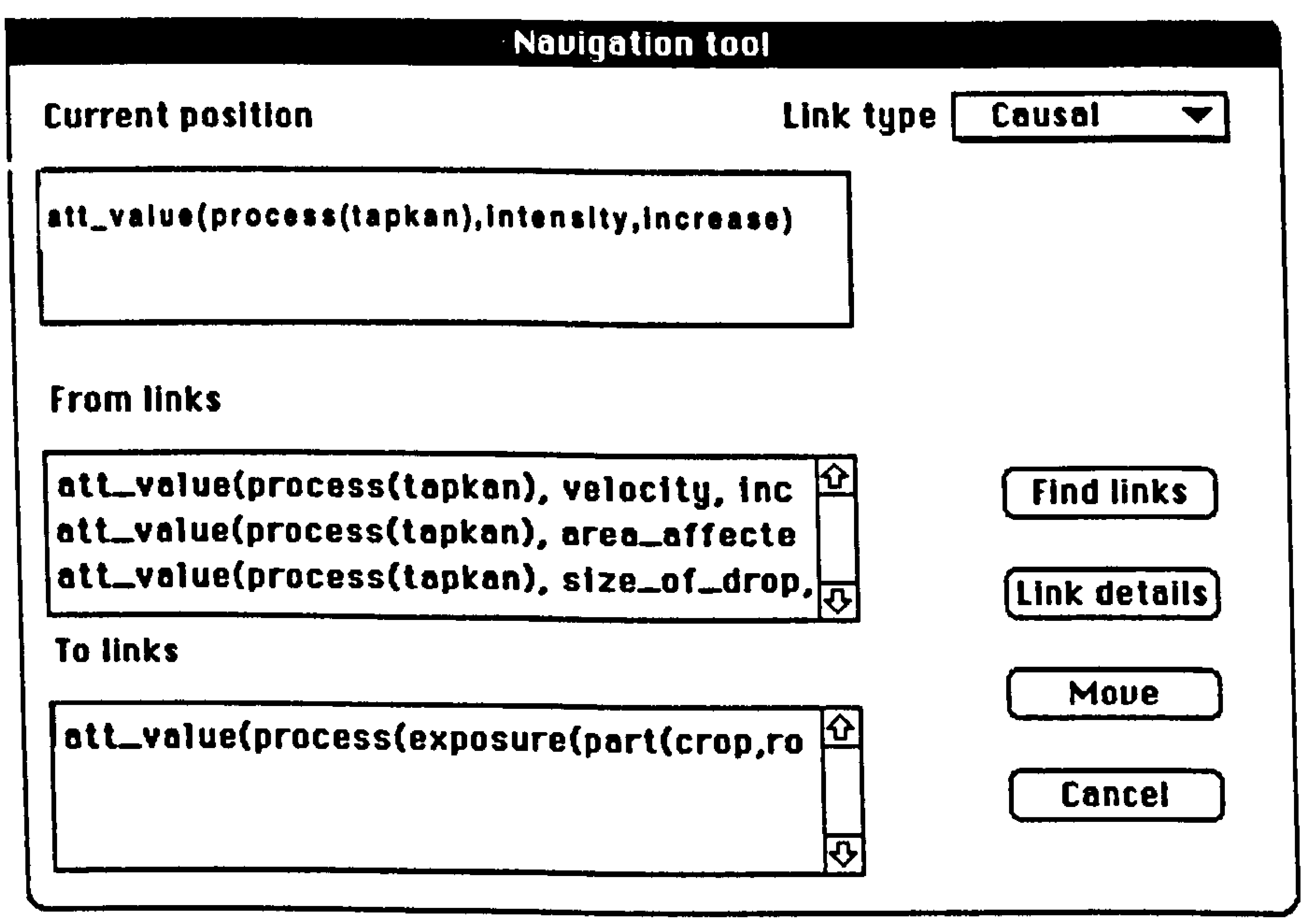


Figure 5.3 The navigation tool interface. The particular question about the event is typed in the upper box termed 'Current position'. The lower two boxes termed 'From links' and 'To links' display the rule linking to the current position and provide the choice for which direction to take (either upstream or downstream) from the current position. This is achieved by selecting one of the statements from one of the two boxes and clicking the 'move' button.

An example of how this navigation tool was used in exploring and analysing the tree fodder knowledge base in the present study is presented in Figure 5.4. The example shows the knowledge articulated by farmers relating to the *tapkan* effects caused by fodder trees grown on *bari* land crop terrace risers. The starting point of this reasoning chain was: 'an increase in the intensity of *tapkan*'. Figure 5.4 shows both what may cause an increase in the intensity of *tapkan* and the implications of an increase in the intensity of *tapkan*. It is evidently possible to draw conclusions from the knowledge displayed in Figure 5.4, for example, that a decrease in the frequency of fodder lopping leads to a decrease in crop yield.

The navigation tool as implemented worked only across causal linkages, so the degree to which sets of individual statements of fact could be automatically reasoned with was dependant on the degree to which the deducible linkages between statements were captured as causal statements in the process of formalisation. An extension of this facility to comparison (4.3.3.2.3.2) and generic links (4.3.3.2.3.3) would have been useful.

5.3 THE CONTENT OF THE KNOWLEDGE BASE

Preliminary findings relating to farmers' perceptions about the management and use of farmland tree resources, including tree fodder, derived from surveys carried out during the specification stage of fieldwork were presented in Chapter 3. In this section, the following are presented:

- knowledge that was articulated by key informants and recorded in the knowledge base during the knowledge acquisition stage (Chapter 4) about the three topics studied (tree-crop interactions, fodder quality evaluation and tree fodder management techniques); and

- evaluation of the knowledge articulated by farmers in relation to scientific knowledge in selected areas (since scientific information specific to tree fodder in Nepal is limited, evaluation was largely based on comparison of farmers' knowledge with generally accepted scientific understanding from the literature).

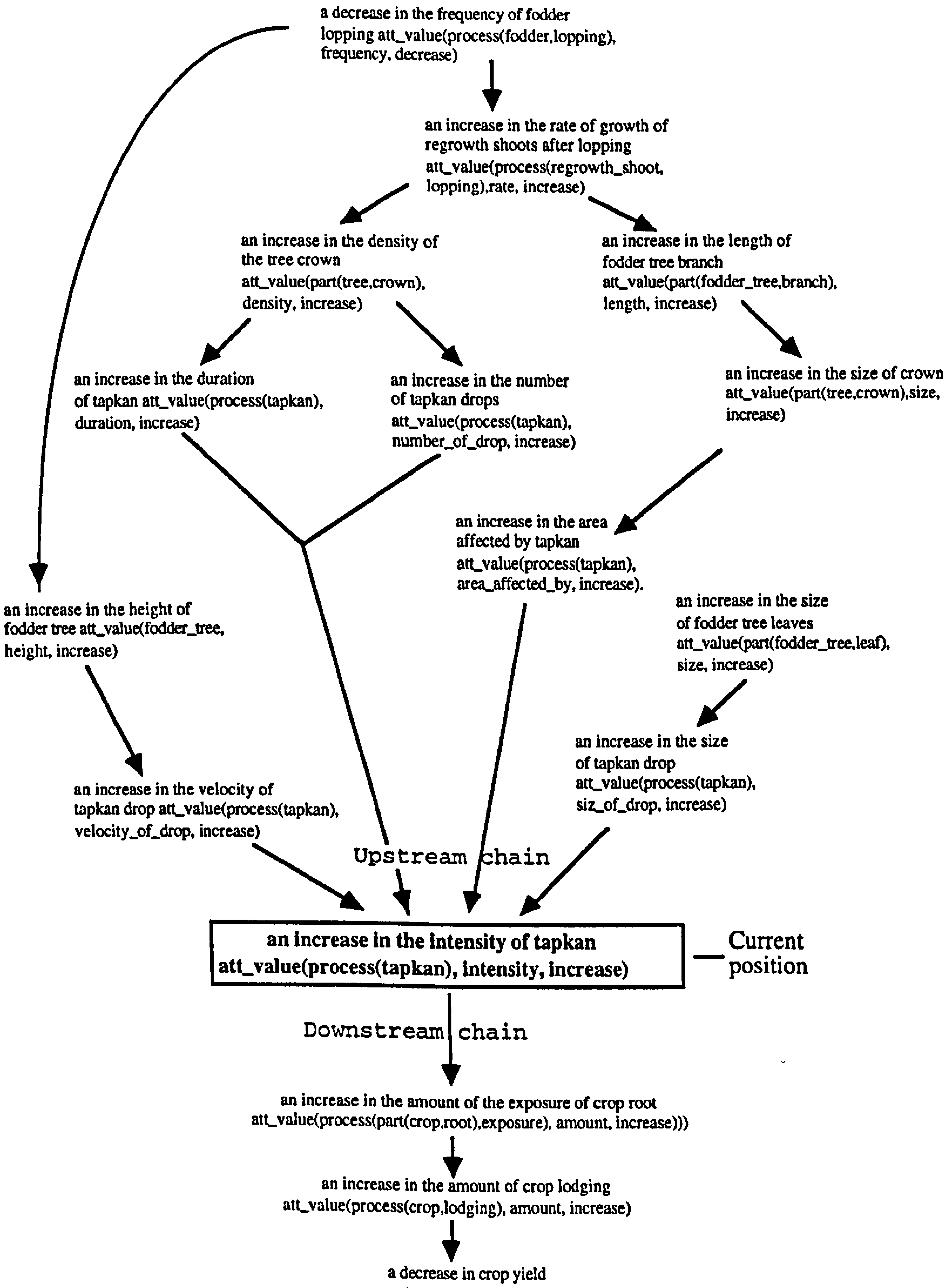


Figure 5.4 Reasoning with knowledge base using navigation tool (an example of the causes and implications of increased intensity of *tapkan*). Each arrow in the diagram means 'cause' or 'causes'.

5.3.1 Farmers' knowledge about tree-crop interactions

The information in the tree fodder knowledge base showed that farmers articulated considerable knowledge about interactions occurring in their tree-crop based farming systems that can be conveniently grouped into knowledge about above- and below-ground interactions.

5.3.1.1 Knowledge about above-ground interactions

5.3.1.1.1 Tree attributes influencing shade and *tapkan*

Farmers' knowledge of above-ground interactions was based largely on an understanding of the relative effects of shade and *tapkan* on crops caused by different tree species. At least five tree attributes were recognised as influencing shade and *tapkan*. These were: leaf size; crown density (leaf area density of the tree crown); crown size; tree height; and leaf inclination angle.

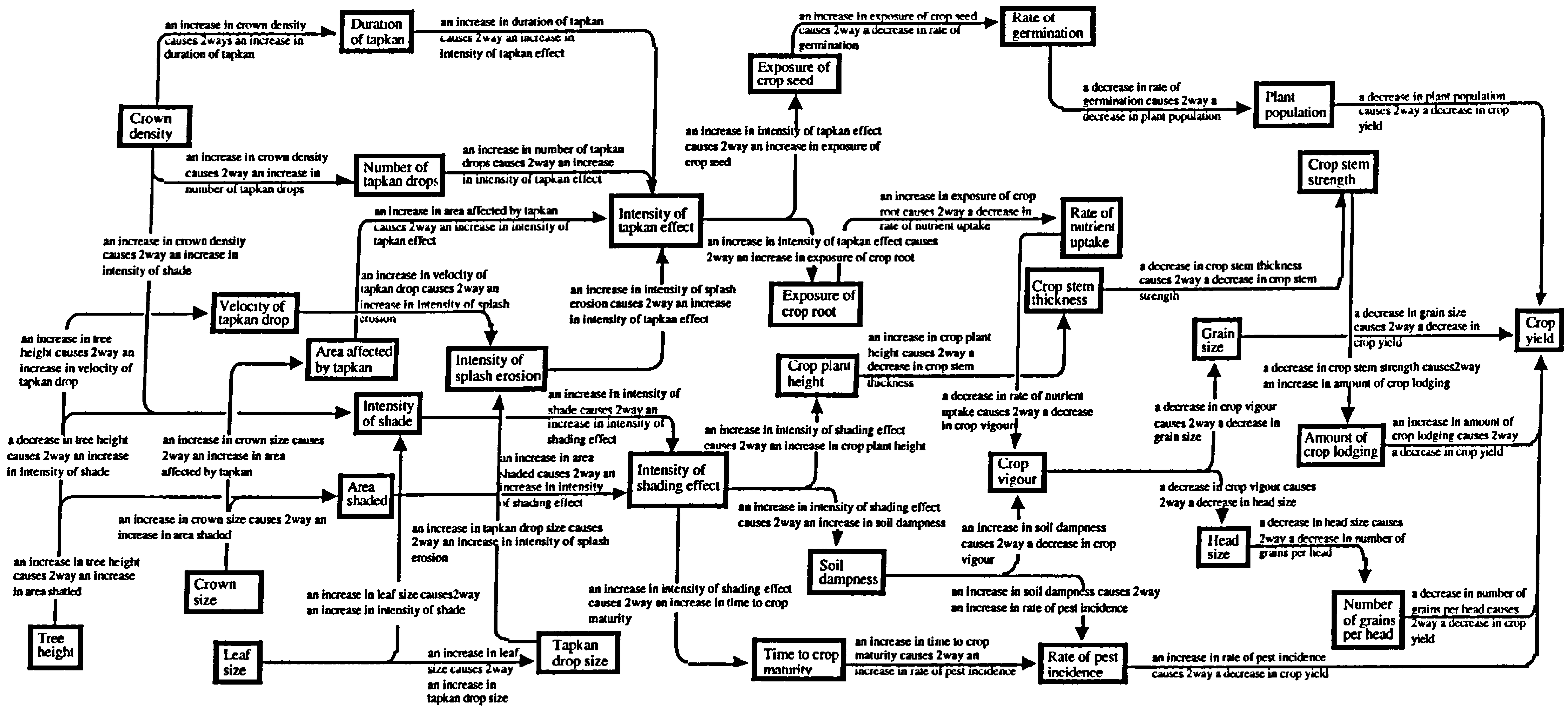
An increase in the value of these attributes was said to increase the intensity of shade and *tapkan* resulting in more intense tree-crop interactions. Individual species-specific knowledge as to which fodder tree species potentially grow tall or develop large or dense crowns and what management practices or techniques (5.3.3) influence these attributes were also articulated. Table 5.4 summarises attributes of some common fodder tree species recognised widely by farmers for causing different degrees of shade and *tapkan* effects.

Explanations of the mechanism of impact of shade and *tapkan* on crops were also well developed (Figure 5.5). Differences of impact on different crop species and cultivars were known (5.3.1.1.3). The impact of a range of spatial and temporal factors such as altitude and aspect were also explained (5.3.1.1.2).

Table 5.4 Attributes of some common fodder tree species recognised by farmers as causing shade and *tapkan* effects of different magnitude.

Fodder tree species	Attributes					Intensity of interaction effects	
	Crown density	Crown size	Leaf size	Leaf inclination angle	Tree height	Shade effect	Tapkan effect
Amalla (Embilica officinalis)	Light	Small	Small	Pointing down	Medium	Light	Light
Baar (*Ficus bengalensis*)	Dense	Large	Large	Horizontal	Tall	Heavy	Heavy
Badahar (*Artocarpus lakoocha*)	Dense	Large	large	Horizontal	Tall	Heavy	Heavy
Bhimsenpati (*Buddleja asiatica*)	Light	Small	Small	Horizontal	Short	Light	Light
Chamlayo (?)	Light	Small	Small	Horizontal	Medium	Light	Light
Chuletro (*Brassiopsis spp*)	Dense	Medium	Large	Pointing up	Medium	Heavy	Heavy
Ghurmise (*Leucosceptrum canum*)	Light	Small	Small	Horizontal	Short	Light	Light
Gogun (*Saurauia nepaulensis*)	Dense	Large	Large	Horizontal	Short to medium	Heavy	Heavy
Kabro (*Ficus lacor*)	Dense	Large	Large	Horizontal	Tall	Heavy	Heavy
Khasreto (*Ficus hispida*)	Dense	Medium	Large	Horizontal	Short to medium	Heavy	Heavy
Latikath (*Coronus oblonga*)	Light	Small	Small	Horizontal	Medium	Light	Light
Nebharo (*Ficus roxburghii*)	Dense	Large	Large	Pointing up	Medium to Tall	Heavy	Heavy
Painyu (*Prunus cerasoides*)	Light	Small	Small	Horizontal	Tall	Light	Light
Rai khanyu (*Ficus semicordata* var. *montana*)	Dense	Medium	Large	Pointing down	Short to medium	Heavy	Heavy
Rato siris (*Albizia julibrissin*)	Light	Small	Small	Pointing down	Tall	Light	Light
Sano pate dudhilo (*Ficus nemoralis*)	Light	Small	Small	Horizontal	Medium	Light	Light
Shyalfusro (*Grewia oppositifolia*)	Light	Small	Small	Horizontal	Medium	Light	Light
Thulo pate dudhilo (*Ficus nemoralis*)	Dense	Large	Large	Horizontal	Tall	Heavy	Heavy
Utis (*Alnus nepalensis*)	Light	Small	Small	Horizontal	Tall	Light	Light

The detailed knowledge articulated by farmers about tree attributes and the way in which each of the attributes influenced the interactive processes of shade and *tapkan* including the impact of shade and *tapkan* on crop yield are depicted in Figure 5.5. The diagram was created using HyperNet (4.2.6.2.2) by selecting causal statements from the



Key:

Arrows represent causal links between the nodes that they connect.

Boxed text are attribute node labels.

'Causes2way' implies reversibility in the causal mechanisms between 'increase' and 'decrease'and are used to represent both the meanings (4.3.3.2.3.1).

Figure 5.5 Causal knowledge articulated by farmers about tree attributes influencing interactive process of shade and *tapkan* and the impact of shade and *tapkan* on crop yield.

knowledge base relating to shade and *tapkan*. The diagram does not contain other associated knowledge; that is, knowledge not formalised using the causal statement type, that was articulated by farmers.

Shade is a word loosely used to describe modification of the microclimate beneath trees in a number of ways, principally effects on the amount and spectral composition of light, the temperature and the humidity. While farmers and scientists have recognised other microclimatic dimensions (5.3.1.1.2), light absorption by plant canopies has been the subject of much scientific research. This makes comparison of farmers' knowledge about shading effects of trees on crop terrace risers with the detailed, quantitative understanding developed scientifically, particularly productive.

It can be surmised that farmers recognised that light extinction or interception by trees was determined both by the incident radiation regime and the canopy structure, since a number of structural aspects of the tree canopy were recognised (Table 5.4) and known to affect shade (Figure 5.5) and shading effects were known to vary with altitude, aspect, time of day and season as a result of variation in the radiation climate (5.3.1.1.2). While scientists have developed quantitative descriptions of the radiation regime on a global basis in terms of direct and diffuse components and the solar track (Iqbal, 1983), it appears as though Solma farmers had at least a qualitative appreciation of these factors, in terms of the extent of their variability on a daily and seasonal basis within the study area.

Farmers recognised attributes of the tree canopy that affected shade at two levels; that of the individual tree crown and that of the individual leaf. The crown was described in terms of both size and density. In terms of size, tree height and crown size (which principally referred to crown diameter) combined to influence the area affected by shade while crown density affected the intensity of the shade that was cast within this area (Figure 5.5). This contrasts with most scientific treatments of light extinction by plant canopies that have considered continuous agricultural crop or forest canopies without confining foliage within envelopes associated with individual plants (Campbell and Norman, 1989). Discontinuity has, however, been modelled with respect to row crops (Allen, 1974), orchards (Jackson and Palmer, 1979) and isolated plants (Mann *et al.*, 1979; Norman and

Welles, 1983). The amount of leaf area and more recently, the spatial distribution of leaf area density in vertical and horizontal dimensions within tree crowns has also been explicitly considered (Wang and Jarvis, 1990), however, despite elaborate simulation models and schemes for statistical description of canopy structure (Ross, 1981), few data are available on the actual variation of leaf area density in plant stands and random or uniform distributions are generally used as approximations (Campbell and Norman, 1989). It is unclear to what extent farmers perceptions of crown density referred to the total amount of foliage within the crown as opposed to the grouping of foliage elements, but is likely that it was the overall effect of these two factors combined that corresponded to the differences in crown density recognised by farmers.

At the leaf level, both leaf size and leaf inclination angle were said to affect the intensity of shade. Farmers knowledge relating to effects of leaf size on shade should, however, be treated with some caution because:

- farmers were more confident in articulating knowledge about the effect of leaf size on *tapkan* than on shading and it is unclear to what extent shade and *tapkan* effects were thought of separately by farmers; and

- their perception of effects of leaf size were particularly associated with consideration of a single species, *Ficus roxburghii,* which has particularly large leaves.

However, the explicit consideration of leaf size by farmers contrasts with the emphasis of most of the scientific research. While passing mention has been made that the size of individual leaves may influence the absorption of radiation (Wang and Jarvis, 1990) the turbid medium analogy, which involves treating leaf area as a statistical density function within a given volume or layer, rather than the individual leaf surfaces being represented, has been almost exclusively adopted since the seminal work of Monsi and Seiki (1953). Farmers knowledge about the effect of leaf inclination angle on shade was not captured as formal causal statements and, therefore, does not appear in Figure 5.5 but farmers recognised trees as having leaves which either pointed upwards, downwards or were horizontal and that horizontal leaves were associated with more intense shade than those that were vertically oriented, consistent with the scientific observation and theoretical explanation that planophile canopies intercept a higher proportion of incident light than erectophile canopies (de Wit, 1965).

Farmers did not articulate knowledge about effects of crown shape, the spectral properties of leaves or the azimuthal orientation of leaves on shade nor did they appear to be aware of variation of either leaf inclination angles or leaf area density within crowns. This may reflect that these factors were not important in relation to shading by the particular tree species in the situations that they were grown in by farmers in Solma or that the elicitation process was not able to elucidate such knowledge. Questioning was certainly directed to differences between tree species, which would not encourage discussion of variability of structural properties within crowns of a particular species. It is also notable, however, that while non-uniform distribution of leaf area density within crowns has been shown to have significant effects in closed-canopy coniferous forest stands of high leaf area density in Europe (Wang and Jarvis, 1990), much less pronounced effects were apparent with widely spaced trees in agroforestry configurations (Sinclair and Jarvis, 1993). Similarly, while there have been numerous studies of crown shape, particularly in Finland, a recent comparative study of the influence of various crown structural properties on radiation absorption, photosynthesis and transpiration by individual Sitka spruce (*Picea sitchensis*) trees concluded that crown shape, when considered independently of crown size, was relatively unimportant (Wang and Jarvis, 1990). Azimuthal orientation of leaves would not be expected to have large effects on shading except where leaves were heliotropic (Campbell and Norman, 1989), and none of the tree species that were discussed with farmers are known to have leaves that exhibit solar tracking. Reflectance and tranmissivity of leaves does vary considerably between tree species and within individual crowns (Russell *et al.*, 1989), but it is not clear whether there was, in fact, significant variation in these respects, for the species used by farmers in Solma. Further research would be required to ascertain this. While farmers did not appear to have explicit knowledge of changes in the spectral composition of shade light they did associate etiolation effects of crops with increasing shade intensity (Figure 5.5).

It seems reasonable to conclude that, while farmers knowledge of shade effects was qualitative and far less detailed than state of the art scientific models in most respects, farmers appeared to be aware of the major structural properties of tree crowns that affect shade and their knowledge may reflect which properties were in fact most significant for the tree species and conditions that prevailed in the study area.

Various scientific studies on rainfall interception by tree canopies have been conducted, and are reviewed by Anderson and Sinclair (1993) but detailed explanation about the mechanism by which the tree attributes considered by farmers as influencing *tapkan* do not appear well represented in the scientific literature. Comparison of what information was available suggests that farmers explanatory knowledge about the mechanism by which tree attributes influenced *tapkan* may be analogous to what might be derived from scientific explanation. For example, one of the explanations given by farmers for tall trees causing serious *tapkan* effects on crops was:

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An increase in tree height causes serious tapkan effects on crops
because the velocity of tapkan drops falling from tall trees exerts a
powerful force when hitting the ground that causes serious splash
erosion.
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Thornes (1989) supports this by stating that the kinetic energy of water dropping from tree leaves in the rainforests of Borneo is higher than that of rain falling in the open and that water droplets falling from short trees causes less erosion than water droplets falling from tall trees because drops falling from short trees have a lower velocity and less energy for erosion on impact with the soil.

Figure 5.5 shows that farmers possess considerable knowledge about the mechanisms by which shade and *tapkan* affect crops. The ultimate impact of shade and *tapkan* on crops was a reduction in crop yield.

While some authors (Forestry Services, 1992) have reported shade from trees on terraces causing a decrease in the rate of weed infestation, others (Carter, 1991) have noted increased weed infestation under tree shade. The information in the tree fodder knowledge base shows that farmers recognised at least 11 common species of weeds found on their farmland (Figure 4.6; Chapter 4). Of these, all except two species, *ratnaulo* (*Bistorata amplxicaulis*) and *illame* (not identified) which were considered to be shade tolerant, were said to grow less well under the tree crown because of shade and *tapkan* effects.

Delayed crop maturity and increased soil dampness caused by an increase in soil moisture and humidity beneath the tree crown resulting from shade and *tapkan* (Figure 5.5) was reported to cause an increase in the rate of pest incidence. Two diseases, head smut (locally known as *kali poke*) and common rust (locally known as *sindurae*) in maize and millet crops respectively were reported to occur particularly under tree shade. Tree shade was also said to increase the insect population, particularly a white grub (locally known as *khumle*), which lives inside the soil and feeds on crop roots. Tree shade and *tapkan* were reported to cause a decrease in crop vigour causing crops, particularly maize, to produce smaller head and grain sizes both of which ultimately reduced crop yield. The knowledge articulated by farmers (Figure 5.5) is consistent with the findings of experiments conducted to investigate effects of trees on rice and wheat crops in Northeast Thailand (Sae-Lee *et al.*, 1992) and Pakistan (Akbar *et al.*, 1990) respectively. Both studies have shown tree shade causing increases in crop plant height, rendering crops more prone to lodging, reduction in the number of tillers, an increased percentage of unfilled grains and reduced crop yield.

5.3.1.1.2 Impact of spatial and temporal factors on shade and *tapkan*

The term *aule, kachhad* and *lekh* have already been introduced (3.7.1) as descriptions of low, middle and high elevations. Both tree shade and *tapkan* effects were considered more detrimental to crops in *lekh* areas than in *kachhad* or *aule* areas. The reasons given for this were that there were fewer sunshine hours, there was more rainfall and that heavier dew formed on tree leaves, particularly during winter. However, the role of tree shade in protecting crops from frost damage in *lekh* areas during winter was also widely acknowledged by farmers.

Some authors (Teketay and Tegineh, 1991; Nortcliff, 1992) have suggested that tree shade may provide a favourable microclimate by reducing air and soil temperature at low altitudes during hot, dry conditions and at higher altitudes by keeping crops warmer at night during winter. The information in the tree fodder knowledge base shows that the extent to which tree shade plays such a role is influenced by the position of trees on cropland. Morning and evening sun was considered to be beneficial for crops while midday sun was said to cause burning and so be harmful for crops particularly during hot, dry seasons at low altitudes. Grain weight of crops fully exposed to midday sun was said to be low while the grain weight of crops receiving morning or evening sun and less exposed to midday sun was said to be high suggesting that pruned trees with a clear bole may be particularly beneficial since overhead sun would be shaded but light at lower solar altitudes would not be.

East facing slopes were thought to receive more sunlight than west facing slopes during the monsoon, resulting in a smaller effect of shade on east facing slopes, while north facing slopes were more affected by tree shade during winter months than south facing slopes. A similar observation that farmers grow fewer trees on north facing slopes to reduce shade effects on crops in Suri in the central mid-hills of Nepal has been reported (Carter, 1991). Subedi *et al.* (1990) from their study in the eastern *terai* (lowland belt of Nepal) have reported that farmers have the customary right to plant trees only on the east and south boundary of their fields and not on the north or west boundary because of differential tree shading effects.

5.3.1.1.3 Crop cultivar response to shade

For a variety of reasons, as elsewhere in the mid-hills of Nepal (Schoreder, 1985), Solma farmers cultivate different crop cultivars on their farmland. Reasons include satisfying cooking and taste requirements and matching crop cultivars to specific ecological niches. The information in the tree fodder knowledge base revealed that farmers categorised different crop species and cultivars either as shade tolerant, intolerant or intermediate.

Rice was said to be more adversely affected by shade than maize, and millet to be least affected. Shade effects on rice were said to cause sterility, observed as the proportion of unfilled grains and this may partly explain why trees were not grown on *khet* land (3.8.2.1) where rice is exclusively grown. For maize and millet (the main crops grown on *bari* land in association with trees) a number of cultivars were recognised to have different shade tolerance (Table 5.5).

Table 5.5 Response to shade in maize and millet cultivars.

Species	Cultivars	Cultivar characteristics and response to shade
Maize	Thulo pahale (local cultivar)	Tall, thin and long stem, prone to lodging, shade intolerant.
	Sano pahale (local cultivar)	Short to Medium in height, thick stem, shade tolerant.
	Thulo seti (local cultivar)	Tall, thin and long stem, prone to lodging, shade intolerant.
	Sano seti (local cultivar)	Short to medium in height, thick stem, shade tolerant.
	Kali (local cultivar)	Short to medium in height, thick stem, moderate shade tolerant.
	Khumal pahalo (improved cultivar attribution)	Short to medium in height, thick stem, shade intolerant.
	Manakamana (improved cultivar attribution)	Short, thick stem, shade intolerant.
Millet	Chhakre (also known as nang katuwa or fakrae)	Tall, soft stem, prone to lodging, shade intolerant.
	Mudke (also known as dalle)	Short, strong stem, shade tolerant.
	Mugale	Medium height, strong stem, moderate shade tolerant

It is interesting to note that the improved cultivars of maize generated through government crop breeding programmes and supplied to farmers through agricultural extension programmes, were said to perform poorly under tree shade which is consistent with them being selected and evaluated under full sunlight. The knowledge articulated by farmers on shade tolerant crop cultivars suggest a considerable potential for selecting crop cultivars for use with different levels of shade.

5.3.1.2 Knowledge about below-ground interactions

Farmers' knowledge of below-ground interactions was based largely on an understanding of the attributes of tree root systems, principally the depth and spread of roots (the size and morphology of the tree root system), rate of litter decomposition and their variability between species. The depth and spread of tree root systems was said to govern the extent of competition between trees and crops for soil nutrients and soil moisture and trees were often classified in terms of their rooting habit as either *rukho, malilo* or intermediate between *rukho* and *malilo.*

5.3.1.2.1 The *rukho-malilo* classification

The most literal translation of the Nepali terms *rukho* and *malilo* are infertile and fertile respectively. The meaning and definition of these terms as used by Solma farmers in the context of the present study may be more fully described in terms of the effects of trees on soil; that is, *rukho* trees are those that depress soil fertility and *malilo* trees are those that improve soil fertility.

Rukho trees were said to have shallow root systems with a widespreading, predominantly horizontal root distribution. Leaves of *rukho* trees were said to take a long time to decompose and not to improve fertility of soil through leaf decomposition and to cause a negative impact on crops. Trees were classified as *rukho* either because their leaves or their root systems had *rukho* attributes (Table 5.6). In contrast, *malilo* trees were said to be deep rooted and *malilo* tree leaves were said to decompose rapidly and improve soil fertility.

A decrease in the depth of tree roots or an increase in the horizontal spreading of tree roots was said to cause an increase in the amount of tree and crop root competition for soil nutrients and soil moisture. Because of the shallow, wide spreading and horizontal distribution of *rukho* tree roots, they were said to aggressively invade crop terraces, making ploughing difficult, even to the extent of causing ploughs to break, so resulting in inadequate land preparation. *Rukho* root systems were said to soak up water and soil nutrients aggressively, resulting in dry and hard soil underneath tree crowns. Conversely, *malilo* trees were said to have deep roots and to compete less than *rukho* trees with crop roots for soil moisture and soil nutrients. Soil around *malilo* trees was reported to be soft, light and loose, and was considered fertile by farmers.

Analysis of fodder tree species recorded in the inventory showed that of the 90 species, at least 23 species were recognised as *rukho* and 17 species as *malilo.* A large number of tree species were said to be neither *rukho* nor *malilo* and considered as intermediate (Figure 4.7; Chapter 4). A list of the fodder tree species considered unanimously to be *rukho* or *malilo* by informants is presented in Table 5.6.

Table 5.6 List of fodder tree species considered on the basis of root and shoot characteristics as falling into *rukho* or *malilo* categories by informants. Explanation of *rukho* and *malilo* appears in the text. Symbol (*) indicates unanimous agreement by informants.

Rukho fodder tree species	Because of: Leaf attribute	Because of: root attribute	*Malilo* fodder tree species	Because of: Leaf attribute	Because of: root attribute
Baar (*Ficus bengalensis*)		*	Amalla (*Emblica officinalis*)	*	
Babis (?)	*	*	Bakaino (*Melia azedarach*)	*	*
Bans (*Bambusa spp* and *Dendrocalamus spp*)	*	*	Bhimsenpati (*Buddleja asiatica*)	*	
Chilaune (*Schima wallichii*)	*	*	Dhusure (*Colebrookia oppositifolia*)	*	
Darimpate (?)	*	*	Ghurmise (Leucosceptrum canum)	*	*
Dhayero (*Woodfordia fruticosa*)	*	*	Gidari (*Premna spp*)	*	
Gayo (*Bridelia retusa*)		*	Kadam (?)	*	
Karam (*Holoptelea integrifolia*)	*	*	Katus (*Castanopsis spp*)	*	
Koiralo (*Bauhinia variegata*)	*	*	Khari (*Celtis australis*)	*	
Mahuwa (*Madhuca indica*)	*		Khayer (*Acacia catechu*)	*	*
Mayal (*Pyrus pashia*)	*	*	Khirra (*Wrightia antidysenterica*)	*	
Nigalo (*Arundinaria spp*)	*	*	Rato siris (*Albizia julibrissin*)	*	*
Odal (*Sterculia villosa*)	*	*	Seto siris (*Albizia procera*)	*	*
Painyu (*Prunus cerasoides*)	*		Kaingyu (*Wendlandia exserta*)	*	
Parayang (*Arundinaria spp*)	*	*	Tanki (*Bauhinia purpurea*)	*	
Pipal (*Ficus religiosa*)		*	Tatola (*Oroxylon indicum*)	*	*
Saj (*Terminalia tomentosa*)		*	Utis (*Alnus nepalensis*)	*	*
Satibayar (*Rhus parviflora*)		*			
Shyalfusro (*Grewia oppositifolia*)		*			
Silange (?)	*	*			
Simali (*Vitex negundo*)		*			
Sindure (?)	*	*			
Tilke (?)	*	*			

The knowledge articulated by farmers matches closely with the statement made by Vandenbeldt *et al.* (1990) that trees often exploit the crop root zone for nutrients and water because the majority of their fine roots occur in upper soil layers. This may be particularly true for *rukho* trees whose roots are shallow with horizontal distribution. On this basis Vandenbeldt *et al.* (*op. cit.*) argue that the simplistic model potrayed in most agroforestry literature of trees as complementary and uncompetitive with annual crops (because they exploit different soil depths for water and nutrients), be used with caution. Research has shown that a great variation in rooting pattern both within and between species can occur, which may be influenced by several factors including silvicultural manipulations, such as pruning and environmental factors. For example a more severe pruning of *Peltophorum pterocarpum* was shown to result in development of a large number of fine roots in the top 10 cm of soil in acid soils in Indonesia, resulting in strong competition for water and nutrients with crop roots (Van Noordwijk *et al,* 1991). However, literature also suggests that mixtures of trees and crops may exhibit more extensive niche differentiation than would be expected from their rooting patterns in monoculture because of responses to reduced water and nutrient availability in upper soil layers as a result of resource consumption by companion crops (Sinclair *et al.,* 1994) .

Tree fodder lopping was a common practice and farmers applied different lopping regimes to different species and individual trees. It is likely that farmers' lopping practices would have considerably influenced the rooting pattern of their fodder trees with consequences for crops. However, no knowledge was articulated by farmers in this respect.

The effects of *rukho* and *malilo* tree leaves on crops, particularly *rukho* leaves were less well understood. Fodder trees were generally lopped and the cut branches carried to stall fed animals. There was no evidence that farmers grew trees on their farmland in order to improve or maintain soil fertility. However, farmers were consistent in saying that certain tree leaves which they considered as *rukho* were detrimental to crops. For example, *Prunus cerasoides* was said to have deep roots and for its leaves to decompose rapidly and, therefore, would be expected to fall under the *malilo* tree category, but it was in fact widely categorised as *rukho* because farmers had observed low rates of crop germination and seedling growth underneath the tree which was attributed to allelopathic effects.

Melkania, (1986) reported that although toxic substances are distributed in various plant parts in various concentrations, leaves are often the most potent source. Studies carried out in Garhwal Himalaya, India indicate that leaves of several agroforestry tree species including *Prunus cerasoides* exhibit allelopathic effects and inhibit crop (soybean and millet) germination and growth rate significantly (Bhatt and Todaria, 1990). While farmers articulated knowledge about deleterious effects of tree leaves, which clearly have a significant bearing on crop production, no studies have so far been conducted to investigate allelopathic influences of farmland tree species common in the hill farming systems of Nepal.

Malilo tree leaves were said to enhance seedling growth rate and this was reflected in the fact that *malilo* tree leaves were widely used by farmers as green manure particularly in rice and millet nursery beds. Studies carried out at Pakhribas Agricultural Centre (Sherchan *et al.*, 1992) on green manuring effects of various tree leaves including *Albizia julibrissin* (one of the species in Table 5.6 recognised by farmers as malilo) showed an increase in the grain yield of rice by as much as 71% over controls.

Some authors (Nortcliff, 1992) have suggested that trees may ameliorate soil through root decomposition and through atmospheric nitrogen fixation. However, the information in the tree fodder knowledge base showed no such knowledge being articulated by farmers. Only four of the species considered as *malilo* by farmers (*Acacia catechu, Albizia julibrissin, Albizia procera* and *Alnus nepalensis*) are reported in the literature to be capable of fixing nitrogen (Campbell, 1983), but there is little evidence for reduced competition with companion crops for nitrogen as a result of nitrogen fixation by trees.

In summary, it may be concluded that farmers articulated more comprehensive knowledge of above than below-ground interactions. However, it was unclear whether this was because above-ground interactions were more important than below-ground interactions or because they were more readily observed. Both what farmers do know about tree-crop interactions and they do not know present opportunities either to inform researchers or to fill gaps in farmers' knowledge constraining productivity of the system, particularly in relation to soil amelioration by trees.

5.3.2 Farmers' knowledge about fodder quality evaluation

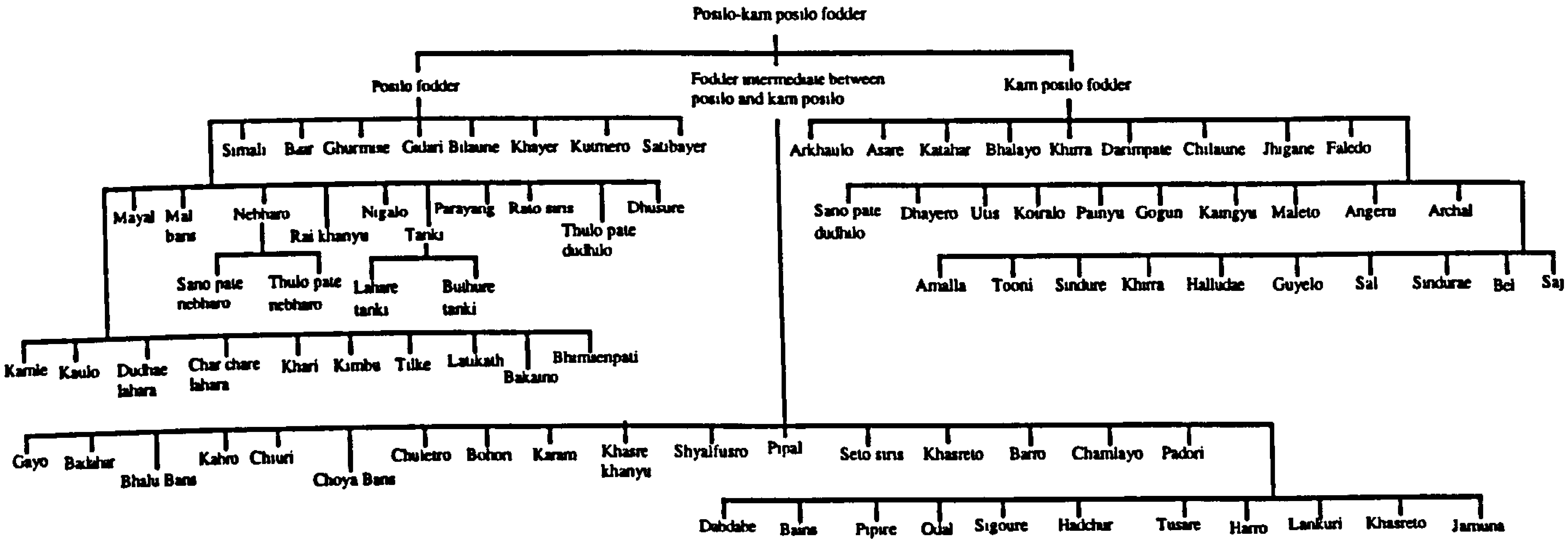
The information in the tree fodder knowledge base showed that from the farmers' perspective, fodder quality was determined by:

- the ability of fodder to satisfy appetite;
- the effects of fodder on milk and *ghee* (butter fat content) production including the effects of fodder on milk odour;
- the ability of fodder to improve animal growth rate (body weight gain);
- the effects of fodder on animal health;
- the comparative preference of different livestock for different fodder; and
- the palatability of fodder.

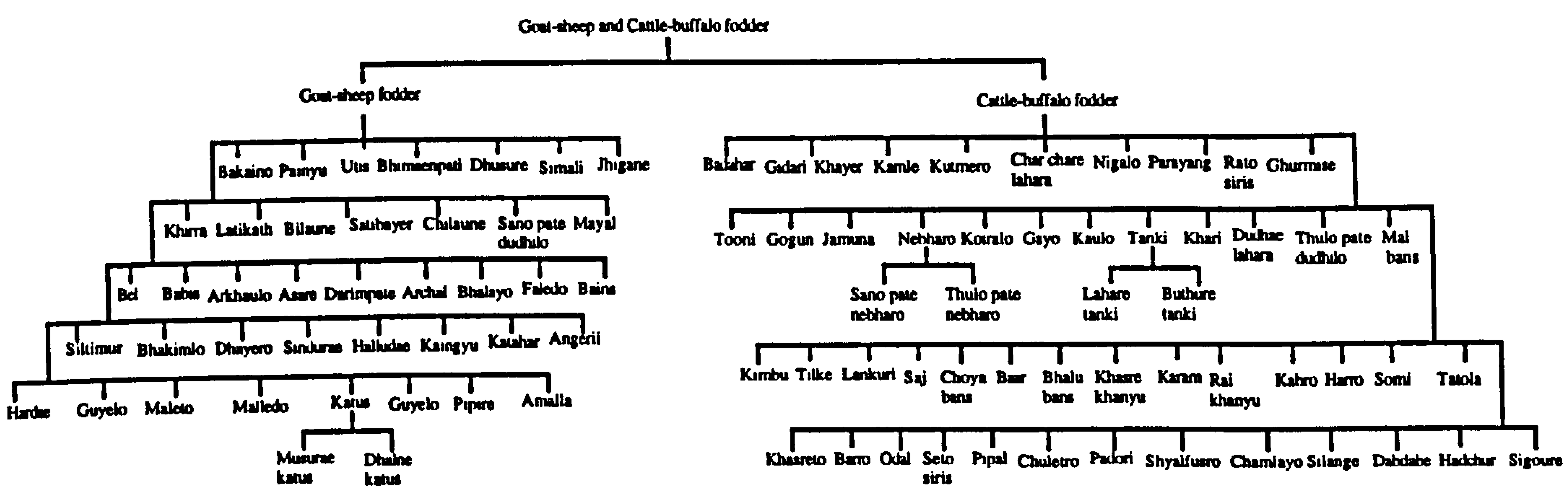
A number of attributes were known to influence fodder quality. These were:

- leaf texture;
- leaf maturity;
- leaf bitterness;
- fodder toxicity;
- season; and
- the management regimes applied to the fodder tree.

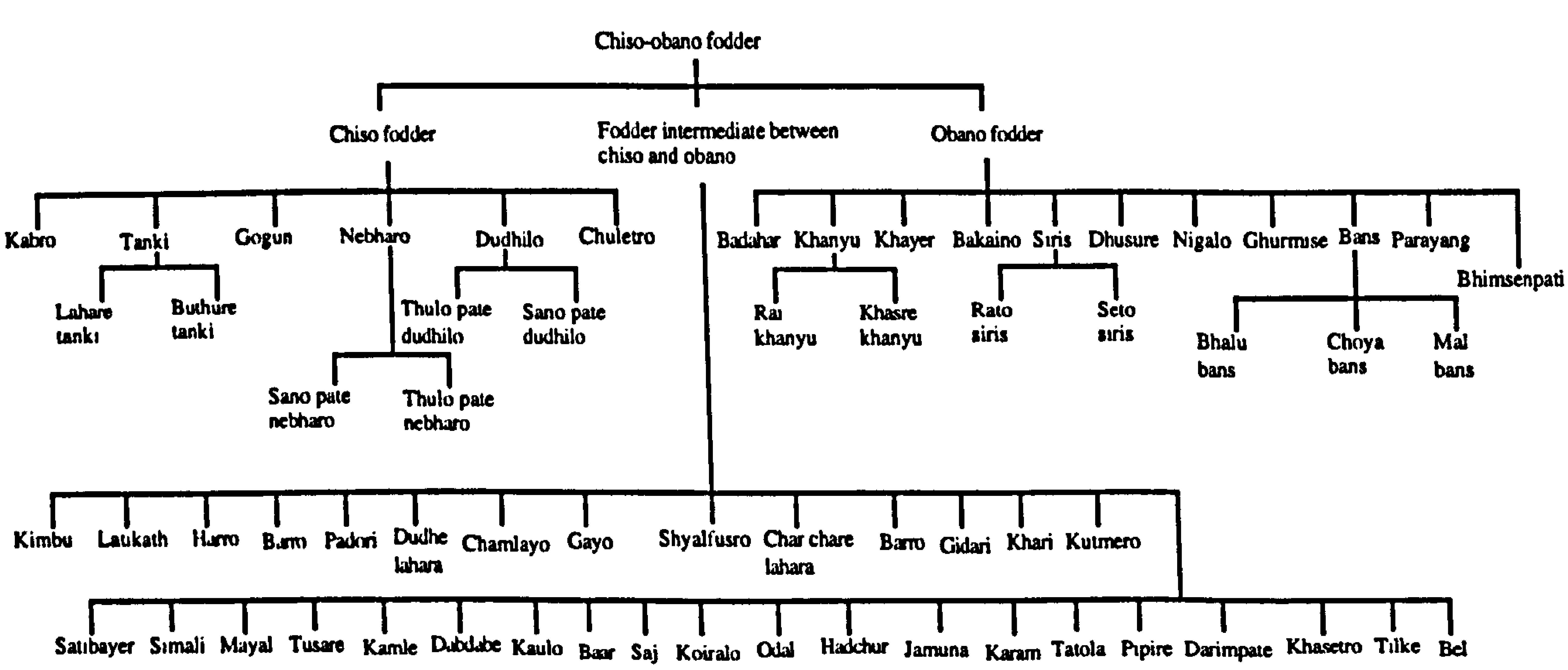
Intra-species variation in terms of fodder quality was recogised and varient management of sub-species practised (5.3.2.7). Farmers classified fodder using three partial and overlapping taxonomies as *posilo* or *kam posilo* (Figure 5.6.a), as *chiso* or *obano* (Figure 5.6.b) and as goat-sheep fodder or cattle-buffalo fodder (Figure 5.6.c), each classification system appropriate to a different purpose. Fodder trees were also classified according to



(a) Farmer classification of fodder trees according to *posilo-kam posilo* status.



(b) Farmer classification of fodder trees in relation to animal type.



(c) Farmer classification of fodder trees according to *chiso-obano* status.

Figure 5.6 Farmer classification of fodder trees according to *posilo-kam posilo* and *chiso-obano* status and in relation to animal type.

their effect on crops and soil fertility in terms of their *rukho-malilo* status as previously presented (Figure 4.7). Each of these fodder classification systems are discussed in detailed in the respective secition below.

5.3.2.1 *Posilo-kam posilo* classification

The most common terms used for describing fodder quality were *posilo* and *kam posilo.* The most literal translation of these terms is nutritious (high nutritive value) and less nutritious (low nutritive value) respectively. Farmers knowledge of fodder quality was based on an understanding of *posilo* and *kam posilo* attributes of fodder, their variability between tree species and their implications for the productivity of animals feeding on these fodders.

Of the 90 fodder tree species recorded in the inventory, 28 were considered as *posilo,* 29 as *kam posilo* and 28 as intermediate between *posilo* and *kam posilo* (Figure 5.6.a). There was disagreement among informants about the *posilo-kam posilo* status of 15 species (Appendix, 2.c). The main characteristics distinguishing *posilo* and *kam posilo* fodder are summarised in Table 5.7. Authors such as Rusten (1989) and Robinson (1990) have also noted farmers in Salija (western mid-hills of Nepal) and Dolakha district (central mid-hills of Nepal) describing certain fodders as nutritious and less nutritious, matching closely with the *posilo* and *kam posilo* classification in Table 5.7. However, the categorisation of fodder into *posilo* and *kam posilo* types is complicated by the fact that what is considered *kam posilo* fodder to one class of animal may be considered as *posilo* fodder when fed to another type of animal and fodder palatability similarly depends upon the type of animal that is fed (5.3.2.2).

Table 5.7 Characteristics of *posilo* and *kam posilo* fodder.

Posilo fodders	*Kam posilo* fodders
Cause increase in milk production	Do not increase milk production and, reduce milk yield if fed as a sole fodder to lactating animals for a long period of time
Cause increase in *ghee* (milk fat content) production	Do not increase *ghee* production, and reduce *ghee* production if fed as a sole fodder to lactating animals for a long period of time
Cause animals to gain body weight	Cause animals to lose body weight if fed as a sole fodder for a long period of time
Make animals strong	A animal health deteriorates if fed as a sole fodder for a long period of time
Improve animal health	Do not improve animal health
High palatability	Low palatability
Satisfy appetite	Do not satisfy appetite.

5.3.2.2 Goat-sheep and cattle-buffalo fodders

Farmers in the study area recognised that certain fodders were eaten preferentially by goats and sheep while the same fodders were not eaten preferentially by cattle and buffalo. Similarly, certain fodders were considered as *posilo* to goats and sheep while the same fodders were known to be *kam posilo* to cattle and buffalo. On the basis of this understanding, farmers often classified tree fodders as goat-sheep fodder and cattle-buffalo fodder (Figure 5.6.b).

Of the 90 species recorded in the inventory, 38 were considered as goat-sheep fodder, while 52 were considered as cattle-buffalo fodder (Figure 5.6.b). Further analysis of the 28 species listed as *posilo* fodder (Figure 5.6.a) in relation to animal type revealed that 19 species were considered as *posilo* fodder to all classes of animal while nine were considered as *kam posilo* and less palatable to cattle and buffalo but *posilo* and palatable to goats and sheep (Appendix 2.C). Tree species considered unanimously by farmers as *posilo* and palatable to these two categories of animal are presented in Table 5.8.

Table 5.8 List of fodder tree species considered as *posilo* and palatable to two categories of animals (goat-sheep and cattle-buffalo) by informants. Symbol (*) indicates unanimous agreement by informants.

Fodder tree species	*Posilo* to goats and sheep only	*Posilo* to all classes of animals	*Kam posilo* to all classes of animals	Palatable to goats and sheep only	Palatable to all classes of animals
Badahar (*Artocarpus lakoocha*)		*			*
Bakaino (*Melia azedarach*)	*			*	
Mal bans (*Bambusa nutans*)		*			*
Bhimsenpati (*Buddleja asiatica*)	*			*	
Bilaune (*Maesa chisia*)	*			*	
Char chare lahara (?)		*			*
Chilaune (*Schima wallichii*)			*	*	
Dhusurae (*Colebrookia oppositifolia*)	*			*	
Dudhae lahara (?)		*			*
Ghurmise (*Leucosceptrum canum*)		*			*
Jhigane (*Eurya acuminata*)			*	*	
Kamle (*Pilea wightii*)		*			*
Kaulo (*Machilus odoratissima*)		*			*
Khari (*Celtis australis*)		*			*
Khayer (*Acacia catechu*)		*			*
Khirra (*Wrightia antidysenterica*)			*	*	
Kimbu (*Morus alba*)		*			*
Kutmero (*Litsea monopetala*)		*			*
Latikath (*Coronus oblonga*)	*			*	
Mayal (*Pyrus pashia*)	*			*	
Nebharo (*Ficus roxburghii*)		*			*
Nigalo (*Arundunaria spp*)		*			*
Painyu (*Prunus cerasoides*)			*	*	
Parayang (*Arundinaria spp*)		*			*
Rai khanyu (*Ficus semicordata* var. *montana*)		*			*
Rato siris (*Albizia julibrissin*)		*			*
Sano pate dudhilo (*Ficus nemoralis*)	*			*	
Satibayar (*Rhus parviflora*)	*			*	
Simali (*Vitex negundo*)	*			*	
Tanki (*Bauhinia purpurea*)		*			*
Thulo pate dudhilo (*Ficus nemoralis*)		*			*
Tilke (?)		*			*
Utis (*Alnus nepalensis*)			*	*	

Farmers could not provide an explanation for why certain fodders were *posilo* to certain classes of animal and *kam posilo* to others and why certain classes of animal eat certain fodders preferentially when others did not. Paterson (1993) suggested that cattle generally showed a marked preference for fodder with soft leaves rather than tough leaves and that this characteristic was shared to some extent by sheep but probably not by goats. However, Paterson (*op. cit.*) further states that such a preference assumes importance only when animals are presented with a choice. Since all fodders considered as *posilo* and palatable to cattle and buffalo are also considered as *posilo* and palatable to goats and sheep (Table 5.8), it may be that the distinctions made by farmers between cattle-buffalo fodder and goat-sheep fodder were based on the value of different classes of farm animals. For example, farmers may view cattle and buffalo as more important farm animals than sheep and goats and, therefore, cattle and buffalo may have been fed with *posilo* fodders while goats and sheep fed with *kam posilo* fodders so that each category of animal may have become accustomed to a particular type of fodder.

5.3.2.3 Effects of fodder on milk and *ghee* production

The information in the tree fodder knowledge base revealed that the choice of fodder fed to livestock was partially determined by the products desired from livestock. A number of fodders were known to promote milk production while others were known to decrease milk production. For milk promoting fodders, further distinctions were made between fodders that promoted an increase in milk yield *per se* and those that caused an increase in *ghee* content of the milk. For example, *Bauhinia purpurea* and *Ficus nemoralis* fodders were said to increase milk production, however, the milk of animals fed with these two fodders was said to be thin corresponding with a low *ghee* content. By contrast, *Bambusa nutans* and *Arundinaria spp* fodders were known to produce thick milk and, therefore, a high *ghee* content. Fodders that promote high milk production as well as a high *ghee* content were particularly prized such as *Artocarpus lakoocha, Litsea monopetala* and *Bambusa nutans* (Table 5.9).

Certain fodders were considered to cause animals to produce milk with a pungent odour and were, therefore, not fed to lactating animals (though they may otherwise promote milk and *ghee* production or both) such as *Premna* spp. Fodder tree species considered unanimously by farmers to affect milk and *ghee* production and to affect milk odour are listed in Table 5.9.

Table 5.9 Fodder tree species considered by informants to affect milk and *ghee* production and to affect milk odour. Symbol (*) indicates unanimous agreement by informants.

Fodder tree species	Cause pungent odour milk	Cause milk production to cease	Promote on increase in milk production	Promote on increase in ghee production
Baar (*Ficus bengalensis*)	*			
Badahar (*Artocarpus lakoocha*)			*	*
Dudhae lahara (?)			*	*
Gayo (*Bridelia retusa*)		*		
Ghurmise (*Leucosceptrum canum*)			*	*
Gidari (*Premna spp*)	*		*	*
Khari (*Celtis australis*)			*	
Khayer (*Acacia catechu*)			*	*
Koiralo (*Bauhinia variegata*)		*		
Kutmero (*Litsea monopetala*)			*	*
Mal bans (*Bambusa nutans*)			*	*
Mayal (*Pyrus pashia*)		*		
Nebharo (*Ficus roxburghii*)			*	
Nigalo (*Arundinaria spp*)			*	*
Painyu (*Prunus cerasoides*)		*		
Parayang (*Arundinaria spp*)			*	*
Rai khanyu (*Ficus semicordata* var. *montana*)			*	
Rato siris (*Albizia julibrissin*)			*	*
Tanki (*Bauhinia purpurea*)			*	
Thulo pate dudhilo (*Ficus nemoralis*)			*	

No causal explanations for certain fodders causing a decrease in milk production and others causing an increase in milk and/or *ghee* production were articulated. Mangan (1988) and Kumar and Vaithiyanathan (1990) reported that leaves of woody plants contain a wide range of anti-nutritive factors, the most notable being tannins, which can affect the productivity of animals. Significant reductions in milk production as a result of feeding tannin-rich fodder have been reported (Kumar and Singh, 1984). Tannins are assumed to reduce voluntary feed intake by animals because of their astringency and to lower animal productivity by reducing protein digestion and absorption (Paterson, 1993).

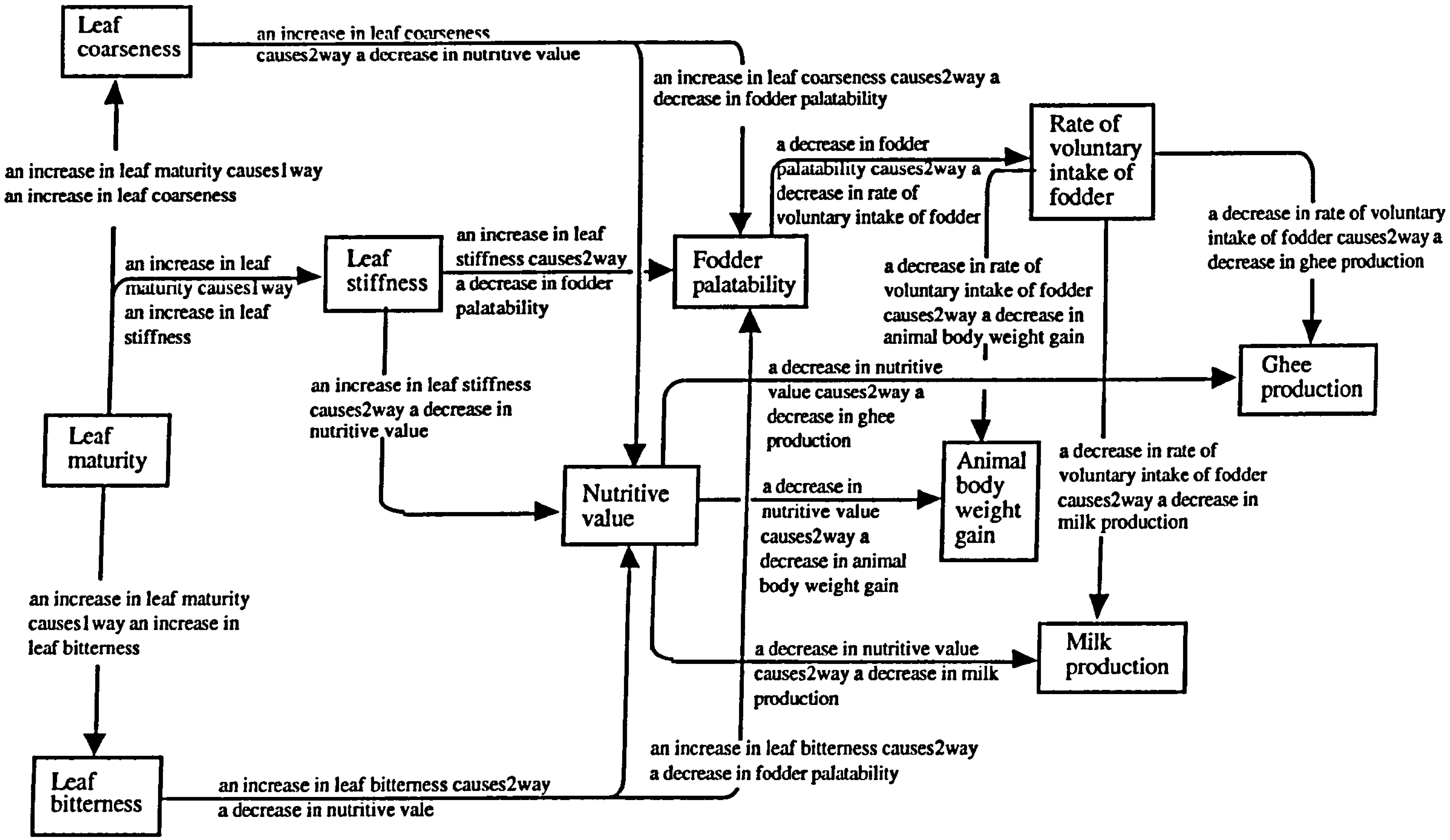
5.3.2.4 Tree attributes influencing fodder palatability and nutritive value

Fodder palatability in relation to type of animal has already been discussed (5.3.2.2). In this section, tree attributes recognised by farmers as influencing fodder palatability and nutritive value are examined. These were: leaf texture; leaf maturity; and leaf bitterness. Causal knowledge articulated by farmers about tree attributes influencing fodder palatability and nutritive value and their impact on animal productivity is depicted in Figure 5.7.

Generally, fodders that were palatable were also considered to be of high nutritive value. However, these two terms were quite different and fodders that were palatable were not always of high nutritive value. For example, *Litsea monopetala* fodder was considered to be of high nutritive value but of low palatability, while *Bridelia retusa* fodder was considered to be palatable but of low nutritive value.

Farmers described leaf texture as soft, coarse and stiff. Fodders with soft leaves were said to be more palatable and nutritious than coarse and stiff leaves. Generally, leaves were said to become coarser and stiffer with an increase in leaf maturity and, therefore, fodders became less palatable as well as less nutritious as they matured.

Leaf maturity was described in terms of ripeness. Three categories of ripeness were recognised: unripe (immature); ripe (mature); and over-ripe (senescing). Ripe leaves were considered to be very palatable and nutritious, while over-ripe leaves were considered not very palatable and of low nutritive value with unripe leaves intermediate. Unripe leaves were generally described as reddish in colour and shiny (a condition locally termed, *paulo*). They were also sometimes considered to be bitter. Over-ripe leaves were generally said to be yellowish in colour and bitter. Ripe leaves were generally said to be dark green in colour and less shiny than unripe leaves and were considered the most appropriate for lopping and feeding to animals.



Key:

Arrows represent causal links between the nodes that they connect.

Boxed texed are attribute node labels.

'Causes2way' implies reversibility in causal mechanisms between 'increase' and 'decrease' and are used to represent both the meanings. 'Causes1way' implies irreversibility between 'increase' and 'decrease' (4.3.3.2.3.1).

Figure 5.7 Causal knowledge articulated by farmers about tree attributes influencing fodder palatability and nutritive value and their impact on animal productivity.

Leaf bitterness was said to make fodder less palatable and to decrease nutritive value. Leaf bitterness was also said to cause a decrease in the voluntary intake of fodder by animals. Generally, leaf bitterness was said to increase with an increase in leaf maturity. However, certain tree fodder leaves such as *Melia azedarach, Prunus cerasoides, Vitex negundo* and *Pyrus pashia* were said to be extremely bitter irrespective of leaf maturity and were considered only to be palatable to goats and sheep. Some of the fodder tree species considered unanimously by informants as having coarse and stiff leaf texture and with bitter taste are presented in Table 5.10.

Table 5.10 Fodder tree species considered by informants as having coarse and stiff leaves and/or a bitter taste. Symbol (*) indicates unanimous agreement by informants.

Fodder tree species	Leaf texture			Leaves bitter in taste	Comment
	Soft	Coarse	Stiff		
Bakaino (*Melia azedarach*)	*			*	Leaves bitter in taste irrespective of age or maturity.
Chilaune (*Schima wallichii*)			*		Matured leaves stiff and unpalatable to animals.
Ghurmise (*Leucosceptrum canum*)	*				Leaves bitter in taste when mature.
Gogun (*Saurauia nepaulensis*)		*			
Khasreto (*Ficus hispida*)		*			
Khasre khanyu (*Ficus semicordata* var. *semicordata*)		*			
Koiralo (*Bauhinia variegata*)			*	*	Leaves bitter in taste irrespective of age or maturity.
Kutmero (*Litsea monopetala*)	*				Leaves bitter in taste when mature.
Mayal (*Pyrus pashia*)				*	Leaves bitter in taste irrespective of age or maturity.
Painyu (*Prunus cerasoides*)	*			*	Leaves bitter in taste irrespective of age or maturity.
Shyalfusro (*Grewia oppositifolia*)	*				Leaves bitter in taste when mature.
Simali (*Vitex negundo*)	*			*	Leaves bitter in taste irrespective of age or maturity.

Many features of woody plants ranging from purely physical (for example, thorns, spines and leaf coarseness) to chemical (for example, offensive odour, tannin content and alkaloid content) have been reported in the literature as influencing palatability and nutritive value of a particular fodder. A recent review (Paterson, 1993) suggests that the presence of tannins because of their astringency and alkaloids because of their bitter taste can reduce nutritive value and fodder palatability considerably. D'Mello (1992) reports that the tolerance to tannins and alkaloids varies between animal species with goats being most tolerant followed by sheep and cattle. D'Mello (*op. cit.*) also reported that unlike cattle, goats and sheep saliva contains proline-rich protein which can act as a defence against tannins explaining why goats and sheep may be able to eat more tannin or alkaloid rich-fodder than cattle.

5.3.2.5 Effects of fodder on animal health

The information in the tree fodder knowledge base showed a considerable knowledge amongst farmers about the deleterious effects of fodders on animal health. A number of fodders were known to be toxic to animals. Detailed species specific knowledge including the extent of deleterious effects, variability of effects according to season and different stages of leaf development, and the mechanisms by which these effects could be minimised, either by avoiding feeding particular fodders at particular times or by post-harvest treatments were also articulated. Fodder tree species known to cause deleterious effects on animals including season or leaf development stage at which they were considered to be particularly harmful are given in Table 5.11.

In most cases it was the *paulo* leaves (young leaves at flushing stage) which were said to cause toxic effects on animals. Three species (*Albizia julibrissin, Bridelia retusa* and *Lyonia ovalifolia*) were known to be highly toxic to animals at the *paulo* stage and, if fed, the consequences could be fatal and their foliage was, therefore, avoided at that particular time. Maslin *et al.* (1987) reported that tree leaves which contain cyanogenic glycosides produce hydrogen cyanide through reaction in the digestive tract with hydrolysing enzymes. Hydrogen cyanide can lead to the immediate death of animals (Paterson, 1993). Preliminary laboratory analyses of fodder toxicity at Pakhribas Agricultural Centre has

Table 5.11 Fodder tree species considered unanimously by informants to cause deleterious effects on animal health.

Fodder tree species	Season or stage of leaf development at which toxic	Symptoms	Extent of effect
Rato siris (*Albizia julibrissin*)	*Paulo* (leaf flushing stage)	Laboured breathing (dyspnoea), frothing at the mouth, bloat and convulsions.	Fatal (immediate death of animal)
Gayo (*Bridelia retusa*)	*Paulo* (leaf flushing stage)	Laboured breathing (dyspnoea), frothing at the mouth, bloat and convulsions.	Fatal (immediate death of animal)
Angerii (*Lyonia ovalifolia*)	*Paulo* (leaf flushing stage)	Laboured breathing (dyspnoea), frothing at the mouth, bloat and convulsions.	Fatal (immediate death of animal)
Painyu (*Prunus cerasoides*)	Throughout the season	Red urine, gradual loss of body weight.	Gradual, eventually leading to the death of animal
Dudhilo (*Ficus nemoralis*)	*Paulo* (leaf flushing stage)	Leaves stick in animal's throat and cause laboured breathing	Not serious but may be fatal at times if no immediate treatment
Kabro (*Ficus lacor*)	*Paulo* (leaf flushing stage)	Leaves stick in animal's throat and cause laboured breathing	Not serious but may be fatal at times if no immediate treatment

indicated that these three species do contain high levels of cyanogenic substrates which may be reduced to acceptable levels by boiling leaves before feeding to animals (Subba, *pers. comm.*)[1]

Certain fodder leaves, notably the leaves of *Ficus nemoralis* and *Ficus lacor* were said to stick in animals throats, a condition locally known as *gala lagne.* No serious consequences were generally expected but the condition could be fatal at times if immediate action was not taken. Generally, farmer practice in such cases was to remove the leaves manually from the animal's throat. These species were known by farmers to produce a sticky milky latex which is what was said to cause the leaves to become stuck. The latex content of leaves was said to decrease with increased leaf maturity and, therefore,

[1] Mr D B Subba is laboratory analyst at Pakhribas Agricultural Centre.

deleterious effects occurred only if *paulo* leaves were fed to animals. Post harvest treatments, for example, wilting of *paulo* leaves for about 12 hours before feeding to animals was thought to eliminate the effect and this was widely practised by farmers. Feeding *Prunus cerasoides* fodder to cattle was said to cause red urine disease known locally as *lahue mute,* which would lead to loss of body weight and ultimately death.

Certain fodders, for example, all species of bamboos and *Arundinaria spp* were considered to have positive effects on animals, particularly young calves. Feeding these fodders to young calves was said to decrease gastro-intestinal worms.

5.3.2.6 *Chiso-obano* classification

The terms *chiso* and *obano* have already been introduced (3.8.4.2). Farmers often classified fodders as *chiso, obano* or intermediate between *chiso* and *obano.* The definition of *chiso* and *obano* fodder given by Solma farmers is similar to that acquired by Rusten (1989) in Salija in the western mid-hills of Nepal. Some of the fodder tree species recognised unanimously by informants as *chiso* or *obano* and their characteristics are given in Table 5.12.

Of the 90 fodder species recorded in the inventory, the majority (34 species) were said to be neither *chiso* nor obano and considered to be intermediate (Figure 5.6.c). Only a few species were mentioned as purely *obano,*while none of the species were mentioned as purely *chiso,* but the extent to which a fodder was *chiso* or *obano* moved along a scale becoming gradually *obano* as leaves matured. For example, the *chiso* fodder tree species listed in Table 5.12 were considered as *chiso* from mid December to mid February and, therefore, were said to be *kam posilo,* less palatable to animals, to cause diarrhoea and to reduce milk and *ghee* production if fed during this time of the year, but from mid February onwards they were said to become gradually *obano* as the leaves matured so that many of them (*Bauhinia purpurea, Ficus nemoralis* and *Ficus roxburghii*) were considered *posilo* for rest of the year.

Table 5.12 Fodder tree species recognised unanimously by informants as *chiso* or *obano* and their characteristics.

	Obano fodder	*Chiso* fodder
Fodder tree species	Badahar (*Artocarpus lakoocha*) Bakaino (*Melia azedarach*) Bans (*Bambusa* and *Dendrocalamus spp*) Bhimsenpati (*Buddleja asiatica*) Dhusure (*Colebrookia oppositifolia*) Ghurmise (*Leucosceptrum canum*) Khanyu (*Ficus spp*) Khayer (*Acacia catechu*) Nigalo (*Arundinaria spp*) Parayang (*Arundinaria spp*) Siris (*Albizia spp*)	Chuletro (*Brassiopsis spp*) Dudhilo (*Ficus nemoralis*) Gogun (*Saurauia nepaulensis*) Nebharo (*Ficus roxburghii*) Tanki (*Bauhinia purpurea*) Kabro (*Ficus lacor*)
Characteristics	. tend to be eaten well by animal during cold months; . lead to the production of dry and firm dung; . cause constipation if fed in excessive amounts; . satisfy animals' appetite; and . generally improve animal health and contribute to milk and ghee production	. not eaten well by animal during cold months; . cause diarrhoea (watery dung) if fed as a sole fodder during cold months; . do not satisfy animals' appetite; and . cause decrease in milk and ghee production if fed as a sole fodder during cold months.

The adverse effects of *chiso* fodder were restricted to colder months of the year and only occurred when fed as a sole fodder. The common practice reported was to feed a mixture of *chiso* and *obano* fodder to obtain a desirable mixture.

Panday (1982) noted farmers reporting *Ficus roxburghii* fodder causing a decrease in milk yield in the Dolakha area. Similarly, Shrestha and Pakhrin (1989) reported a decrease in milk yield of 0.2 kg per day when *Ficus roxburghii* fodder was fed *ad lib* to lactating buffaloes. However, these authors make no mention of whether a decrease in milk yield was caused by *chiso* attributes associated with *Ficus roxburghii* fodder.

5.3.2.7 Intra-species variation

A number of fodder tree species which are identified as single taxonomic units by botanists and foresters were said by farmers to occur as different varieties with differences in fodder quality and to require different silvicultural management. The information in the tree fodder knowledge base showed that at least seven species of tree fodder were recognised by farmers as occurring in two or more distinct varieties. Differences were not only in physical appearance but also related to tree productivity and fodder value. The qualitative analytical tool used by farmers in distinguishing these varietal differences was based on their knowledge of various attributes (for example, leaf shape, leaf size, leaf texture, time of leaf shedding and the implications of these attributes for fodder palatability, productivity and management options), nutritive value (*posilo* or *kam posilo* status) and *chiso-obano* status. The varietal differences and characteristics of three fodder tree species recognised unanimously by informants to display intra-species variation are summarised in Table 5.13.a and those recognised less consistently are listed in Table 5.13.b.

The reasons for some farmers recognising and others not recognising these varietal differences may reflect the fact that some farmers did not have these fodder tree species on their farms and hence might not have had any practical experience or knowledge of these species. While these varietal differences are noted, fodder improvement work based on such information has not received attention because forestry researchers active in Nepal have not been aware of intra-species variability. However, recently some authors have reported the existence of varietal difference in certain fodder tree species in other parts of Nepal (Upton and Robinson, 1988; Dutt, 1993). One varietal distinction used by farmers (*khanyu* sub species *khasre khanyu* and *rai khanyu*) has been accepted by the scientific community in recent years in that *Khasre khanyu* has been classified as *Ficus semicordata* var. *semicordata* and *Rai khanyu, Ficus semicordata* var. *montana* (Amatya, 1989).

Table 5.13.a Varietal differences and characteristics of three fodder tree species recognised unanimously by informants.

Fodder tree species	Farmers' variety	Varietal characteristics
Dudhilo (*Ficus nemoralis*)	Sano pate dudhilo	. leaf size small, leaf shape elongated with pointed tips; . sheds leaves early in the dry season (winter shedder); . rapid growth of regrowth shoots after lopping; . lopping frequency greater than one time per year (can be lopped at least two to three times per year and so produce a large quantity of fodder); . only *posilo* to and eaten preferentially by goats and sheep; . more *chiso* than thulo pate dudhilo; and . produces more sticky milky latex than thulo pate dudhilo and hence causes leaves to stick in animal throats more than thulo pate dudhilo.
	Thulo pate dudhilo	. leaf size big, leaf shape round with flat tips; . sheds leaves late in the dry season (spring shedder); . slow growth of regrowth shoots after lopping; . lopping frequency one time per year (can be lopped only one time per year for fodder, therefore, produces a smaller quantity of fodder than sano pate dudhilo); . *posilo* and eaten preferentially by all classes of animals; . more *obano* or less *chiso* than sano pate dudhilo; and . produces less sticky milky latex than sano pate dudhilo and hence less of a problem in respect of leaves sticking in animal's throats.
Tanki (*Bauhinia purpurea*)	Buthure tanki	. leaf size big; leaf shape round (large leafed); . leaf texture stiff; . leaves bitter in taste; . leaf inclination angle - horizontal . more *kam posilo* than lahare tanki; and . more *chiso* than lahare tanki.
	Lahare tanki	. leaf size small; leaf shape elongated; . leaf texture soft; . leaves not bitter in taste; . leaf inclination angle - drooping (sticking down) . *posilo* and eaten preferentially by all classes of animals; and . more *obano* or less *chiso* than buthure tanki.
Nebharo (*Ficus roxburghii*)	Sano pate nebharo	. leaf size small, leaf shape round with flat tips; . leaf texture soft; . *posilo* and eaten preferentially by all classes of animals; . more *obano* or less *chiso* than thulo pate nebharo; and . sheds leaves late in the dry season (spring shedders)
	Thulo pate nebharo	. leaf size big, leaf shape round with pointed tips; . leaf texture coarse; . more *kam posilo* than sano pate nebharo; . more *chiso* than sano pate nebharo; and . sheds leaves early in the dry season (winter shedders).

Table 5.13.b Fodder tree species recognised by some informants to occur in two or more varieties.

Fodder tree species	Variety	% of informants recognising varietal differences
Kabro (*Ficus lacor*)	Kalo kabro, seto kabro, rato kabro and lahare kabro with latter being exclusively preferred over others as quality fodder.	52
Khanyu (*Ficus semicordata*)	Rai khanyu and khasre khanyu with former being considered as quality fodder.	42
Koiralo (*Bauhinia variegata*)	Seto koiralo and kalo koiralo (except phenological character, no differences recognised in terms of fodder quality).	17
Gogun (*Saurauia nepaulensis*)	Seto gogun and rato gogun with former being considered as quality fodder.	27

5.3.2.8 Fodder productivity and availability

The previous sections have considered a range of tree attributes influencing the quality of fodder and the knowledge held by farmers about the way these attributes impact on fodder quality. While this knowledge system appears to be crucial in making decisions about when, what and how much fodder to cut, the information in the tree fodder knowledge base showed that other factors were also important in determining the value of fodder to the farmers. The most important were:

- seasonal availability (availability of fodder from different tree species at different times of the year); and

- the ability of fodder trees to withstand multiple lopping, which, in turn, influenced when fodder from trees was available.

Certain fodder tree species were known to shed leaves early in the winter while others were known to retain leaves late into the spring. Some fodder tree species could be lopped more than one time per year while others only once. Farmers often preferred those fodder species which could withstand multiple lopping within a year and those that retained leaves late into the dry season so that more fodder could be supplied at critical times of the year. Fodder tree species recognised unanimously by informants for retaining leaves late into the dry season and to be able to withstand multiple lopping are given in Table 5.14. It can be noted that four of the seven species in Table 5.14 are *kam posilo* in terms of their fodder quality but they are nevertheless cultivated on farmland.

Table 5.14 Fodder tree species recognised unanimously by informants for retaining leaves late into the dry season and for withstanding multiple lopping. Symbol (*) indicates unanimous agreement by informants.

Fodder tree species	Ability to withstand multiple lopping annually	Ability to retain leaves late into the dry season	Nutritive value		
			Posilo	Intermediate	*Kam posilo*
Sano pate dudhilo (*Ficus nemoralis*)	Yes	No			*
Khasre khanyu (*Ficus semicordata* var. *semicordata*)	Yes	Yes		*	
Shyalfusro (*Grewia oppositifolia*)	Yes	Yes		*	
Painyu (*Prunus cerasoides*)	Yes	Yes			*
Latikath (*Coronus oblonga*)	Yes	Yes			*
Kutmero (*Litsea monopetala*)	No	Yes	*		
Gogun (*Saurauia nepaulensis*)	No	Yes			*

The need to supply fodder throughout the dry season and the fact that different tree species shed their leaves at different times of the year and, therefore, supplied fodder at different times of the year meant that trees producing fodder of high nutritive vale were not always preferred because the type of trees cultivated was dictated as much by the necessity to supply fodder at different times of the year as by the desire to maximise nutritive value at any particular time in the season. The inventory data are consistent with this as of the total of 6 350 fodder trees recorded, 56.6% produce *kam posilo* fodder, 7.1% fodder of intermediate status and only 36.3 % *posilo* fodder (Appendix 2.C). The situation was further complicated by the fact that fodder was not the only tree product required by farmers. With a declining supply of tree products from public forestland (common property resources) and farmers having to rely increasingly on their own farmland to meet their tree product needs they may prefer to grow fodder tree species that supply multiple products (for example, fodder, fuelwood and timber), so that the fodder quality of a tree species may be balanced against its other attributes. This may be particularly true for farmers with small land holdings whose pressing concern may be to meet these basic tree product needs, whereas larger farmers who are less constrained by lack of land, may have more opportunity to make full use of knowledge about fodder quality and so improve the plane of nutrition of their animals.

In summary it appears that farmers are very knowledgeable about fodder quality, however, the quality of fodder fed to their animals may be moderated by constraints imposed by the product mix required from trees on small land holdings and the need to supply fodder throughout the dry season.

5.3.3 Farmers' knowledge about tree fodder management techniques

In this section, the knowledge articulated by farmers about tree fodder management, particularly timing, frequency and techniques of fodder lopping are discussed.

5.3.3.1 Timing of fodder lopping

The information in the tree fodder knowledge base showed that at least three tree attributes were recognised by farmers as influencing the time that fodder lopping could be done. These were: fodder palatability; fodder toxicity; and time of leaf fall or shedding. Detailed knowledge articulated by farmers relating to fodder palatability (5.3.2.4) and toxicity (5.3.2.5) have already been discussed and were used as a basis for developing strategies for controlling the timing of fodder lopping.

The period at which tree fodder was at a premium was from November to June, a period of eight months when grass production was low because of limited available soil water. No single tree species produced fodder for the whole period with some species producing in winter and others in spring. In order to bridge this fodder gap, the common practice reported by farmers was to use early leaf shedding fodder tree species in the beginning of the dry season, retaining the late leaf shedders as long as possible, but not so long that they became unpalatable to animals. This was said to be achieved by carefully arranging the time of lopping differentiating the early leaf shedders and the late leaf retainers. The second strategy reported was to adopt a bi-annual lopping practice. This was used to bring forward the time of flushing of tree species with leaves that were palatable and non-toxic when young by lopping them early in the winter so that they put on regrowth and were available for a second spring lopping. Fodder tree species valued particularly for this purpose included: *Prunus cerasoides; Grewia oppositifolia; Ficus semicordata* var. *semicordata;* and *Ficus nemoralis* sub species *sano pate dudhilo.*

The time of leaf fall of particular tree species was said to be influenced by the type of planting site. Trees on moist sites such as those growing along gullies were known to retain leaves longer into the dry season while trees on dry sites (for example *pakho* land and *kharbari*) were known to shed leaves early in the dry season. *Posilo* trees were often said to be planted in moist sites so that they retained leaves longer and were available to supply quality fodder during the dry season.

5.3.3.2 Frequency of fodder lopping

Farmers' knowledge about the frequency of fodder lopping was based on their understanding of: the rate at which shoots regrew after lopping; the ability of trees of different species to withstand frequent lopping; and the implications of increased or decreased frequency of lopping on fodder quality, fodder production and tree health. Fodder tree species that regrew rapidly after lopping and could withstand frequent lopping were particularly valued because they could be lopped more than one time per year and so produced a large quantity of fodder well spread through the season. Manipulation of lopping was also used as a tool for manipulating the amount of shade and *tapkan* effects on crops by reducing the size of the tree crown and the height at which shoots grew which facilitated lopping of fodder by women and children.

Certain fodder tree species, despite being known for rapid regrowth of shoots after lopping, were considered to be vulnerable to pest attack if frequently lopped and, therefore, were only lopped once a year. Examples included *Ficus roxburghii* and *Artocarpus lakoocha.* These species were also highly prized species for the quality fodder they produced. An increased frequency of lopping with these species was said to result in rapid drying up of branches which eventually could lead to the death of the tree. The young leaves of these species were said to have high nutritive value and to be subject to heavy insect attack, causing heavy foliage damage and reduction in fodder production.

Some fodder tree species were valued for edible shoots and quality fruits for human consumption. For example, shoots of *Bauhinia purpurea* and *Ficus lacor* were valued as a nutritious vegetable and were, therefore, frequently lopped to encourage young shoots. *Artocarpus lakoocha* and *Pyrus pashia* were valued for the nutritious fruits they produced and were, therefore, lopped only once per year because an increase in the frequency of lopping caused a decrease in fruit production.

The lopping frequency of a particular tree species was also partly determined by the need to obtain other tree products, notably fuelwood. As discussed previously any trees that could potentially supply fodder were lopped. Generally, the branches representing previous years growth were cut. Leaves and twigs were fed to the animals and the branches used as fuelwood or fencing materials. Farmers, through their experience, have identified fodder tree species which supply both high and low quality fuelwood. They were aware that a decrease in the frequency of lopping led to an increase in branch size, crown size and crown density that caused heavy shade and *tapkan* effects on crops. However, since increased lopping frequency also caused a decrease in branch size and hence decrease in fuelwood production, they often reconciled the negative effects of decreased lopping frequency with increased fuelwood production because fuelwood was often the only source of energy. This balance was achieved by applying different lopping frequencies to trees and by planting them on different farm sites. For example, *Ficus nemoralis* sub species *sano pate dudhilo* was considered to be a good quality fuelwood but was also a species that could be lopped more than once per year for fodder. Such species were often said to be planted in more than one site so that trees away from crop land could be managed for fuelwood by lopping only once per year while those on crop land were lopped more frequently in order to reduce shade and *tapkan* effects on crops and to supply fodder spread through the season.

5.3.3.3 Tree fodder lopping techniques

The single most important objective of farmers in managing tree fodder was to maximise fodder production. The information in the tree fodder knowledge base shows that in order to achieve this, farmers concentrated on those aspects of tree fodder management which influenced the number and growth rate of regrowth shoots after lopping because these two factors were considered to ultimately determine the amount of fodder produced by a particular tree. Although a number of factors were said to influence the number and growth rate of regrowth shoots after lopping (for example, the severity of last lopping, type of site), lopping techniques and the type and conditions of tools used were considered by far the most important determinants of productivity.

The common practice reported was to leave a few branches with leaves intact as this encouraged trees to produce a large number of regrowth shoots and to increase the growth rate of new shoots. Total defoliation was said to weaken tree health. The severity at which a given tree was lopped was said to be influenced by the type of site on which a given tree was being grown. Trees on moist and fertile sites were known to produce a larger number of regrowth shoots with rapid growth rates and, therefore, were lopped more severely, while the opposite was the case for trees grown on dry or less fertile sites.

According to Solma farmers, fodder tree branches were cut using either an upward or downward slash and the choice of cutting direction was considered to be critical in determining the subsequent number and growth rate of regrowth shoots. The best results were said to be achieved if the branches were lopped with an upward cutting direction because downward cutting resulted in a splitting of bark which in turn caused rapid drying up of branches resulting in fewer regrowth shoots with low vigour.

During lopping a certain length at the basal portion of the branches was left intact from which new regrowth shoots would emerge. The length of intact branch remaining was said to be critical in determining the number and growth rate of regrowth shoots after lopping. Fewer regrowth shoots occurred if the length was too short while long branch stumps were said to dry up quickly, also resulting in fewer regrowth shoots after lopping than if the optimum stump length of one *bitta* (about 20 cm) remained.

The type and condition of the cutting knife used during fodder lopping was also said to influence the number and growth rate of regrowth shoots after lopping. Two types of tools were used: *khukuri;* and sickle, the former being bigger and heavier than the latter. Fully mature branches were lopped using the *khukuri* while young flush was lopped using the sickle because lopping young flush with *khukuri* was said to cause heavy branch damage resulting in fewer regrowth shoots after lopping. The best results were said to be achieved if the tools used were sharp because blunt tools resulted in more lopping strokes that mutilated and split branch wood. Such wounded branches were said to dry up quickly and to suffer severely from disease and insect attack, ultimately resulting in fewer regrowth shoots with low vigour.

5.4 CONCLUSIONS

This chapter has considered farmers' ecological knowledge about the management and use of tree fodder resources on farmland. It is clear that farmers in the study area possess detailed ecological knowledge which enabled them to classify and evaluate different tree fodders and make predictions about their management and use. The study has shown that farmers have knowledge which can be used to deliberately manage tree fodder on farmland based on ecological principles tree-crop interactions and the perceived feeding value of the species concerned.

The study has revealed that farmers held detailed ecological knowledge of above-ground interactions between trees and crops, with some interesting contrast in emphasis to the scientific literature, notably the importance of leaf size in determining shade and *tapkan* effects. Similarly, farmers articulated detailed knowledge about fodder quality including information on intra-species variation not previously recognised by the scientific community. Farmers articulated markedly less knowledge of below-ground interactions and soil processes, however, with little mechanistic detail in this respect.

In general, the study has shown that farmers' ecological knowledge was largely based on their understanding of tree attributes and the way that these attributes influenced various interactive processes that were easily observed by them. What farmers know about the management and use of farmland tree fodder resources present opportunities to inform researchers while what they do not know identifies where further research may be targeted to fill gaps in farmers knowledge that may be constraining the productivity of the system.

CHAPTER 6

EVALUATION OF THE KNOWLEDGE BASE

6.1 INTRODUCTION

Knowledge acquired from key informants about the management and use of farmland tree fodder resources and the underlying ecological knowledge upon which this was based were presented in Chapter 5. In this chapter, the knowledge is evaluated in respect of its representativeness, the extent to which it was used by farmers and the extent to which it complements and contradicts the professional knowledge held by research workers. Therefore, the objectives of the evaluation were:

- to evaluate the extent to which the knowledge acquired from a purposive sample of key informants was representative of the knowledge held by the population of farmers in the study area;
- to evaluate the extent to which the knowledge articulated by farmers informed their practice; and
- to evaluate the extent to which the farmers' knowledge was complementary and/or contradictory to the professional knowledge held by research workers operating in the study area.

6.2 EVALUATION OF THE REPRESENTATIVENESS OF THE KNOWLEDGE BASE

6.2.1 Rationale

The degree to which a knowledge base is representative of the source community from which the knowledge was elicited largely determines how it may be used in research and development. For example, if knowledge from the purposive sample is characteristic of farmers in the study area it becomes appropriate to inform research and extension workers, where it is not, there may be opportunities for redistributing or disseminating knowledge within the community. Representativeness in the present study was defined as the degree to which farmers in the study area provided similar ecological explanations to those already held in the knowledge base. The farming population was randomly sampled in the evaluation whereas the knowledge base itself was created by acquiring knowledge from a small purposive sample of key informants.

6.2.2 Methodology

The representativeness of the knowledge base was evaluated by comparing the content of the knowledge base with the knowledge held by members of the community not originally interviewed. Given that the tree fodder knowledge base contained a large amount of knowledge it was not practical to evaluate the representativeness of the content of the knowledge base as a whole. Therefore, specific subsets of knowledge were selected from the knowledge base for detailed investigation in the expectation that they would characterise the representativeness of the knowledge base as a whole. Farmers' knowledge about *tapkan* was explicit and contained both species-specific information about tree attributes influencing *tapkan* and detailed ecological explanations of the causal mechanisms involved. For these reasons this topic was considered to reflect the type of knowledge contained in the knowledge base as a whole and was selected with which to investigate representativeness.

Representativeness was tested in the mid altitude zone of the study area (locally called *kachhad*) roughly equivalent to land between 1 000 m and 1 600 m in altitude. Information on household numbers, location and the names, sex and age of household members, compiled during the specification stage of fieldwork (Chapter 3), was used to draw a random sample of 50 farmers excluding those used as key informants. This sampling strategy resulted in 23 female and 27 male informants being sampled.

It will be recalled from Chapter 5 that farmers' knowledge about *tapkan* was largely based on their understanding of tree attributes: leaf size; crown density; crown size; tree height; and leaf inclination angle and their variability between tree species. Therefore, the primary objective of the study was to elicit knowledge about the extent to which these attributes were known by the sample population and used by them in assessing *tapkan* effects on crops. A total of six fodder tree species falling into two categories were selected as a basis for developing questions, including, three species known to cause heavy *tapkan* (*Ficus roxburghii, Artocarpus lakoocha* and *Saurauia nepaulensis*) and three species known to cause light *tapkan* (*Albizia julibrissin, Embilica officinalis* and *Alnus nepalensis*).

The objective was to test the extent to which the random sample of farmers articulated similar knowledge to that held in the knowledge base rather than to assess their reaction to previously articulated knowledge. This was an exacting requirement that involved constructing non-leading questions based on the knowledge acquired about *tapkan* (Table 6.1).

Table 6.1 Questions constructed to elicit knowledge about the extent to which tree attributes contained in the knowledge base were known or considered by the sample population in assessing *tapkan* effects.

Which of the following fodder tree species cause light or heavy *tapkan* effects on crops?

Fodder tree species	Heavy *tapkan*	Light *tapkan*	Don't know
Nebharo (*Ficus roxburghii*)			
Badahar (*Artocarpus lakoocha*)			
Gogun (*Saurauia nepaulensis*)			
Utis (*Alnus nepalensis*)			
Amalla (*Embilica officinalis*)			
Rato siris (*Albizia julibrissin*)			

What is it about these fodder tree species that causes *tapkan* effects on crops to be light or heavy ?

Fodder tree species	Reasons for causing heavy *tapkan* effect	Reasons for causing light *tapkan* effect	Reasons for not knowing
Nebharo (*Ficus roxburghii*)			
Badahar (*Artocarpus lakoocha*)			
Gogun (*Saurauia nepaulensis*)			
Utis (*Alnus nepalensis*)			
Amalla (*Embilica officinalis*)			
Rato siris (*Albizia julibrissin*)			

Firstly, farmers were asked whether each of the six fodder tree species caused heavy or light *tapkan*. This question was designed to set the interview in context and to provide comparative information from that particular informant on the different tree species. This information was then used to test whether the concept of *tapkan* was consistently held by farmers. Secondly, farmers were asked to provide explanations for why particular fodder tree species caused heavy or light *tapkan*. This question was designed to encourage farmers to articulate the tree attributes that they thought influenced *tapkan*. The frequency with which farmers articulated each attribute was then used to assess:

- the extent to which attributes contained in the knowledge base were considered by farmers in assessing *tapkan* effects on crops; and
- since farmers were free to articulate explanations, any new knowledge that was articulated was also recorded and used to evaluate the extent to which the knowledge base provided a comprehensive coverage of the knowledge held by farmers.

6.2.3 Results and discussion

Table 6.2 shows the frequency with which the six species of fodder trees were said to cause heavy or light *tapkan*. Except for *Alnus nepalensis*, farmers were consistent in categorising which tree species on their farmland caused heavy and light *tapkan*. More than 80% of farmers in the sample said that *Ficus roxburghii*, *Artocarpus lakoocha* and *Saurauia nepaulensis* caused heavy *tapkan* and that *Albizia julibrissin* and *Embilica officinalis* caused light *tapkan*. This represents a broad consensus about five species and indicates that *tapkan* is a commonly and consistently held concept by farmers in the study area.

Table 6.2 Farmer categorisation of six species of fodder tree species in respect of their *tapkan* effects. Results are expressed as the percentage of farmers sampled responding to each of the three possible categories. Figures in parentheses are standard errors.

Fodder tree species	Heavy *tapkan* (%)	Light *tapkan* (%)	Don't know (%)
Ficus roxburghii	92 (± 3.8)	4 (± 2.8)	4 (± 2.8)
Artocarpus lakoocha	82 (± 5.4)	4 (± 2.8)	14 (± 4.9)
Saurauia nepaulensis	80 (± 5.6)	4 (± 2.8)	16 (± 5.2)
Alnus nepalensis	34 (± 6.7)	66 (± 6.7)	0
Embilica officinalis	4 (± 2.8)	84 (± 5.1)	12 (± 4.6)
Albizia julibrissin	4 (± 2.8)	92 (± 3.8)	4 (± 2.8)

Excluding *Alnus nepalensis,* most of the variability in farmers responses was in the number of farmers not able to categorise the trees into either of the major categories (heavy and light *tapkan*). This can be explained to some extent by the fact that not all the farmers sampled actually cultivated all of the six tree species on their farmland, and the most common response when farmers did not have direct experience of a species was 'don't know'. Thus, in general farmers only categorised tree species which they had experience of cultivating on their farms and of which they had management knowledge. The four percent contradicting the consensus view for these five species were in fact, the same two farmers. Explanations given by them for their categorisation revealed that they had interpreted the question differently than the others. Their basic reasoning was as follows.

> *Ficus roxburghii, Artocarpus lakoocha* and *Saurauia nepaulensis* have larger leaves and more dense crowns than *Albizia julibrissin* and *Embilica officinalis,* therefore, their crowns intercept more rain and cause lighter *tapkan* than *Albizia julibrissin* and *Embilica officinalis* under low intensity rainfall conditions.

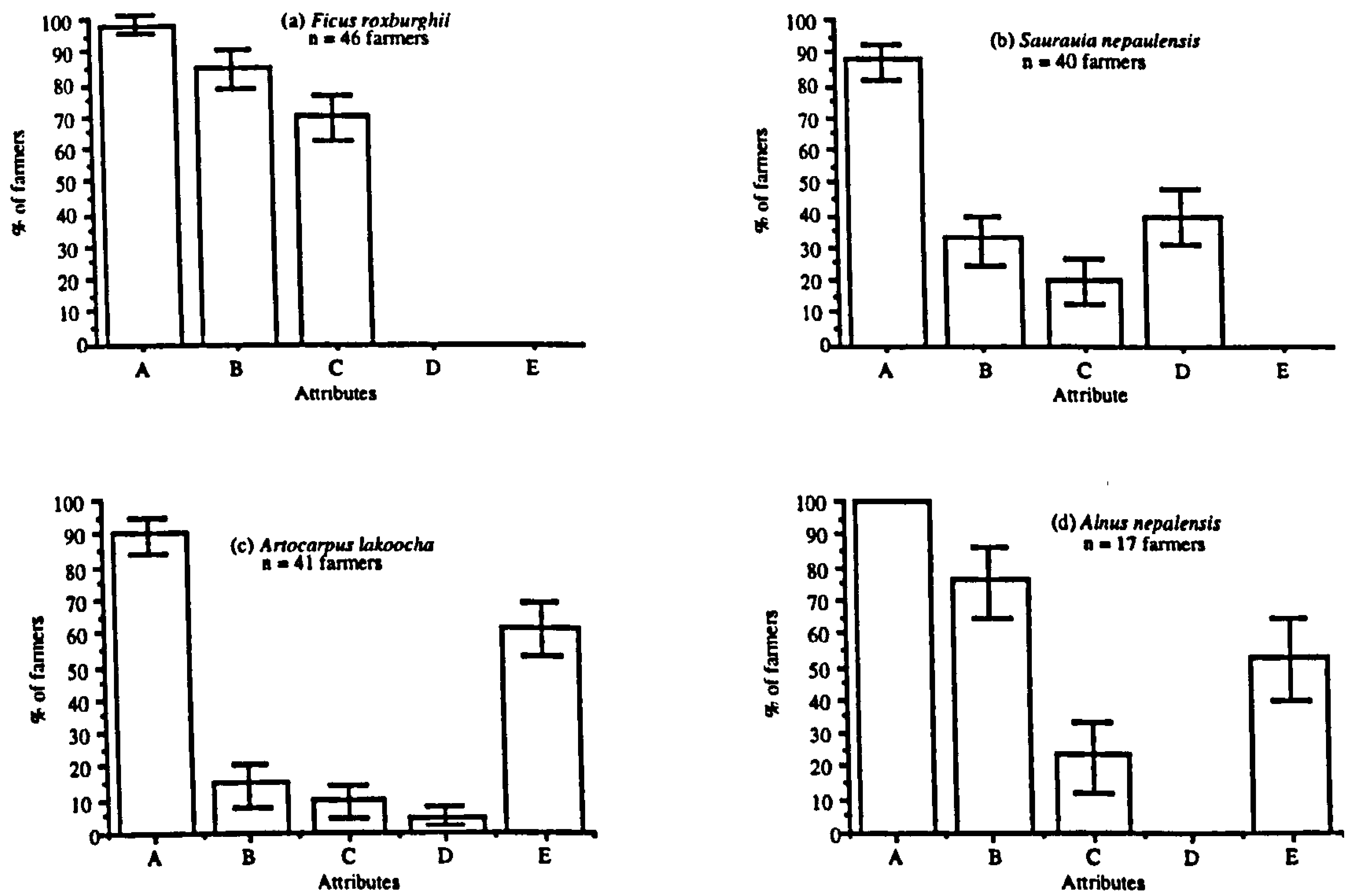
These farmers have clearly made a conditional assumption of low rainfall intensity whereas it is likely that most farmers made an implicit assumptions that the question referred to conditions of high rainfall intensity. Thus, using the same basic reasoning but with different conditional assumptions, different answers resulted. This illustrate the need to take care in designing questions based on information in the knowledge base. Most of the statements in the knowledge base were conditional and it would, therefore, be prudent to specify relevant conditional information when designing future questionnaires. The first question in Table 6.1 might, therefore, be rephrased as shown in Table 6.3.:

Table 6.3 The first question in Table 6.1 with conditional information attached.

Which of the following fodder tree species cause light or heavy *tapkan* effects on crops IF the rainfall intensity is high AND the trees are planted on crop terrace risers ?			
Fodder tree species	Heavy *tapkan*	Light *tapkan*	Don't know
Nebharo (*Ficus roxburghii*)			
Badahar (*Artocarpus lakoocha*)			
Gogun (*Saurauia nepaulensis*)			
Utis (*Alnus nepalensis*)			
Amalla (*Embilica officinalis*)			
Rato siris (*Albizia julibrissin*)			

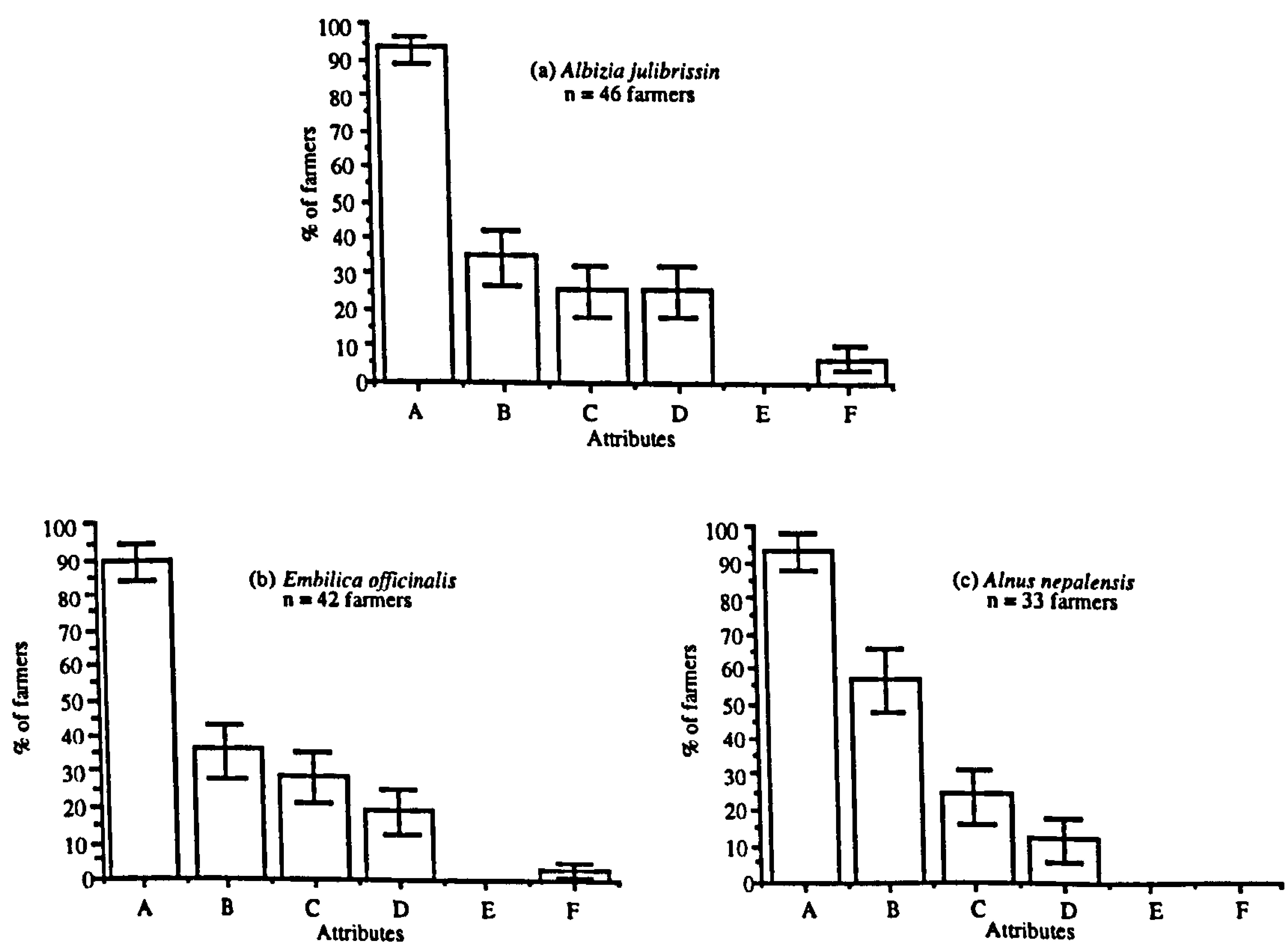
In the case of *Alnus nepalensis,* about a third of the farmers reported that the species caused heavy *tapkan* while two thirds made a conflicting categorisation that the species caused light *tapkan* (Table 6.2). The reasons given by farmers for these responses was often contradictory. For example, all farmers categorising *Alnus nepalensis* as causing heavy *tapkan* cited large leaves as a reason, while the vast majority (94%) of the farmers categorising it as causing light *tapkan* cited small leaves as a reason. Similar contradictory information was recorded in respect of other tree attributes such as crown density and crown size (Figure 6.1d and 6.2.c).

Alnus nepalensis is one of the most abundant trees in the study area and accounted for more than 27% of all trees recorded in the inventory (Appendix 2.C). No farmers responded to questions about the species with 'don't know' (Table 6.2) suggesting that all of the farmers interviewed were familiar with the species and had views about it.



A = Large leaves; B = Heavy crown density; C = Large crown size; D = Coarse leaf texture; and E = Tall tree height

Figure 6.1 Tree attributes cited by farmers for four species causing heavy *tapkan* (frequency of responses (%) ± standard error).



A = Small leaves; B = Light crown density; C = Small crown size; D = Smooth leaf texture; E = Short tree height; and F = Drooping leaf inclination angle

Figure 6.2 Tree attributes cited by farmers for three species causing light *tapkan* (frequency of responses (%) with ± standard error).

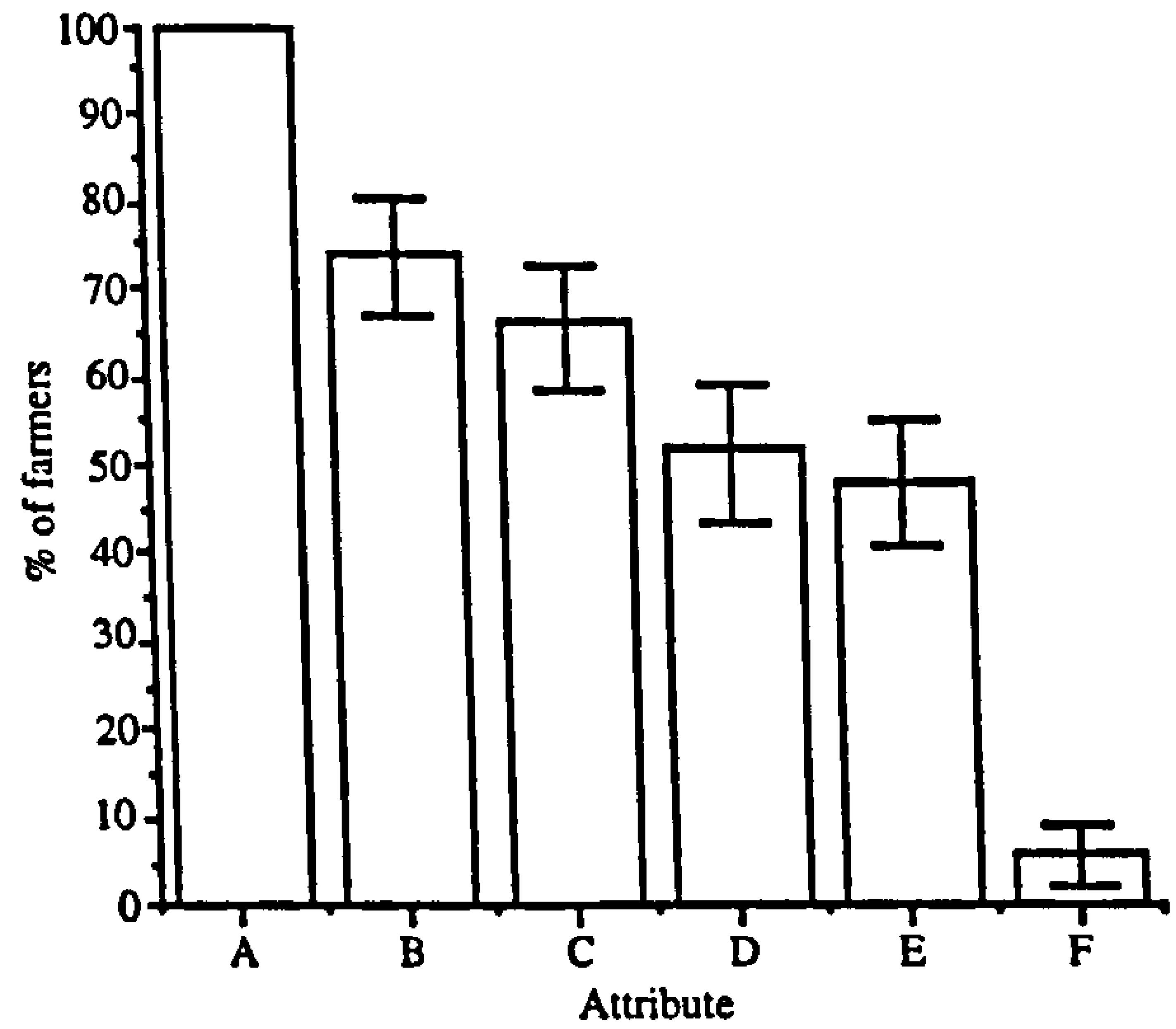
Therefore, it is reasonable to assume that the contradictions in farmers statements about the species were not caused by problems in familiarity with the species. Possible explanations for the contradictions are summarised below.

- *A. nepalensis* is rarely cultivated on crop terrace risers. In the inventory only 16% of *A. nepalensis* trees recorded were cultivated on crop terrace risers. Since farmers' knowledge about *tapkan* effects on crops was largely based on their understanding of the effects caused by trees cultivated on crop terrace risers, farmers may be less aware of the *tapkan* effects caused by trees planted on other farm sites. It is possible that only a proportion of the farmers sampled were cultivating *A. nepalensis* on crop terrace risers which may explain differences in their responses.

- *A. nepalensis* is not as intensively managed for fodder as other species because it is considered by farmers as low quality fodder (Chapter 5). Therefore, the management regimes applied to *A. nepalensis* often differ from other species. Tree attributes such as leaf size, crown size, crown density and tree height are known to be influenced by the management regimes applied. It is possible that different management regimes applied by individual farmers may have resulted in differences in the form of trees which in turn may have caused differences in farmers responses about attributes of *A. nepalensis* and their implications for *tapkan.*

- Farmers were given only two categories (heavy or light) with which to classify the species in respect of *tapkan*. It is possible that farmers considered *A. nepalensis* to be intermediate between these categories and faced with only two alternatives the farmers were not consistent in which category they placed the species.

Tree attributes considered by farmers (irrespective of species) as influencing *tapkan* and the percentage of farmers articulating each is presented in Figure 6.3. Altogether six attributes: leaf size; crown density; crown size; tree height; leaf inclination angle; and leaf texture were mentioned. Five of the six attributes were contained in the knowledge base, suggesting that it was reasonably representative of the knowledge held by farmers in the study area. However, while leaf inclination angle which was in the knowledge base, was mentioned by only a few of the farmers sampled, almost half of them mentioned leaf texture which had not been articulated by key informants during knowledge acquisition. In addition to recognising leaf texture as an attribute with values



A = Leaf size; B = Crown density; C = crown size; D = Tree height; E = Leaf texture; and F = Leaf inclination angle

Figure 6.3 Tree attributes considered by farmers as influencing *tapkan* (frequency of response (%) ± standard error; data from all species combined).

smooth or coarse, farmers articulated a consistent explanation for how leaf texture affected *tapkan* which is summarised below.

> Trees with coarse leaves cause a decrease in the rate of movement of rain water across leaf surfaces. A decrease in the flow rate of rain water across leaves causes large quantities of water to collect on leaves, which increases the size of *tapkan* drops so that when they fall they cause heavy *tapkan* effects. In contrast, trees with smooth leaves exhibit opposite effects.

Knowledge articulated by farmers about tree attributes influencing *tapkan,* except for leaf size, was species specific (Figure 6.1 and 6.2). Tree height was mentioned only in relation to *Artocarpus lakoocha* and *Alnus nepalensis* and leaf inclination angle only in relation to *Albizia julibrissin* and *Embilica officinalis.* The pattern of response was markedly different for each species. The fact that the knowledge elicitation strategy used during the knowledge acquisition fieldwork (Chapter 4) was not specifically based on tree species but on asking farmers more general questions about effects of trees on their farms, and the fact that farmers knowledge about tree attributes influencing *tapkan* was species specific, may partly explain why leaf texture was not acquired in the initial knowledge acquisition phase. Since farmers manage different tree species on farmland (Chapter 3) it may be that other knowledge not contained in the knowledge base was held by farmers about attributes influencing *tapkan* and might be acquired through further knowledge elicitation with questions based on a wider range of individual tree species. Such species-oriented questioning has been used successfully in less formal knowledge elicitation about trees in Africa (Barrow; 1988).

Of the six attributes mentioned as influencing *tapkan* (Figure 6.3), all farmers cited leaf size and only a negligible number of farmers mentioned leaf inclination angle. For the remaining four attributes statistical analyses were required to determine whether some attributes were quoted more frequently than others and whether farmers tended to mention particular combinations of attributes.

The MacNemar test is appropriate for small sample sizes with nominal data (Siegel and Castellan, 1988) and was used to test for significant differences in the number of farmers mentioning particular attributes. For each pair of attributes to be tested a fourfold table was constructed (Table 6.4). The number of farmers quoting crown density was significantly higher than those quoting tree height and leaf texture but there were no significant differences in the number of farmers quoting the other attributes (Table 6.5).

Table 6.4 Example of fourfold table used to create an appropriate data set for the MacNemar test and for calculating Phi coefficient.

		Crown size	
		–	+
Crown density	+	A	B
	–	C	D

Cell A contains the number of farmers who mentioned crown density but not crown size; cell B contains the number of farmers who mentioned both crown density and crown size; cell C contains the number of farmers who neither mentioned crown density nor crown size; and cell D contains the number of farmers who mentioned crown size but not crown density

To test whether each of the four attributes were quoted more often in conjunction with other attributes than without them (for example, whether crown density was quoted more often in conjunction with crown size than without it), a Phi coefficient was calculated, which is appropriate for measuring the extent of association between two sets of attributes measured on a nominal scale that may take only two values (Siegel and Castellan, 1988). There were no significant associations amongst the attributes (Table 6.5).

Table 6.5 Two-way table of tree attributes cited by farmers as influencing *tapkan.*

	Crown density	Crown size	Tree height	Leaf texture
Crown density	*37*	*23* (0.375) ns **(0.095)ns**	*19* (6.260) **(0.188)ns**	*18* (6.0) **(0.373)ns**
Crown size		*33*	*20* (1.893) ns **(0.198)ns**	*14* (2.206) ns **(0.126)ns**
Tree height			*26*	*8* (0.029) ns **(3.622)ns**
Leaf texture				*24*

Figures in italics are numbers of farmers citing tree attributes influencing tapkan (for example, of the 50 farmers, crown density was articulated by 37, while crown size was articulated by 33 farmers. Of these, the number of farmers who articulated both crown density and crown size was 23).

Figures in parentheses in normal type face are the observed Chi-square values calculated according to the MacNemar test from the 2 x 2 contingency tables. Significance was tested at $p = 0.05$ with one degree of freedom (Table C; pp 323; Siegel and Castellan, 1988).

Figures in parentheses in bold type face are the observed Chi-square values calculated using the Phi coefficient from the 2 x 2 contingency tables. Significance was tested at $p = 0.05$ with one degree of freedom (Table C; pp 323; Siegel and Castellan, 1988).

ns = Not significant

The results of this study showed that not all the knowledge about tree attributes influencing *tapkan* contained in the knowledge base were held widely by the members of the community. Indeed, some knowledge was widely held, other knowledge was not. Access to the knowledge base by less knowledgeable farmers could, therefore, have considerable utility and, if the knowledge was of practical use, could result in improved management of tree fodder resources. For example, a significant number of farmers were apparently unaware of the importance of crown density, tree height and leaf texture in influencing *tapkan* and this knowledge could be disseminated to them via forestry extension services.

On the basis of this study it appears that, for the subset of the knowledge base tested, the knowledge elicited from interviews with key informants and represented in the knowledge base was broadly representative of the knowledge held by farmers in the study area and reasonably comprehensive. Basic conceptual understanding of interactive processes (such as *tapkan*) were consistent amongst farmers which is not perhaps surprising since human survival is dependent upon successful manipulation of these interactions by farmers where trees are grown on farms and tree growing on farms is a ubiquitous practice.. However, detailed knowledge about species-specific tree attributes which influenced the application of general concepts in practical management varied amongst farmers, apparently associated with which particular species they had experience of cultivating. There is some evidence that useful knowledge relating to tree attributes not represented in the species presently studied may be held by farmers. Thus, formal evaluation of the representativeness of entire knowledge bases would seem a justified process when working with a heterogeneous population such as the farming households in the present study area, both in terms of identifying opportunities for re-distribution of knowledge and in ensuring a comprehensive coverage of farmers knowledge.

6.3 EVALUATION OF THE USE OF KNOWLEDGE BY FARMERS

6.3.1 Rationale

The present research assumed that the knowledge articulated by farmers about particular domains was also used by them in their decision making processes; that is, that local knowledge informed practice. However, research has shown that there are often discrepancies between what people do and what they say they do (Harris, 1974). The extent to which local knowledge does influence farmers practice is, therefore, important in determining its use in research and development programmes.

6.3.2 Methodology

In common with the evaluation of representativeness in the previous section, the extent to which knowledge informed practice was evaluated by selecting specific sub sets of knowledge articulated by farmers. The choice of subject matter was largely determined by what elements of knowledge would have simple practical consequences if used by farmers and so could be unequivocally verified in the field. Farmers made clear statements about the suitability of *malilo* and *rukho* trees and species causing light and heavy *tapkan* effects for planting on crop terrace risers and trees of each type are readily identified in the field. This provided a convenient means of testing whether farmer practice was consistent with stated knowledge about the suitability of growing various types of trees in conjunction with crops.

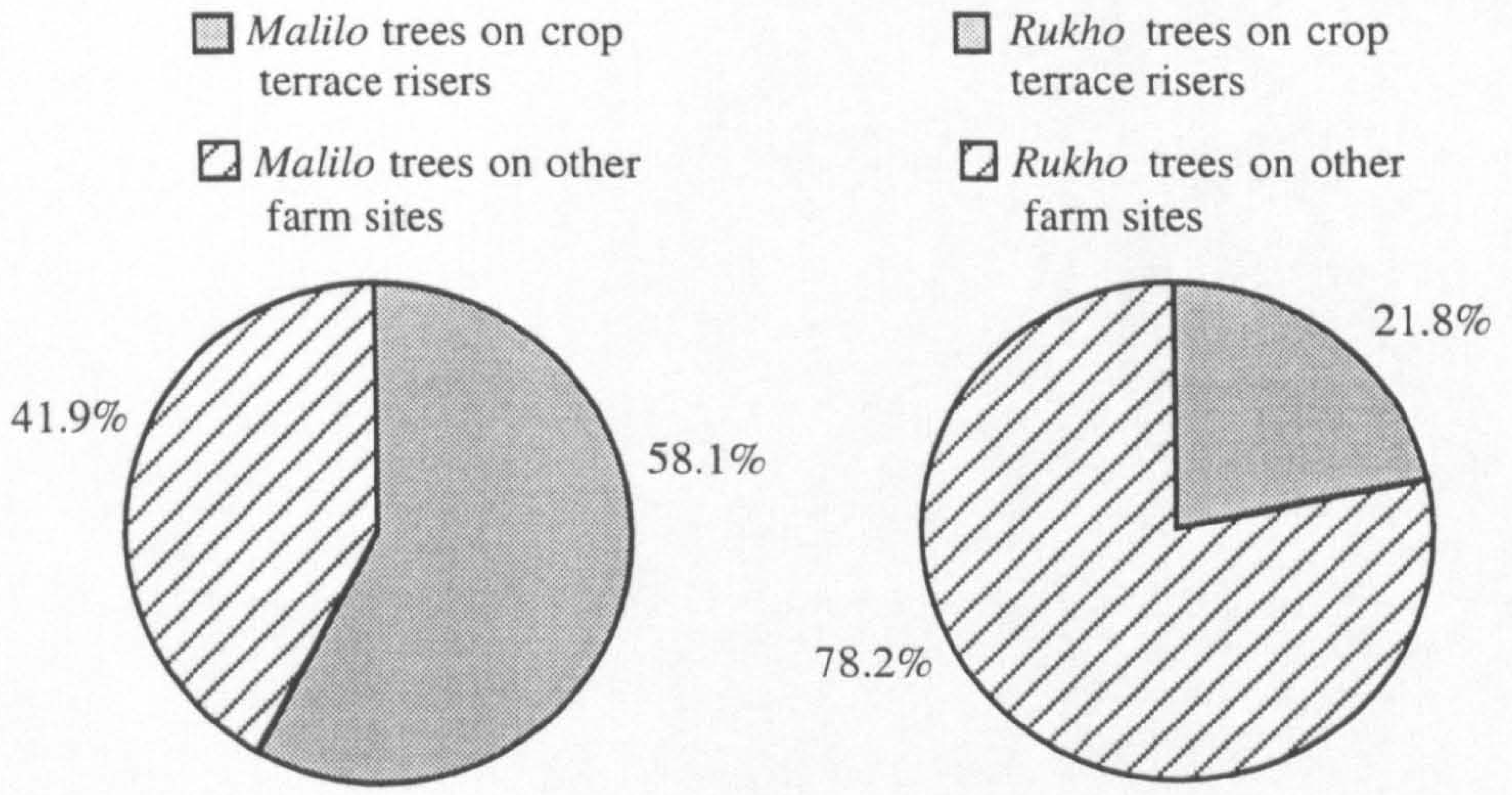
It will be recalled from Chapter 3 that there were at least seven different site types used by farmers for growing fodder trees on their farmland. Of these, *bari* land crop terrace risers were by far the most important and a wide variety of fodder tree species were grown on them. Analysis of the content of the knowledge base suggested that farmers' decisions about which tree species to plant or not to plant on *bari* land crop terrace risers was largely based on their knowledge about *rukho-malilo* attributes and *tapkan* effects (Chapter 5). It is, therefore, reasonable to expect that since *rukho* tree species and species causing heavy *tapkan* were said to cause negative effects on crops and to reduce crop yield that they would tend not to be cultivated on *bari* land crop terrace risers but to predominate on other farm sites, while *malilo* trees and those causing light *tapkan* effects would tend to predominate on the crop terrace risers. Therefore, for any *rukho* tree species the proportion of trees cultivated on *bari* land crop terrace risers would be expected to be lower than for *malilo* tree species. Similarly, a lower proportion of trees having severe *tapkan* effects would be expected on crop terrace risers than species causing light *tapkan*.

Data from the farmland tree inventory was used to evaluate these hypotheses. As part of the inventory, the total number of different tree species and their location was recorded for 30 households (Chapter 3). On the basis of information available in the knowledge base, tree species recorded in the inventory were categorised as *rukho* or *malilo* and as causing heavy or light *tapkan* effects. They were further categorised on the basis of the inventory, according to the site type on which they were found growing. Only those tree species which key informants had considered unanimously as *rukho* or *malilo* (Table 5.6; Chapter 5) and as causing heavy or light *tapkan* effects (Table 5.4; Chapter 5) were included in the analysis.

6.3.3 Results and discussion

6.3.3.1 *Rukho-malilo* effects

Figure 6.4.a and 6.4.b summarise the overall proportion of *malilo* and *rukho* trees found growing on *bari* land crop terrace risers and other farm sites on 30 farms. With data from all the farms combined more than half of the *malilo* trees were on *bari* land crop terrace risers (Figure 6.4.a). In contrast, less than a quarter of the *rukho* trees on farmland were cultivated on crop terrace risers. While this overall result is broadly consistent with the knowledge base, in order to attach a relevant statistical significance to the difference



(a) Proportion of *malilo* trees on *bari* land crop risers and other farm sites

(b) Proportion of *rukho* trees on *bari* land crop terrace risers and other farm sites

Figure 6.4 Proportion of *rukho* and *malilo* trees on *bari* land crop terrace risers and other farm sites.

between the proportions it is necessary to examine the proportion of *rukho* and *malilo* trees on crop terrace risers on each farm, since each farm represents a decision making unit where knowledge may or may not inform practice; that is, it is the proportion of farmers in the sample for which practice is consistent with knowledge that is relevant.

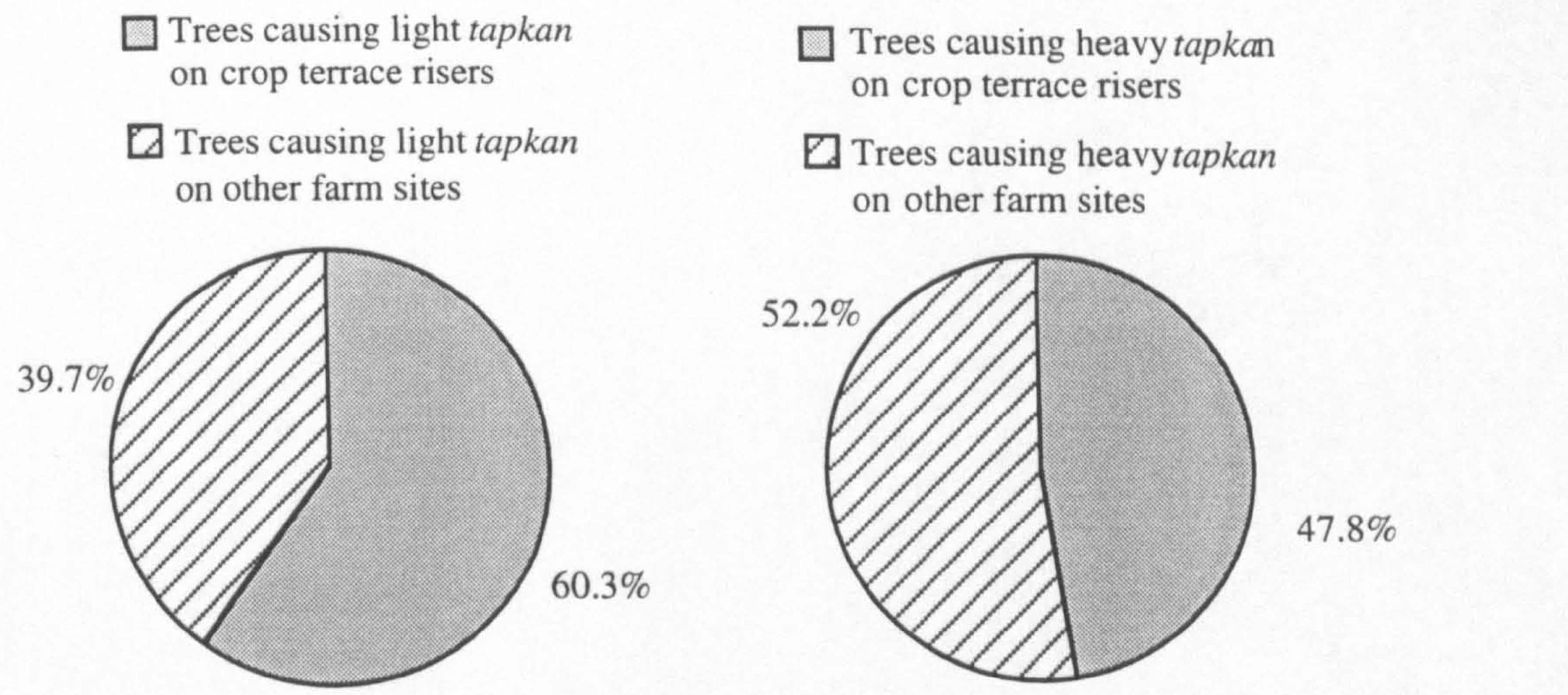
To test whether the proportion of *rukho* and *malilo* trees planted on *bari* land crop terrace risers and other farm sites were significantly different, a binomial test was carried out at the farm level. If the value of (A x D)/(B x C) in Table 6.6 was greater than one then the hypothesis was supported for that particular farm, whereas if the value was below one then the hypotheses was not supported. Of the 30 farms, 21 supported the hypotheses, while nine did not (Table 6.6). The probability (p) of randomly obtaining a frequency as low as nine in a sample of 30 is 0.021 (Table D; page 324; Siegel and Castellan, 1988) and, therefore, the hypothesis that farmers cultivated a higher proportion of their *malilo* trees than their *rukho* trees on crop terrace risers was accepted at $p = 0.05$. It is possible to conclude from this that the majority of farmers sited trees in a manner consistent with knowledge of *rukho-malilo* effects and the classification of tree species in this respect recorded in the knowledge base.

Table 6.6 Proportion of *rukho* and *malilo* trees on *bari* land crop terrace risers and other farm sites recorded for 30 households.

Farm	*Malilo* trees on crop terrace risers (A)	*Malilo* trees on other farm sites (B)	*Rukho* trees on crop terrace risers (C)	*Rukho* trees on other farm sites (D)	(A x D) / (B x C)
1	62	59	6	114	19.96
2	46	17	21	171	22.03
3	111	34	33	117	11.57
4	0	3	2	3	0
5	61	40	38	116	4.65
6	83	136	57	235	2.51
7	22	32	11	7	0.44
8	30	25	19	84	5.30
9	81	38	17	35	4.38
10	20	13	5	27	8.30
11	41	20	15	33	4.51
12	26	8	4	5	4.06
13	99	35	26	51	5.54
14	4	19	1	3	0.63
15	44	13	12	14	3.94
16	62	27	6	58	22.19
17	34	16	7	36	10.92
18	0	2	1	4	0
19	12	16	3	2	0.50
20	46	42	3	13	4.74
21	7	9	8	6	0.58
22	37	3	1	4	49.33
23	17	29	21	40	1.11
24	8	3	9	2	0.60
25	20	6	7	0	0
26	36	67	7	13	1.00
27	192	128	10	52	8.25
28	85	95	1	21	18.00
29	7	6	21	12	0.67
30	78	49	4	74	29.44

6.3.3.2 *Tapkan* effects

The overall proportion of trees causing heavy and light *tapkan* effects found growing on *bari* land crop terrace risers were not as different as for the *rukho-malilo* classification (Figure 6.5.a and 6.5.b). Of particular significance was that almost half the trees causing heavy *tapkan* effects and, hence, negative effects on crops, grown by farmers were cultivated on crop terrace risers which is roughly double the proportion of the *rukho* trees grown in association with *bari* land crop terrace risers. This may reflect: a necessary trade-off between the needs of fodder quality and supply with the desire to minimise *tapkan* effects; differences in the options for cultivating species causing heavy



(a) Proportion of trees causing light *tapkan* on *bari* land crop terrace risers and other farm sites

(b) Proportion of trees causing heavy *tapkan* on *bari* land crop terrace risers and other farm sites

Figure 6.5 Proportion of trees causing light and heavy *tapkan* effects on *bari* land crop terrace risers and other farm sites.

Table 6.7 Proportion of trees causing light and heavy *tapkan* effects on *bari* land crop terrace risers and other farm sites recorded for 30 households.

Farm	Trees causing light *tapkan* on crop terrace risers (A)	Trees causing light *tapkan* on other farm sites (B)	Trees causing heavy *tapkan* on crop terrace risers (C)	Trees causing heavy *tapkan* on other farm sites (D)	(A x D)/(B x C)
1	53	10	21	12	3.03
2	27	25	20	15	0.81
3	79	24	7	46	21.63
4	7	3	10	13	3.03
5	28	15	23	27	2.19
6	99	41	63	72	2.78
7	4	1	8	25	12.5
8	10	13	57	54	0.73
9	50	23	16	20	2.72
10	21	15	17	9	0.74
11	23	8	30	24	2.30
12	11	7	21	3	0.22
13	58	56	88	79	0.93
14	18	14	24	8	0.43
15	26	24	48	7	0.16
16	23	15	13	20	2.34
17	29	27	17	43	2.72
18	0	2	1	5	0
19	19	8	5	8	3.8
20	45	24	4	6	2.81
21	13	3	8	12	6.50
22	37	6	5	22	27.13
23	26	43	4	20	3.02
24	8	2	3	10	13.33
25	22	6	7	17	8.90
26	37	71	10	5	0.26
27	75	79	12	21	1.66
28	84	65	8	14	2.26
29	13	8	33	15	0.74
30	86	64	41	49	1.60

tapkan effects on other farm sites; or, that effects of heavy *tapkan* on crops were considered less important than effects of *rukho* trees on crops.

At the farm level using the same approach as that described previously for the *rukho-malilo* classification (6.3.2.1), 20 farms supported the hypothesis that the proportion of trees known to cause heavy *tapkan* grown on crop terrace risers was lower than the proportion of those known to cause light *tapkan* effects (Table 6.7). The probability (p) of obtaining a frequency as low as 10 in a sample of 30 is 0.049 (Table D; page 324; Siegel and Castellan, 1988) and so the hypothesis was just accepted at $p = 0.05$. Thus, although the evidence was not quite as strong as in the case of the knowledge about *rukho-malilo* tree attributes, it is possible to conclude that a majority of farmers' cited trees in accordance with knowledge about *tapkan* effects recorded in the knowledge base.

A range of socio-economic factors varied across the study area (Chapter 3) but were not considered in the ecological knowledge presently tested and may also have influenced where trees were cultivated. However, the present results give a strong indication that underlying ecological knowledge held by farmers did, at least to some extent, determine practice. The fact that trees known by farmers to have disproportionately negative ecological consequences for crop yield and soil erosion were nevertheless cultivated on crop terrace risers indicates substantial potential for improvement in the system through future research and extension.

6.4 COMPARISON OF FARMERS' KNOWLEDGE WITH PROFESSIONALS' KNOWLEDGE

6.4.1 Rationale

In recent years, there has been a growing recognition amongst researchers and development professionals of the value of combining scientific and/or professional knowledge with local knowledge in planning research and development programmes. However, taking advantage of the complementarity of local, scientific and/or professional knowledge in a development context demands that the knowledge on specified topic (s) be evaluated from each of these sources.

A discursive comparison of local and scientific knowledge was presented in Chapter 5 but the amount of scientific information currently available on tree fodder in Nepal was too sparse to make a more formal evaluation. However, the knowledge held and used by research workers in Nepal, referred to here as professional knowledge, could be investigated and was of direct relevance to the present development of agroforestry interventions in the study area.

6.4.2 Methodology

To allow meaningful comparison of local and professional knowledge required that the knowledge was acquired from the professional staff on the same topics as previously obtained from farmers. Accordingly two topics: tree-crop interactions; and fodder quality evaluation were selected for this purpose. Two separate professional knowledge bases, one on each topic, were created. The creation of the professional knowledge bases involved the fieldwork strategy, approach and cycle employed previously in the creation of the tree fodder knowledge base (Chapter 4).

For each of the two topics studied, two groups of professional staff were selected for interviews. For tree-crop interactions, all the research officers from the Agronomy and Forestry Section of Pakhribas Agricultural Centre and the Forest Research Division, Kathmandu who were available at the time of the study were selected. This resulted in a total of nine research officers, three agronomists and six foresters, being selected as key informants. In the case of fodder quality evaluation, all the research officers (a total of six) from the Livestock and Veterinary Investigation and Analytical Services Section of Pakhribas Agricultural Centre were selected for interview.

The content of the local and professional knowledge bases created were compared through the use of facilities available within the AKT software as described in Chapter 5. A list of processes, attributes, and terminologies considered by farmers and professionals in managing tree-crop interactions and in ascertaining fodder quality were produced and compared.

6.4.3 Results and discussion

6.4.3.1 Comparison of farmers' and professionals' knowledge about tree-crop interactions

Evaluation of the professional knowledge base relating to tree-crop interactions against the farmers' knowledge revealed critical gaps in knowledge. It will be recalled from Chapter 5 (Figure 5.5) that farmers' knowledge about above-ground interactions was based on an understanding of the relative shade and *tapkan* effects on crops caused by different tree species. In contrast, the information in the professional knowledge base showed that only knowledge about shade was articulated by professionals. The process of *tapkan,* which farmers considered important in managing above-ground interactions was not recognised let alone considered important by professionals.

Table 6.8 summarises tree attributes considered by farmers and professionals in assessing shade effects on crops. The information in Table 6.8 shows that except for leaf inclination angle the attributes considered by farmers in predicting shade effects on crops were also known to professionals. The remarkably close matching of tree attributes considered by farmers and professionals indicate that farmers and professionals often shared a common domain of knowledge surrounding shade effects on crops. This was further supported by the fact that the knowledge articulated by professionals about the mechanisms by which shade influenced crops were remarkably similar to those articulated by farmers (Figure 5.5; Chapter 5). The knowledge articulated by farmers about the impact of shade on crop attributes such as: crop plant height; crop stem thickness and strength; crop lodging; crop vigour; and crop yield were also articulated by

Table 6.8 Tree attributes considered by farmers and professionals influencing shade effects on crops.

Tree attributes	Professional	Farmer
Crown size	Yes	Yes
Leaf inclination angle	No	Yes
Crown density	Yes	Yes
Leaf size	Yes	Yes
Tree height	Yes	Yes

professionals. However, it is interesting to note the complete lack of information in the professional knowledge base relating to knowledge articulated by farmers about the impact of spatial and temporal factors on shade (5.3.1.1.2); allelopathic effects of trees on crops (5.3.1.2.1) and crop cultivar responses to shade (5.3.1.1.3). This suggests that the professionals knowledge about shade effects on crops was limited to an understanding of tree attributes influencing shade. In contrast, farmers considered a range of other factors and appeared to hold a more comprehensive knowledge than professionals in this respect.

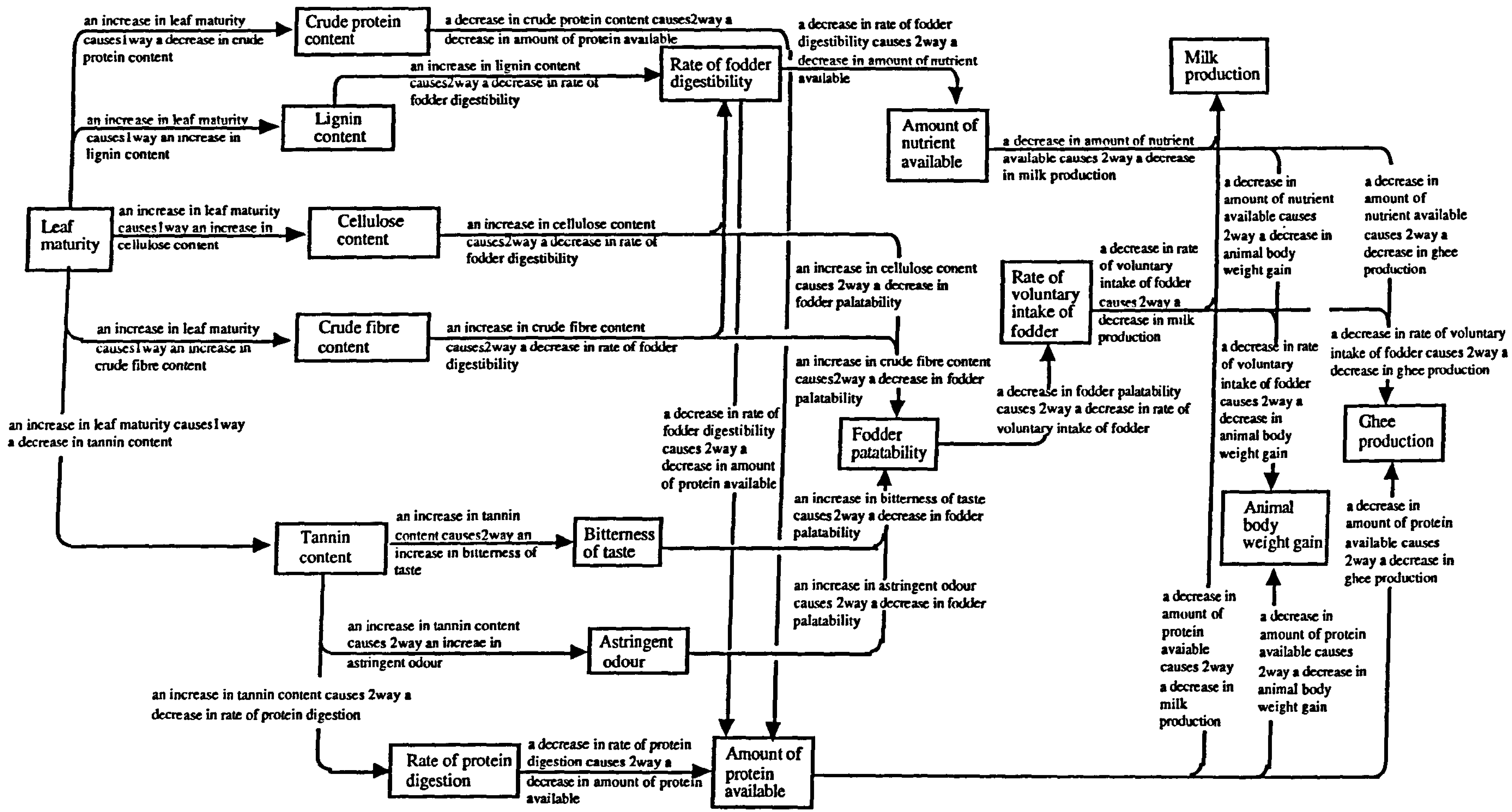
Evaluation of farmers' and professionals' knowledge relating to below ground interactions showed that the knowledge in terms of their understanding of tree attributes and the way tree attributes influenced below-ground interactions did not vary significantly. The attributes of tree root systems such as depth and spread of roots considered by farmers in assessing the extent of competition between crop and tree roots for soil nutrients and moisture and its implications for crop yield were also widely recognised by professionals (5.3.1.2). However, the other terms and concepts associated with the *rukho-malilo* classification used by farmers, for example, the rate of litter decomposition and allelopathic effects of tree leaves on soil were not articulated by professionals. It was also revealed that while farmers could categorise many tree species as either *rukho* (23 species; Table 5.6) or *malilo* (17 species; Table 5.6), professionals were only able to categorise limited number of trees as *rukho* (six species) or *malilo* (two species).

6.4.3.2 Comparison of farmers' and professionals' knowledge about fodder quality

The causal knowledge articulated by professionals about tree attributes influencing fodder quality is depicted in Figure 6.6 and can be compared with causal knowledge articulated by farmers (Figure 5.7; Chapter 5). The elements of tree fodder quality considered by farmers and professionals are summarised in Table 6.9. Of the six elements of tree fodder quality considered by farmers, only four were considered by professionals (Table 6.9). The ability of the fodder to satisfy animal appetite and the comparative preference for different fodder by different classes of livestock, which farmers considered important in ascertaining fodder quality, were neither recognised nor considered by professionals. This is an important distinction because farmers were very specific in describing fodder quality in terms of the type of animal to which it was to be fed (for example, distinguishing between goat-sheep fodder and cattle-buffalo fodder; Chapter 5) and fodders that would satisfy animal appetite so that only a small quantity of the fodder was needed at critical times of the year for fodder supply.

Table 6.9 Elements of tree fodder quality considered by farmers and professionals.

Elements of tree fodder quality	Professional	Farmer
The ability of the fodder to satisfy animal appetite	No	Yes
The effects of the fodder on milk production (including the effect of fodder on milk odour)	Yes	Yes
The effects of the fodder on *ghee* production	Yes	Yes
The comparative preference for different fodder by different classes of livestock	No	Yes
The ability of the fodder to improve animal body weight gain	Yes	Yes
Palatability	Yes	Yes



Key:

Arrows represent causal links between the nodes that they connect.

Boxed text are attribute node labels.

'Causes2way' implies reversibility in the causal mechanisms between 'increase' and 'decrease' and are used to represent both the meanings. 'Causes1way' implies irreversibility between 'increase' and 'decrease' (4.3.3.2.3.1.)

Figure 6.4 Causal knowledge articulated by professionals about fodder quality evaluation. The elements of tree fodder quality and attributes of tree fodder that were considered in ascertaining fodder quality are shown.

The terms used to describe attributes of tree fodder that were considered in ascertaining fodder quality also varied between farmers and professionals (Table 6.10). The only knowledge shared by these two groups of people about attributes influencing fodder quality was leaf maturity. The two most important sets of terms and concepts articulated by farmers in defining fodder quality and classifying fodders, *posilo-kam posilo* (5.3.2.1) and *chiso-obano* (5.3.2.6), were neither used nor considered by professionals. Similarly, knowledge about leaf texture was not articulated by professionals. Furthermore, farmers had detailed knowledge about intra-species variability in tree attributes affecting fodder quality (5.3.2.7) not articulated by professionals.

Table 6.10 The differing terms used by farmers and professionals to describe attributes of tree fodder that were considered in ascertaining fodder quality.

Attributes of tree fodder with values that each attribute took in brackets, where no values are specified a continuous scale applied	Professional	Farmer
Leaf texture (soft, stiff, coarse)	No	Yes
Chiso-obano (*chiso, obano,* intermediate)	No	Yes
Posilo-kam posilo (*posilo, kam posilo,* intermediate)	No	Yes
Leaf maturity (unripe, ripe, over-ripe)	Yes	Yes
Leaf bitterness (bitter, not bitter)	No	Yes
Cellulose content	Yes	No
Crude fibre content	Yes	No
Crude protein content	Yes	No
Lignin content	Yes	No
Tannin content (Astringency, bitterness)	Yes	No

The study suggests that the terms used by professionals (for example, crude protein, lignin, cellulose, crude fibre, tannin content) were largely derived from experimental research and indicate that this research has been to some degree mechanistic. By contrast, the terms used by farmers (for example, *posilo, kam posilo, chiso, obano*) reflect empirical knowledge that appear to lump a number of scientifically identified attributes together.

Attempts were made to investigate whether some of the differing terms used by farmers and professionals were equivalent by comparing sets of statements articulated by these two groups of people about particular attributes. The term 'tannin content' used by professionals appeared similar to the term 'leaf bitterness' used by farmers. Table 6.11 summarises the two sets of statements articulated by farmers and professionals relating to these two terms for fodder from *Bauhinia variegata* (*koiralo*) and its implications for fodder quality.

Table 6.11 Sets of statements articulated by farmers and professionals about tannin content and leaf bitterness of *Bauhinia variegata* (*koiralo*) and its implications for fodder quality.

Knowledge articulated by professionals about tannin content:
Feeding *koiralo* fodder to lactating animals causes a decrease in milk (and *ghee*) production
Koiralo fodder is not very palatable to animals
The tannin content in *koiralo* fodder is high
An increase in tannin content causes an increase in bitterness of taste
An increase in tannin content causes an increase in astringent odour
An increase in bitterness of taste causes a decrease in fodder palatability
An increase in astringent odour causes a decrease in fodder palatability
A decrease in fodder palatability causes a decrease in the rate of voluntary intake of fodder by animals
A decrease in the rate of voluntary intake of fodder causes a decrease in milk (and *ghee*) production.
An increase in tannin content causes a decrease in rate of protein digestion
A decrease in the rate of protein digestion causes a decrease in the amount of protein available to animals
A decrease in the amount of protein available to animals causes a decrease in milk (and *ghee*) production.
Knowledge articulated by farmers about leaf bitterness:
Feeding *koiralo* fodder to lactating animals causes a decrease in milk (and *ghee*) production
Koiralo fodder is not very palatable to animals
Koiralo tree fodder leaf is bitter in taste
An increase in leaf bitterness causes a decrease in fodder palatability
Koiralo tree fodder leaves have an offensive odour
Fodder tree leaves that have an offensive odour are not very palatable to animals
The texture of *koiralo* tree fodder leaf is stiff
An increase in the stiffness of tree fodder leaf causes a decrease in fodder palatability
A decrease in fodder palatability causes a decrease in the rate of voluntary intake of fodder by animals
A decrease in the rate of voluntary intake of fodder causes a decrease in milk (and *ghee*) production.

The information in Table 6.11 shows that from the professionals' perspective, there were two ways by which tannin influenced the quality of *koiralo* fodder (see Figure 6.6 for details). These were: through decreased palatability because of astringency (astringent odour) and bitterness (bitter taste); and through decreased rate of protein digestion, both of which ultimately caused decreased milk and *ghee* production. From the farmers' perspective, the reasons for *koiralo* fodder causing decreased milk and *ghee* production was attributed to decreased palatability because of the offensive odour and bitterness of *koiralo* fodder. Although explanations given by farmers and professionals for *koiralo* fodder causing decreased milk and *ghee* production were not exactly the same, they show broad similarities suggesting that tannin content and leaf bitterness cited by these two groups of people may share at least some meaning. Further investigation of whether all fodder leaves described as bitter by farmers were also described as having a high tannin content by professionals was constrained by the fact that professionals were unable to name other specific fodder tree species with a high tannin content. Thus, before definitive conclusions can be drawn, further research on the tannin content of species classified as bitter by farmers would be required.

It will be recalled from Chapter 5 that from the farmers' perspective, factors beyond the feeding quality of fodder were also important in determining the value of particular fodder trees. The most important were: seasonal availability of fodder from different tree species at different times of the year, which was largely determined by the time of leaf shedding; and the ability of fodder trees to withstand multiple lopping. No comparable knowledge was articulated by professionals.

6.5 CONCLUSIONS

Subsets of the tree fodder knowledge base were evaluated in respect of its representativeness, the extent to which the knowledge informed practice and the extent to which it was complementary and/or contradictory to the professional knowledge held by research workers.

The study showed that the knowledge elicited from a purposive sample of key informants and represented in the knowledge base was broadly representative of the knowledge held by members of the community in the study area. Basic conceptual understanding of interactive processes (such as *tapkan*) was consistent among farmers. However, detailed knowledge about species-specific tree attributes which influenced the application of general concepts to practical management varied amongst farmers, apparently associated with which particular species they had experience of cultivating on their farms. This indicates that farmers knowledge is largely utilitarian in nature and that access to the knowledge base by less knowledgeable farmers via extension services could be of practical use in improving the management of tree fodder resources on their farmland.

The study showed that the majority of farmers cited trees in accordance with the knowledge about interactive effects of trees on crop terrace risers in the knowledge base. Although socio-economic factors may also influence farmers' practice, the study suggests that underlying ecological knowledge held by farmers does, at least to some extent, determine practice. However, it is apparent that trees known by farmers to have negative ecological consequences on crops were never-the-less cultivated in association with crops. This reflects a necessary trade-off between the various needs of farmers and options available to them and indicates potential for improvement in the system through future research and extension.

Comparison of farmers' and professionals' knowledge showed differences in understanding of processes and tree attributes and in the use of terminology in describing and rationalising aspects of tree fodder production and management practices. The study revealed that some knowledge articulated by farmers about the management and use of tree fodder resources was not known to professionals. Indeed, although some knowledge was shared by both groups of people, other knowledge was not. Farmers had detailed species-specific knowledge, while researchers had a more mechanistic understanding of fodder quality evaluation.

While there may be some correspondence of terms used by farmers and professionals (for example, tannin content and leaf bitterness) no definitive conclusions could be drawn. Further research to investigate equivalence of the differing terms used by farmers and professionals would, however, be merited because where terms are equivalent it may be appropriate to inform research and extension workers so that they can communicate with farmers in a shared language. Where there is no equivalence of terms and concepts, research to ascertain the validity of farmers knowledge and to seek scientific explanations for validity could be expected to yield useful results.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

In this concluding chapter the understanding that can be derived from consideration of the present study and its implications for planning future tree fodder research are addressed. Key areas for further research into indigenous knowledge relating to farmland tree fodder resources are indicated.

7.1 IMPLICATIONS FOR PLANNING FUTURE TREE FODDER RESEARCH

The importance of basing research planning on an evaluation of the current state of knowledge on particular problem-oriented topics was highlighted in Chapter 1. It was argued that developing a detailed understanding of the knowledge of target communities was an important component of rural development activities and that research activities are more likely to be effective where they are based on an understanding of the knowledge of target communities.

Systematic research on tree fodder remains in its infancy in Nepal. This is partly because the basic information required to formulate research plans is scarce, which means that a clear research strategy is lacking. In this context the present study has demonstrated the value of gathering indigenous knowledge and using it as a basis for developing appropriate research strategies. The study has provided insights into farmers' current knowledge about the management and use of farmland tree fodder resources and what research could be done to improve farmers' abilities to manage these resources. The study has shown that both what farmers know and what they do not know present opportunities for further research either to inform researchers or to fill gaps in farmers knowledge constraining productivity of the system. The implications for planning tree fodder research identified from consideration of the content of the tree fodder knowledge base are discussed in this section.

7.1.1 Research on tree-crop interactions

The study has provided insights into farmers' current knowledge about tree-crop interactions and what research could be done to improve farmers' ability to manage these interactions. Farmers are aware that shade and *tapkan* reduce crop yield, and that tree attributes such as leaf size, crown density, crown size, tree height and leaf inclination angle influence shade and *tapkan* effects. Similarly, farmers are aware that the nature of tree root systems can significantly influence crop yield either positively where niche differentiation is operative or negatively where tree and crop roots compete. Because farmers view these as primary issues for consideration in managing above- and below-ground interactions, it would seem appropriate for future research on tree fodder to concentrate on the interface between tree and crop and be directed towards examining the ways by which the positive impact of trees on crops could be maximised while minimising negative impacts. Specifically research might usefully aim to:

- develop selection criteria for associative tree ideotypes based on farmers' knowledge that would be appropriate for cultivation on crop terrace risers.

The indication from this study that trees known by farmers to have negative ecological consequences on crops were nevertheless cultivated on crop terrace risers (6.3) reflects a necessary trade-off between the various needs of farmers and options available to them. To provide decision support to farmers in making these trade-offs, research might usefully aim to:

- identify and select genotypes with enhanced ecological combining ability with cereal crops in terms of resource sharing.

7.1.1.1 Developing selection criteria for associative tree ideotypes based on farmers' knowledge

To date, researchers in Nepal have rarely considered shoot or root architecture in developing selection criteria for fodder tree seedlings distributed to farmers either because of a lack of knowledge about these attributes or because they were considered to be of little or no immediate relevance. The absence of understanding about the process *tapkan* amongst researchers, which farmers considered important in managing above-ground interactions reported in Chapter 6 (6.4.3.1), is a case in point. Several government and non-governmental organisations including Pakhribas Agricultural Centre have been involved in selection and distribution of fodder trees to farmers for growing on crop terrace risers in Nepal for over a decade (1.3.1). In the absence of information on tree-crop interactions Pakhribas Agricultural Centre have tended to follow a conventional approach to genotype selection emphasising survival rate, growth rate and total foliage biomass production as important parameters. However, consideration of farmers' knowledge revealed that these are not necessarily the characteristics of most concern to farmers. Instead farmers are concerned about the impact of trees on crops both above and below-ground.

The present study clearly demonstrated that the selection criteria used by Pakhribas Agricultural Centre (and, as it so happens, other development-oriented research organisations involved in the promotion of tree planting on private farmland in Nepal) have not been explicit and may not, therefore, have been relevant to farmers' concerns which may have contributed to the low rate of seedling uptake from nurseries (3.7.1.2). There is clearly a need to be explicit in the development of criteria used to select tree stock and selection of fodder tree species on the basis of tree attributes recognised by farmers could be expected to lead to the production of seedlings more appropriate to farmers needs and, therefore, to higher adoption rates by farmers.

On the basis of these considerations it would seem appropriate to consider the following characteristics of trees in the development of selection criteria of fodder trees for growing on crop terrace risers.

7.1.1.1.1 Tree crown architecture

It is now known that farmers considered shade and *tapkan* as important factors influencing crops. It is known which attributes fodder trees must possess in order to minimise shade and *tapkan* effects. For example, trees with small leaves, sparse and small crowns, short height and drooping leaf inclination angle were known to cause significantly less shade and *tapkan* effects than trees with big leaves, dense and large crowns, tall height and horizontal leaf inclination angle. Thus, in the case of above-ground interactions, tree attributes considered by farmers as influencing shade and *tapkan* could be used as selection criteria. This is in effect allowing farmers to specify associative ideotypes (Huxley, 1985) appropriate to integration in their farming systems. Selection criteria for suitable tree species for cultivation on crop terrace risers might include: small leaf size, sparse crown density, small crown size, short tree height and drooping leaf inclination angle.

These factors are not all equally important and there may be trade-offs between attributes. For example, many trees with high fodder value also have large leaves notably *Ficus roxburghii* and *Artocarpus lakoocha.* Directed breeding programmes to produce small leaved varieties while retaining high fodder value could be envisaged. Similarly, some attributes are more easily manipulated by silvicultural techniques than others, for example, crown density may be decreased by selective pruning (Cannell, 1983), whereas leaf size is not much affected by tree management. Clearly, while those attributes that are plastic in respect of tree management may most appropriately be addressed by management techniques those that are not becomes priorities for genetic selection.

7.1.1.1.2 Tree root architecture

The present research indicated that farmers considered tree root architecture as an important factor influencing crops. It is now known which attributes trees must posses in order to minimise below-ground interactions. For example, deep rooted trees were said to compete less with crops for resources than shallow rooted trees. Farmers often classified trees either as *rukho* or *malilo* on the basis of their understanding about the depth and spread of the tree root systems (5.3.1.2.1). The knowledge articulated by farmers about *rukho-malilo* attributes of trees may form an appropriate basis for developing selection criteria. In this case, selection criteria would be for *malilo* attributes of trees, that is deep rooting species with limited horizontal root distribution to minimise competition with crop roots.

It has been suggested that selection based on altering the partitioning of carbon towards above-ground shoots could result in lower partitioning to roots, and therefore, smaller and shallower root systems (Cannell, 1985). Previous selection by foresters for above-ground foliage production may well have resulted in selection pressure for higher carbon partitioning to the shoot and, therefore, smaller, shallower root systems and increased competition between tree and crop. Indeed the most significant advances in plant breeding have been in increasing the harvest index and secondarily in the adaptation of genotypes to environment rather than fundamentally altering the efficiency with which carbon is fixed (Russell *et al.*, 1989). Difficulties, however, remain in selecting specifically for architectural factors of the root system because there are no simple and effective means of measuring desirable traits.

7.1.1.1.3 Fodder value

As the major purpose for which farmers grew trees was to produce fodder, fodder value can be expected to remain the most important factor in selection requirements. In this context, the knowledge articulated by farmers about fodder quality (5.3.2), particularly the *posilo-kam posilo* status of tree fodder might be of particular interest to researchers. Selection priority might be focused on *posilo* categories of tree fodder. Combinations of appropriate attributes drawing from several of the farmers classifications are likely to be favoured. For example, species that are *posilo, obano* as well as *malilo* and known to cause light shade and *tapkan* effects would be preferred. Further criteria, for example, fodder trees that can withstand multiple lopping and retain leaves late into the dry season would be of particularly high value.

In conclusion, consideration of selection criteria based on farmers' knowledge can be envisaged as resulting in explicit selection of species and genotypes that may be compatible with requirements for incorporation of trees into local farming systems. However, it is clear that selection requirements for fodder trees that will be optimal for growing on crop terrace risers and meet the needs of farmers are complex. This is further complicated by the fact that not all the tree species cultivated possess a desirable combination of attributes, for example, a species that is *posilo* may also be *rukho* or trees that are *malilo* may also be *kam posilo* or cause detrimental shade and *tapkan* effects on crops. However, this problem provides opportunities for further research for selecting desirable genotypes either by altering management actions or through selection and breeding.

The lack of knowledge about the vast majority of fodder tree species used by farmers is yet another problem. In Solma alone, 90 species were used as fodder in some form by farmers. Present knowledge of these species is too sparse to support promotion at farm level and many of species are unfamiliar to researchers and development professionals. The inability on the part of the professionals to name more than a few species reinforce this point (6.4.3.2). Given the dearth of information, it may be sensible in the short term to select a limited number of species considered by farmers to have desirable attributes for detailed investigation. As scientific understanding about these species progresses, more species could be evaluated for their suitability and promotion for growing on crop terrace risers.

7.1.1.2 Targeting research on key gaps in farmers' knowledge

No knowledge system can be complete and farmers' knowledge, like modern science, has weaknesses and imperfections and some complementarity between farmers' and scientists' knowledge is apparent. The fact that trees, known by farmers to have negative ecological consequences for crops, were nevertheless grown in association with crops (6.3), is a case in point. The present research revealed that farmers may often be faced with a series of trade-offs between their various needs and the resources available to them. This clearly suggests potential for improvement in the system through future research.

Key areas identified from consideration of the content of the tree fodder knowledge base constraining the productivity of the system which may be facilitated through future research and extension and so provide decision support to farmers in improving the management of their farmland tree fodder resources are discussed in this section.

7.1.1.2.1 Below-ground interactions

The indication from this study that farmers articulated more comprehensive knowledge of above than below-ground interactions suggests that there may be more to be learnt through research into below-ground interactions than from research on above-ground interactions. Above-ground interactions are more readily observed and may be more easily manipulated through management actions than those below-ground. Because farmers know less about below-ground interactions and because they are important determinants of the system, it is probably the most significant area where scientific research could generate useful information to assist farmers in their decision making processes. The need to concentrate research on below-ground interactions has also been stressed in recent scientific reviews (Anderson and Sinclair, 1993; Sinclair *et al.*, 1994). On the basis of these considerations, it is suggested that the focus of tree-crop interaction studies might be further narrowed down to research investigating processes operating below-ground.

Research on below-ground interactions might primarily be focused on root architecture because root distribution determines the extent of resource capture, and, therefore, competition and is thus a major determinant of the system.

The research topics worthy of further investigation, having potential for improving the productivity of the hill farming systems in the mid-hills of Nepal are presented below.

7.1.1.2.1.1 Effects of lopping on rooting pattern

Recent research indicates that tree root distribution patterns could be altered by silvicultural manipulation such as pruning. For example, on acid soils in Sumatra *Peltophorum pterocarpum,* although having a tap root and horizontal sinkers penetrating to below 1 m into a zone of iron concentration, developed a large number of fine roots in the top 10 cm of soil in response to pruning, with more, smaller diameter roots, when pruning was more severe, implying strong competition for water and nutrients with crop roots (Van Noordwijk *et al,* 1991). Increased pruning frequency also results in removing more foliage and, therefore, could be expected to have a similar effect on rooting pattern.

Tree fodder lopping is a common practice and farmers apply different lopping regimes based on empirical observations of the effects of different lopping regimes on tree health and the vigour of regrowth shoots. The indication that pruning can influence tree root systems suggests that there is an opportunity for developing lopping strategies that result in the development of a complementary rooting pattern for intercropping with cereals. Research on root architecture including intra-species and inter-species variation in rooting patterns of common fodder trees in relation to different lopping regimes, particularly lopping frequency and removal of different proportions of foliage from the crown might, therefore, yield useful results. Research to establish connection between *rukho-malilo* classification and root detection could be expected to narrow the range of materials considered in selection trials. Reduced root length density in upper soil layers and a reduced surface root proliferation response to lopping would be desirable traits. If a fullest understanding of the mechanisms controlling the effect of different lopping regimes on rooting patterns were gained in this way suitable genotypes for growing on crop terrace risers might be selected and distributed to farmers along with information on appropriate lopping regimes. Since lopping is already an integral part of tree fodder management practices, the result of such research could be expected to be compatible with farmers' existing tree management strategies.

7.1.1.2.1.2 Effects of propagation materials and planting methods on root development

The use of different propagation materials and planting methods may influence root development (Toky and Bisht, 1992). Although differences in rooting pattern of seedlings may have a relatively small effect on mature tree root systems, implications for resource sharing may be significant during the early stages of tree establishment and could be explored through future experimentation. Tree root development, particularly evidence for differences in rooting patterns in relation to seedlings originating from different sources, for example, cuttings versus seeds (including poly pot raised versus naturally regenerated seedlings), different pit size and depth and time of planting (for example, pre-monsoon; monsoon, which is the normal time for tree planting; and post-monsoon) might be considered. If evidence for differences in rooting patterns was found, this information could then be used in future seedling production programmes or disseminated to farmers via the forestry extension service.

7.1.1.2.1.3 Studies on nitrogen-fixing tree species

Nitrogen-fixing trees are often promoted as contributing to soil fertility in agroforestry (Young, 1989). However, recent evidence suggests that the fact a species may nodulate does not necessarily mean that fixed nitrogen is contributed to companion crops (Sprent, 1992). The limited number of farmland tree species capable of fixing nitrogen found in Solma (5.3.1.2.1) and the fact that farmers were seemingly unaware of such mutualistic interactions suggests that there may be potential for the introduction and promotion of nitrogen fixing trees in the area. The impact of such interactions could be expected to be significant because under existing practices the depletion of soil nutrient resources by fodder trees on crop terrace risers can be expected to be very high because organic matter accumulation through litter-fall is negligible as fodder is removed as animal feed and return of dung is incomplete. Maintenance of tree fodder for soil fertility improvement through litter-fall is unlikely to be acceptable to farmers because fodder remains the primary tree product requirement. Research to investigate the extent to which indigenous nitrogen fixing tree species found in different environments in the mid-hills of Nepal contribute to soil fertility, particularly evidence for reduced competition for nitrogen including studies on factors controlling the amount of nitrogen fixed, its availability to companion crops and the possibilities of enhancing nitrogen fixation might be carried out. Similar research on exotic nitrogen fixing tree species having potential for introduction in the mid-hills of Nepal might also be considered.

7.1.1.2.2 Studies on allelopathic effects of common farmland trees on crops

The present study has revealed that several farmland tree species are recognised by farmers as exhibiting allelopathic effects which have a significant bearing on crop production (5.3.1.2.1). Recent research has indicated that allelopathic effects of tree species may be selective and may vary between trees and crops. For example, studies carried out in Gharwal Himalaya, India (Bhatt and Todaria, 1990) on the allelopathic effects of four agroforestry tree species (*Celtis australis, Alnus nepalensis, Prunus cerasoides* and *Adina cordifolia*) on three test crops (*Eleusine coracana, Glycine max* and *Hordeum vulgare*) showed that except *C. australis,* all three tree species cause allelopathic affect on crops; that is, they reduced crop germination percentage, root and shoot length, dry matter production and depressed pigment content and the use of these trees as agroforestry species by farmers decreased in relation to the severity of their allelopathic action in the order of *C. australis, A. nepalensis, P. cerasoides* and *A. cordifolia.* Amongst the three test crops, *E. coracana* was observed to be the most resistant, *G. max* as most susceptible and *H. vulgare* as intermediate. These observations indicate that there is an opportunity to minimise allelopathic influences of trees grown on crop terrace risers either by avoiding planting them on crop terrace risers or through identification and selection of compatible mixtures of trees and crops.

Research to investigate allelopathic influences of common farmland fodder trees particularly those considered by farmers as *rukho* because of their leaf attributes (5.3.1.2.1) in relation to various cereal crops including their cultivars is, therefore, merited. Such experiments could be conducted easily by growing test crops in pots using different germination media, for example, top soil collected from around the root systems of the tree and on soils either mulched with leaves or irrigated with aqueous leaf extracts.

7.1.1.2.3 Studies on the characteristics and genetics of shade tolerant crop cultivars

The knowledge articulated by farmers on crop cultivar response to shade (5.3.1.1.4) has indicated potential for selecting crop cultivars for different shade levels. Unfortunately, most improved crop cultivars in government agricultural research stations in Nepal including Pakhribas Agricultural Centre have been selected under full sunlight. This may have partly contributed to the low rate of adoption of new crop cultivars by farmers. A re-evaluation of the existing procedure for selecting crop cultivars, particularly aimed for farmers operating tree-crop based farming systems is, therefore, merited.

It is now known that different crop cultivars exhibit different shade tolerance. Using this knowledge, research could now be directed to investigate the characteristics and genetics of shade tolerant crop cultivars of the major cereal crops grown in the mid-hills of Nepal. This information could then be used in future crop breeding and improvement programmes for generating cultivars suitable for cultivation under tree-crop based farming systems.

In conclusion, the extent of farmers' existing knowledge about tree-crop interactions suggests that one of the most appropriate contributions of the agricultural research sector might involve fundamental research on those aspects of tree-crop interactions not easily observed or well understood by farmers. While it may at first appear counterintuitive for consideration of local knowledge to result in recommendation for a shift in emphasis towards fundamental research on tree-crop interactions, this is in fact, commensurate with targeting research on gaps in farmers' knowledge constraining the productivity and sustainability of the systems and of recognising the farmers' ability to adapt the results of fundamental research to their particular circumstances.

Clearly, more sophisticated extension methods are required to deliver decision support to farmers that might assist them in improving cultivation of trees on their farms rather than in transferring prefabricated technology packages. However, given the heterogeneous nature of the farming systems in Nepal and the myriad opportunities for integrating trees, that are already well tried by farmers, process-oriented research coupled with delivering of decision support to farmers could be expected to be more efficient than attempting to develop adaptive technology packages for each situation. In essence a shift in emphasis towards supporting farmers in their attempts to incorporate trees in their farming systems, where they think appropriate, by providing technical advice rather than persuading farmers to plant trees appears appropriate.

7.1.2 Research on fodder quality

Scientists both in Nepal (Subba *et al.*, 1992; Panday and Osti, 1993) and elsewhere (Gill and Thorne, *pers. comm.*)[1] have been actively trying to ascertain fodder quality through repeatable methods of chemical analysis. However, results from these studies are far from conclusive and often contradictory between different laboratories (Mahato and Subba, 1988; Paterson, 1993), in some cases vindicating farmers preferences and in others finding no chemical explanations for them (Subba *et al.*, 1992). A review of available literature clearly suggests the need for more rigorous work before farmers preferences and nutritional value of tree fodder can be evaluated reliably using chemical means.

This study has shown that the subject of fodder quality is a complex one and that farmers often use overlapping classifications of tree fodder in evaluating fodder quality (5.3.2). The present study suggests that from the farmers perspective, fodder quality was principally determined by: the type of livestock for which it was intended; the ability of the fodder to satisfy animal appetite; the ability of the fodder to promote milk and *ghee* production; the impact of the fodder on animal health; the impact of the fodder on livestock body weight gain; and the palatability of the fodder. Several tree attributes were recognised by farmers as influencing the essential elements of fodder quality including: leaf maturity; leaf texture; leaf bitterness; fodder toxicity; seasonal changes in fodder properties; and the management regimes applied to the fodder trees. Furthermore, farmers also recognised intra-species variation in respect of fodder quality. On the basis of this, farmers often classified fodders as: *posilo, kam posilo* or intermediate; as *chiso, obano* or intermediate; and as goat-sheep and cattle-buffalo fodder. Fodder trees producing *posilo* fodders were generally preferred by farmers.

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[1] Dr Margaret Gill and Dr Peter Thorne are livestock specialist at Natural Resources Institute, Chatham, UK.

At present, researchers have rarely considered these factors in the assessment of fodder quality because the information was not available to forestry and livestock professionals in Nepal. The failure of researchers to recognise tree attributes considered important by farmers in influencing fodder quality were reported in Chapter 6 (6.4.3.2). As a result, much research on nutritional value of tree fodder in Nepal has been based on standard nutritive value assessment methods notably 'proximate analysis' of fodder leaves in which crude protein, crude fibre, lignin, cellulose and tannin content are often considered as important indicators of fodder quality. While these indicators may be important in determining fodder quality, many studies carried out based on these indicators have produced widely differing results for the same species (Subba and Tamang, 1990). This may be because nutritive and anti-nutritive factors often vary with species, sub-species (varieties), season and leaf maturity as suggested in the present study by Solma farmers. This may partly explain why so many attempts to ascertain fodder quality through chemical analysis have failed to draw conclusions of practical utility.

A clear indication from this study is that if farmers preferences and nutritional value of tree fodder are to be evaluated reliably using chemical means, the indicators of fodder quality currently being used in the assessment of nutritive value of tree fodder are inadequate. In this context, consideration of farmers' knowledge particularly the tree attributes that they recognise as influencing fodder quality could lead to the development of more suitable sampling strategies and methods for assessing nutritive value than currently being used. Research to investigate whether methods can distinguish tree fodder on the basis of quality defined according to farmer criteria might, therefore, constitute the first stage in attempting to unify chemical analysis with farmers' knowledge.

The present research has shown that the majority of the characteristics of tree fodder that were used by farmers as indicators of fodder quality were based on physical attributes of the trees that were easily observed by farmers. In some cases, the link between these characteristics and their impact on fodder quality as defined by farmers could be easily inferred (for example, coarse leaves and fodder palatability), while others could not (for example, leaf bitterness and milk and/or *ghee* production). This suggests a high degree of empiricism in farmers' knowledge and that:

- indicators of tree fodder quality that they use may not be capable of differentiating new types of tree fodder or how to use existing types in different ways; and

- there may be scope for nutritive value assessment methods to contribute when farmers need to generate information on new types of tree fodder or the use of existing types under different conditions.

On the basis of these considerations, it is suggested that future research on tree fodder quality might most appropriately be directed to investigate:

- the extent to which indicators currently used by farmers are able to meet their needs for information on tree fodder quality;

- the extent to which the nutritive value assessment methods can differentiate tree fodder quality defined according to farmers' criteria; and

- the extent to which the nutritive value assessment methods can supplement farmers' indicators of fodder quality in an improved system of fodder quality evaluation.

The results of this research would be of practical use because the information derived from this research could then be used to:

- identify deficiencies in farmers' knowledge of tree fodder quality which might then be targeted by future research; and

- identify future priorities for the development and implementation of nutritive value assessment methods that will be able to meet farmers' needs for assessing tree fodder quality.

Initially, research could be carried out by applying a range of established nutritive value assessment methods to a set of tree fodder samples stratified to encompass the full range of variation in the factors considered by farmers to influence fodder quality. Thus, species should be sampled across a range of nutritive value from fodder considered *kam* *posilo* to *posilo.* The knowledge articulated by farmers about intra-species variation in terms of fodder quality could also be taken into account so that the extent to which variation in fodder quality articulated by farmers has a genetic basis could be examined. For each species and sub-species samples of unripe, ripe and over-ripe leaves could be taken at appropriate times so that the *chiso-obano* distinction could also be explained.

If suitable methods of fodder evaluation were identified and nutritional qualities understood, a broader range of indigenous and exotic fodder tree species could be analysed and examined in relation to farmers' perceptions of fodder quality. As it becomes clear which attributes fodder trees must posses to exhibit high nutritive value, research could be directed to maximise these qualities. For example, if the *obano* attributes of tree fodder were found to significantly contribute to fodder quality then further research to develop lopping regimes which maximise the time that leaves were maintained in an optimal *obano* state for times of the season when fodder was required by farmers might be worthwhile.

7.2 RECOMMENDATIONS FOR FURTHER RESEARCH INTO INDIGENOUS KNOWLEDGE

The present research has inevitably led to the formulation of more questions than it has answered and rich opportunities for further research on tree fodder and indigenous knowledge research in Nepal remain. Some of the key areas identified by this study as particularly fruitful for further attention are summarised in this section.

One important area for further research is to gather more information about the indigenous system of tree fodder classification and evaluation used by Solma farmers. Now that the *posilo-kam posilo, chiso-obano and rukho-malilo* classification systems have been identified, further research to determine if similar fodder classification and evaluation system are used more widely by other people across the eastern hills and mid-hills of Nepal would be useful. The study has indicated that basic conceptual understanding of processes such as *tapkan* may not vary very much amongst farmers, but that detailed knowledge about the tree attributes which influence these processes and are used in the application of these general concepts in practical management vary considerably amongst farmers in relation to the particular species that they have experience of cultivating. Furthermore, not all the communities in the mid-hills of Nepal cultivate fodder trees as intensively as in Solma. Thus, by evaluating the Solma farmers' knowledge system in relation to a larger population with varying socio-economic and bio-physical conditions the extent and limits of it's applicability could be defined. This information would be of practical use for planners, researchers and extension workers because such information would have obvious implications for planning future tree fodder research and extension programmes at national, regional and local levels.

The study has indicated that while farmers and development professionals (more specifically researchers) often use different terminology in describing and rationalising aspects of tree fodder production and management practices, some of the terms used by farmers and professionals may be similar (6.4.3.2). Further research along these lines including knowledge of farmers, researchers and extension workers, preferably involving both junior and senior staff involved in tree fodder improvement programmes in Nepal might be useful in understanding how different terms are used to describe tree fodder resources and how they are interpreted and used by different groups of people. The identification of similarities and differences in terms used by various groups of people may have a significant impact on planning future tree fodder research and extension programmes. For example, where terms are equivalent translation of knowledge between farmers and researchers or vice-versa may be facilitated without any further research, where the terminologies of different groups are incompatible, a deficiency of understanding is implied and further research would be required to clarify the situation.

The twenty-five year master plan for the forestry sector in Nepal places considerable stress upon the encouragement of tree planting on farmland (Anon, 1988). As a result, several government institutions have been involved in promoting tree planting on farmland (1.3.1) with considerable emphasis and money being invested in the establishment of nurseries and in motivating and training farmers. However, results of the present study suggest that neither lack of knowledge about tree cultivation nor a lack of planting materials limit tree planting by farmers on private farmland. The study in fact showed that farmers were increasingly cultivating (3.7.1.1) trees on their farmland quite independently of any outside inputs or extension by government agencies, raising doubt about the validity of the assumptions made by many development professionals working in Nepal, that there is a primary need to educate and motivate farmers in tree planting. It appears that farmer knowledge about the management and use of farmland trees has probably been underestimated and the need to promote tree planting on farmland has probably been overestimated. The suggestion that farmers themselves are well equipped with a supply of seedlings and are aware of the need to plant trees on their farmland means that a less interventionist strategy may be more appropriate and that higher returns would be expected from resources invested in investigation of local needs and knowledge and building an effective research and extension system based on this. A re-evaluation of whether there is a fundamental requirement to motivate farmers to plant trees, at least in some parts of the eastern hills of Nepal, is merited. It is reasonable to expect that there may be a similar requirement elsewhere, since few detailed studies of indigenous agroforestry knowledge and practice are available.

7.3 CONCLUSIONS

The present research has demonstrated that farmers' possess a detailed ecological knowledge of tree fodder quality, tree-crop interactions and tree fodder management techniques which they use to assist them in formulating fodder management and feeding strategies. The study has shown that farmers' ecological knowledge is explanatory, predictive and of technical relevance. It has been shown that indigenous ecological knowledge research in general and farmers' ecological knowledge in particular has the potential to improve the researchers' understanding of the complex interdisciplinary field of tree fodder resources and so improve the design of research and development programmes making them more responsive to the needs of the target community.

The study has demonstrated the value of using a knowledge based systems approach to indigenous ecological knowledge research. It is doubtful whether such detailed explanatory ecological knowledge about tree fodder resources would have been collected effectively if less rigorous evaluation of the usefulness of knowledge had been used. The defining feature of the approach was the explicit representation of knowledge and incremental knowledge acquisition based on an iterative and rigorous evaluation of the usefulness of the knowledge already acquired. The practical utility of the approach was that once created, the knowledge base could be maintained and updated as a growing corporate record of current knowledge on the topic in question.

The research has demonstrated that the people of Solma have developed and use a complex knowledge system to help them cope with the management of tree fodder resources on farmland. It is likely that similar knowledge systems are used by farmers in other aspects of natural resource management that are critical to their livelihood. It is hoped that this research will, therefore, contribute to the enlightenment of planners, researchers and development practitioners about the extent and value of indigenous knowledge systems and stimulate further indigenous knowledge research in natural resource management. Given the nature of local knowledge available, universities and training institutions may also benefit by including consideration of it in their curricula.

On the basis of this study, it may be concluded that researchers and development professionals can gain from an explicit account the knowledge which exists in farming communities. Research and development strategies aimed at improving the management and use of natural resources by local communities devised on the basis of an evaluation of their knowledge and needs are likely to be more appropriate than those that are not and can be expected to enjoy higher adoption rates. It is a sad reflection that indigenous knowledge research has received little serious attention from Nepali researchers. Given the heterogeneous environment that prevails in the mid-hills of Nepal, better understanding of the interaction between the people and their environment may take a long time and demands serious and tenacious interest from researchers and development professionals which might be facilitated through studies such as the present one.

Researchers and planners in Nepal have shown interest in developing models to help explain current and changing land use strategies and farmers' decision making process and then to plan research and development efforts to alter these strategies. However, these efforts have been constrained by gaps in the knowledge base needed to formulate such models (Anon, 1988; Griffin, 1991). Many of the variables needed to construct models are not well defined or are poorly understood. It appears, therefore, that much of this model building effort may be premature and that before such models are constructed it would be appropriate for more basic research to be carried out. More generally, micro-level research of the type in the present research is perhaps needed before macro-models to help explain land use strategies and farmers decision making are feasible.

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APPENDIX 1 HOUSEHOLD SURVEY QUESTIONNAIRE (ENGLISH TRANSLATION)

Name of household head (HoH) ____________________

HoH: Male ( )   Female ( )

Age: ________

Jat/Caste (Ethnic group): ____________

Education: Able to read and write ( )   Unable to read and write ( )

Ward Number: ______

Village/Tole name: ___________

Location (Altitude): ___________

1. FAMILY COMPOSITION

Name	Age	Male/Female	Able/unable to read and write	Relationship to HoH	Present/Absent*

* If absent or away from the farm give reasons (for example, in army/civil services etc.)

2. LAND HOLDING

Land type	Area*
1. Bari	
2. Khet	
3. Nagi	
4. Kharka	
5. Kharbari	
6. Other (Specify) 6.1 .... 6.2 .... 6.3	 ....

* Let farmer use their local unit (for example, *ropani, muri, pathi, hal* etc.)

3. CROPS GROWN

Crops	Land type*	Location**	Planting time (Month)	Harvesting time (Month)

* *Bari, khet* etc.
** Altitude (*lekh, kachhad, aule*)

4. LIVESTOCK HOLDING

Livestock type	Number
1. Cattle	
2. Buffalo	
3. Sheep	
4. Goats	
5. Pigs	
6. Other (Specify) 6.1 .... 6.2 .... 6.3	 ....

5. TREE FODDER SOURCES

5.1 What are the different sources of tree fodder for your farm ?

1. Own farmland tree fodder ( )
2. Forest fodder ( )
3. Both (1 and 2) ( )
4. Other (specify)

4.1 -------------------
4.2 -------------------
4.3 -------------------

5.1.1 If both (1 and 2) how much do you collect from the forest and how much do you collect from your own farmland ?

Forest fodder			Farmland fodder		
Mostly	Half	Less than half	Mostly	Half	Less than half

6. SPECIES PREFERENCE

6.1 Which fodder tree species do you prefer most amongst those found in your area or cultivated on your farmland and why ? (in order of priority/preference)

Fodder tree species	Reasons for liking/preference

7. PROPAGATION/SEEDLING SOURCES

7.1 Where do you obtain seedlings for planting ?

1. Nearby government nursery ( )
2. Grown personally ( )
3. Wildings ( )
4. Natural regeneration ( )
5. Other (Specify)

5.1 ------------------
5.2 ------------------
5.3 ------------------

7.1.1 If grown personally, please tell me which tree species do you grow and how do you propagate them ?

Tree species	Method of propagation

8. PLANTING PRACTICES

8. 1 Who in your family plant trees on your farmland ?

	All	Mostly	Half	Occasionally	Never
Adult male					
Adult female					
Children (male)					
Children (female)					

8.2 Which tree species or type of trees have you planted on the following type of land on your farmland and why ?

Land type	Tree species/type of trees*	Reasons
1. Bari land crop terrace riser		
2. Khet land (terrace riser)		
3. Field boundary		
4. Gullies/drainage ways		
5. Khar bari		
6. Kharka		
7. Around homestead/cattleshed		
8. Pakho land		
9. Others (Specify)		
9.1	....	....
9.2	....	....
9.3	....	....

* Fodder, fuelwood, timber, fruit etc.

8.3 Which or what seedlings size do you prefer for planting on your farmland and why ?

Seedlings type	Size*	Reasons
Small		
Medium		
Large		

* Let farmer use their local measurement unit (for example, feet, meter, *bitta, hath* etc.)

9. TREE FODDER MANAGEMENT

9.1 Which fodder trees do you lop in which month (s) ?

Fodder tree species	Lopping season/month (s)

9.2 Who in your family lop your farmland tree fodder ?

	Mostly	Half	Occasionally	Never
Adult male				
Adult female				
Children (male)				
Children (female)				

9.3 What criteria do you use to decide which tree fodder to lop at a particular month (s) ?

9.4 Do you think that your farmland trees affect crops ?

Yes ( )   No ( )

9.4.1 If No, please explain why ?

9.4.2 If Yes, please explain how or in what way do you think that farmland trees affect crops ?

9.5 Which tree species do you think affect crops most and why ?

Fodder tree species	Reasons

9.6 Which crops do you think are most affected by farmland trees and why ?

Crops	Reasons

10. FODDER USE

10.1 Which fodder species do you think are most preferred by the following type of livestock ?

Livestock type	Fodder species
1. Cattle	
2. Buffalo	
3. Sheep	
4. Goats	
5. Other (Specify) 5.1 .... 3.2 .... 5.3	 ....

10.2 Which tree fodder species do you think are nutritious or less nutritious to your animals and why ?

Nutritious fodder tree species	Reasons	Less nutritious fodder tree species	Reasons

10.3 Do you think that some fodders are toxic at certain stage/season if feed to livestock ?

Yes ( ) No ( )

10.3.1 If Yes, please name tree fodder species, at what stage they are toxic and their effect on livestock ?

Fodder tree species	Toxic stage/season	Effects on livestock

11. We have talked for a long time and I am very pleased with your help. Thank you very much for your help and for giving your time to me. Before I leave, is there anything that you would like to tell me about tree fodder or difficulties you have on your farm ?

INTERVIEWER'S COMMENTS

Please note the following by observing the informant's house:

1. Relative size of the house:

Small ( ) Medium ( ) Large ( )

2. Roofing materials:

Thatch grass ( ) Tile ( ) Tin ( )

3. Please describe the interview situation (write down any comments you may have about the interview, the informants or the household).

APPENDIX 2.A INVENTORY CODES

All the woody perennial plants recorded in the inventory of 30 farms are listed. The name by which they are known locally, their botanical identity if known, source of identification, uses and any additional comments made by informants are given (Appendix 2.B). A simplified quality rating of each species for major tree products as assessed by key informants and the elevational range over which they were found growing with their frequency of occurrence is presented (Appendix 2.C). A key to the codes used is given below.

Key

Ref (Source of identification)

1	HMGN (1976)
2	Regmi (1976)
3	Panday (1982)
4	Howland and Howland (1984)
5	Shrestha (1984)
6	Kayastha (1985)
7	Jackson (1987)
8	Amatya (1989)
9	Carter (1991)

Elevation

Aule	Lower elevation, not above 1 500 m
Lekh	Higher elevations, not below 1 500 m

Use

a	Fodder
b	Fuelwood
c	Timber
d	Agricultural tools and implements specified in "comments"
e	Household implements specified in "comments"

Thaki	Wooden vessel for milk products
Harpe	Wooden vessel smaller than *thaki* for milk products
Tongba	Wooden vessel for drinking local beer

f	Cultivated for live hedge/fence
g	Fruit
h	Medicinal use specified in "comments"
i	Religious significance specified in "comments"

j	Household materials specified in "comments"	
	Damlo	Tethering rope
	Nanglo	Winnowing tray
	Chitra	Roofing materials for cattleshed
	Bhakari	Structure made for grain storage
	Choya	Fibre for rope making
k	Ornamental	
l	Other use specified in "comments"	

Fodder characteristics

a	*Chiso* (cold and wet)
b	*Obano* (warm and dry)
c	Intermediate between *chiso* and *obano*
d	*posilo* (nutritious or high nutritive value)
e	*kam posilo* (less nutritious or low nutritive value)
f	Intermediate between *posilo* and *kam posilo*
g	Milk promoting
h	*Ghee* (milk fat content) promoting
i	Causes pungent odour milk
j	Dries up milk production
k	Toxic to animal at certain stage or time of the year
l	Causes animal health problem
m	Disagreement between informants on *chiso-obano* status
q	Disagreement between informants on *posilo-kam posilo* status
o	Most suitable for or mainly fed to cattle and buffalo
p	Most suitable for or mainly fed to goats and sheep

Fodder value

1	Excellent (eaten preferentially)
2	All right (intermediate)
3	Not eaten preferentially
n	Not a fodder

Fuelwood value

1	Excellent (fiercely burning and heat producing)
2	All right (intermediate)
3	Not very fiercely burning and heat producing
n	Not a fuelwood

Timber value

1	Very strong and durable (or wood valued for other purposes specified in "comments")
2	All right (intermediate)
3	Not very strong and durable
n	Not a timber

Fruit value

1	High quality fruit for human consumption (or for other purposes specified in "comments")
2	All right (intermediate)
3	low quality fruit for human consumption
n	Not a fruit

APPENDIX 2.B WOODY PERENNIAL PLANTS RECORDED IN THE INVENTORY OF 30 FARMS IN SOLMA AND THEIR USES

Local name	Botanical name	Family	Ref	Use	Comments
Aap	*Mangifera indica*	Anacardiaceae	4	b, c, g, i	primarily grown for fruits; leaves used during religious ceremonies
Aaru	*Prunus persica*	Rosaceae	4	b, g	primarily grown for fruits
Aat	?	?		b, h	latex used as medicine against cuts and wounds
Aalcha	*Prunus spp.*	Rosaceae	9	b, g	primarily grown for fruits
Amalla	*Embilica officinalis*	Euphorbiaceae	4	a, b, l	edible fruits; fruits used as pickles
Ambak	*Psidium guajava*	Myrtaceae	4	b, g	primarily grown for fruits; bark used as medicine against cough
Anar	*Punica spp*	Punicaceae	4	b, g	primarily grown for fruits
Angerii	*Lyonia ovalifolia*	Ericaceae	4	a, b	young leaves poisonous to livestock
Archal	?	?		a, b, l	edible fruits
Arkhaulo	*Quercus fenestrata*	Fagaceae	3	a, b	
Asare	*Lagerstroemia parviflora*	Lythraceae	4	a, d	Wood for sickle, spade and axe handle
Baar	*Ficus bengalensis*	Moraceae	4	a, b, i, l	leaves used during religious ceremonies; edible fruits
Babis	?	?		a, b, c, h	fruits used as medicine against head ache and fever
Badahar	*Artocarpus lakoocha*	Moraceae	4	a, b, c, e, l	Wood for *thaki*, *tongba* and *harpe*; edible fruits
Bains	*Salix spp*	Salicaceae	9	a, b	
Bakaino	*Melia azedarach*	Meliaceae	4	a, b, l	leaves used as green manure
Bandrae	*Cynocardia odorata*	Falcourtiaceae	4	b	
Barro	*Terminalia belerica*	Combretaceae	4	a, b, c, h, l	bark used as medicine against cough; edible fruits
Bel	*Aegle marmelos*	Rutaceae	4	a, b, i, l	leaves used during religious ceremonies; edible fruits
Bhakimlo	*Rhus semialata*	Anacardiaceae	5	a, b, l	edible fruits
Bhayalo	*Rhus succedanea*	Anacardiaceae	1	a, b, e	wood for *thaki*, *harpe* and *tongba*
Bhalu bans	*Dendrocalamus hookeri*	Gramineae	3	a, b, l	poles for construction and fencing
Bhimsenpati	*Buddleja asiatica*	Loganiaceae	4	a, b	
Bhogate	?	?	2	b, l	fruits used for making alcohol
Bilaune	*Maesa chisia*	Myrsinaceae	4	a, b	
Bokae timur	*Zanthoxylum armatum*	Rutaceae	2	b, l	fruits used for relishes and as medicine against tooth ache
Chamlayo	?	?		a, b, c, e	wood for *thaki* and *harpe*
Champ	*Michelia champaca*	Magnoliaceae	4	a, b, c	wood valued for furniture making

Char chare lahara	?	?		a	
Chilaune	*Schima wallichii*	Theaceae	4	a, b, c, d	wood for making ploughs
Choya bans	*Dendrocalamus hamiltonii*	Gramineae	3	a, b, j, l	poles for construction and fencing; fibre for *choya*, *doko*, *nanglo*, *damlo* etc.
Chuletro	*Brassiopsis spp*	Araliaceae	9	a, b	
Chuthro	*Berberis asiatica*	Berberidaceae	4	b, f, l	oil from fruits for lighting house
Dabdabe	*Garuga pinnata*	Burseraceae	4	a, b	
Darim	*Punica granatum*	Punicaceae	5	b, g	Primarily grown for fruits
Darimpate	?	?		a, b	
Datharum	?	?		b	
Dhalne katus	*Castanopsis indica*	Fagaceae	4	a, b, c, l	Young leaves used as green manure; fruits edible
Dhayero	*Woodfordia fruticosa*	Lythraceae	1	a, b	
Dhusure	*Colebrookia oppositifolia*	Labiatae		a, b	
Dudhae lahara	?	?		a	
Dudhilo	*Ficus nemoralis*	Moraceae	4,3	a, b, c	
Dhupi	*Juniperus wallichiana*	Cupressaceae	9	i, k	Wood used as incense
Faledo	*Erythrina variegata*	Leguminosae	4	a, b	
Gayo	*Bridelia retusa*	Euphorbiaceae	4	a, b, c	young leaves poisonous to livestock
Ghangaru	*Pyracantha crenulata*	Rosaceae	4	b, f, d	wood for sickle, spade and axe handle; walking stick; edible fruits
Ghurmise	*Leucosceptrum canum*	Labiatae	3	a, b	
Gidari	*Premna spp*	Verbenaceae	9	a, b	
Gogun	*Saurauia nepaulensis*	Saurauriaceae	4	a, b, e	wood for *thaki* and *harpe*; fruits edible
Gohore	?	?		b	
Guras	*Rhododendron arboretum*	Ericaceae	4	b, c, k	
Guyelo	*Elaeagnus latifolia*	Elaeagnaceae	4	a, b	
Hadchur	*Viscum articulatum*	Loranthaceae	5	a, b	
Hallaudae	?	?		a, b	
Hardae	*Morinda citrifolia*	Rubiaceae		a, b	
Harro	*Terminalia chebula*	Combretaceae	4	a, b, c, h	fruits used as medicine against cough
Hoksae	*Citrus grandis*	Rutaceae	4	b	
Jamuna	*Syzygium cumini*	Myrtaceae	4	a, b, c, l	edible fruits
Jayamir	*Citrus jambhiri*	Rutaceae	2	b, g	primarily grown for fruits
Jhigane	*Eurya acuminata*	Theaceae	4	a, b	
Junar	*Citrus spp*	Rutaceae	4	b, g	primarily grown for fruits
Kabro	*Ficus lacor*	Moraceae	4,3	a, b, l	young buds used as vegetables
Kadam	?	?		h, l	oil from fruits for lighting house
Kafal	*Myrica esculanta*	Myricaceae		b, g	
Kagati	*Citrus aurantifolia*	Rutaceae	2	b, g	primarily grown for fruits
Kaingyu	*Wendlandia exserta*		3	a, b, e	Wood for *thaki*, *harpe* and *tongba*

Kamle	*Pilea wightii*	Urticaceae	4	a, b	
Karam	*Holoptelea integrifolia*	Ulmaceae	4	a, b	
Keraa	*Musa spp*	Musaceae		g	leaves may be fed to livestock
Katahar	*Artocarpus integra*	Urticaceae	4,3	a, b, g, e	primarily grown for fruits; Wood for *thaki* and *harpe*
Kaulo	*Machilus odoratissima*	Lauraceae	4	a, b	
Keshari	*Lathyrus sativus*	Leguminosae	4	b, f	
Kharane	*Lindera pulcherrima*	Lauraceae	9	b, l	cooking oil from fruits
Khari	*Celtis australis*	Ulmaceae	3	a, b, e	wood for *thaki*, *harpe* and *tongba*
Khasreto	*Ficus hispida*	Moraceae	3	a, b	
Khasre Khanyu	*Ficus semicordata* var. *semicordata*	Moraceae	8	a, b	
Khayer	*Acacia catechue*	Leguminosae	4	a, b, l	wood valued for dye making
Khirra	*Wrightia antidysenterica*	Euphorbiaceae	1	a, b, l	young leaves used as green manure
Kholme	*Symplocos spp*	Symplocaceae	3,9	b	
Khotae salla	*Pinus roxburghii*	Pinaceae	4	b, c, l	fresh wood used for lighting house
Kimbu	*Morus alba*	Moraceae	4	a, b, l	edible fruits
Koiralo	*Bauhinia variegata*	Leguminosae	4,3	a, b, e, l	wood for making *thaki* and *harpe*; flowers used as vegetables
Kutmero	*Litsea polyantha*	Lauraceae	4	a, c, b	
Lankuri	*Fraxinus floribunda*	Oleaceae	4	a, b, d	wood for yokes
Lapsi	*Choerospondias axillaris*	Anacardiaceae	4	b, c, l	primarily grown for fruits
Latikath	*Coronus oblonga*	Cornaceae	4,6	a, b	
Mahuwa	*Madhuca indica*	Sapotaceae	4	b	dye from bark
Mal bans	*Bambusa nutans*	Gramineae	7	a, b, j	poles for construction and fencing
Maleto	*Macaranga pustulata*	?		a, b	
Malledo	?	?		a, b	
Mayal	*Pyrus pashia*	Rosaceae	4	a, b, d, g	primarily grown for fruits; wood for making ploughs
Mewa	*Carica papaya*	Caricaceae		g	primarily grown for fruits
Musurae katus	*Castanopsis tribuloides*	Fagaceae	4	a, b, c, l	leaves used as green manure; edible fruits
Naspati	*Pyrus cumminus*	Rosaceae	4	b, g	primarily grown for fruits
Nebharo	*Ficus roxburghii*	Moraceae	4,3	a, b, l	leaves made into plates; fruits edible
Nibuwa	*Citrus lemon*	Rutaceae	8	b, g	primarily grown for fruits
Nigalo	*Arundinaria intermedia*	Gramineae	4,5	a, b, j	fibre for *chitra* and *bhakari*
Odal	*Sterculia villosa*	Sterculiaceae	4	a, b	
Okhar	*Juglans regia*	Juglandaceae	4	b, c, l	wood valued for furniture making; edible fruits
Padori	*Stereospermum personatum*	Bignoniaceae	4	a, c, b	
Painyu	*Prunus cerasoides*	Rosaceae	4,6	a, b, c, d	wood for ploughs
Parayang	*Arundinaria spp*	Gramineae	4,7	a, b, j	fibre for *chitra* and *bhakari*
Patpatae	*Leycesteria formosa*	Caprifoliaceae	4	a, b	
Pipal	*Ficus religiosa*	Moraceae	4,3	a, b, i	leaves used during religious ceremonies

Pipire	?	?		a, b	
Rai khanyu	*Ficus semicordata* var. *montana*	Moraceae	8	a, b, l	fruits edible
Rato siris	*Albizia julibrissin*	Leguminosae	4,6	a, b, c, l	leaves used as green manure; young leaves poisonous to livestock
Ritha	*Sapindus mukorossi*	?		b, l	fruits used as soap
Saj	*Terminalia tomentosa*	Combretaceae	4	a, b, c	
Sal	*Shorea robusta*	Dipterocarpaceae	4,6	a, b, c	wood for ploughs
Sati bayer	*Rhus parviflora*	Anacardiaceae	4,5	a, b, f, l	edible fruits
Seto siris	*Albizia procera*	Leguminosae	4,6	a, b, l	leaves used as green manure
Shyalfusro	*Grewia oppositifolia*	Tiliaceae	4	a, b	
Sigourae	?	?		a, b, d	wood for yorkes
Silange	?	?		a, b	
Siltimur	*Litsea cubeba*	Lauraceae	4	a, b, l	fruits used for relishes and as medicine against diarrhoea and tooth ache
Simal	*Bombax ceiba*	Bombacaceae	4	b, l	wood valued for furniture making
Simali	*Vitex negundo*	Verbenaceae	4	a, b, f, l	wood for sickle, spade and axe handle; leaves used as green manure
Sindurae	?	?		a, b	
Somi	*Ficus benjamina*	Moraceae	4,3	a, b	
Suntala	*Citrus nobilis*	Rutaceae	4	b, g	primarily grown for fruits
Syaau	*Pyrus malus*	Rosaceae	4	b, g	primarily grown for fruits
Tanki	*Bauhinia purpurea*	Leguminosae	4	a, b, l	young shoots used as vegetables; wood for *thaki* and *harpe*
Tatola	*Oroxylon indicum*	Bignoniaceae	4	a, b, l	leaves used as green manure; flowers used during religious ceremonies
Tejpat	*Cinnamomum tamala*	Lauraceae	4	b, l	leaves used for relishes
Tilke	?	?		a, b	
Tooni	*Toona ciliata*	Meliaceae	4	a, b, c	
Tusare	*Debregeasia salicifolia*	Urticaceae	9	a, b	
Utis	*Alnus nepalensis*	Betulaceae	4	a, b, c, l	leaves used for compost making

APPENDIX 2.C A SIMPLIFIED QUALITY RATING OF SPECIES FOR MAJOR TREE PRODUCTS RECORDED IN THE INVENTORY

A simplified quality rating (scale 1 to 3; Appendix 2.A) of each species for major tree products (fodder, fuelwood, timber and fruits including fodder characteristics) as assessed by key informants and elevational range over which they were found growing (sorted by overall frequency of occurrence) is given. The symbol (*) indicates disagreement between informants over the value of the species for a given purpose and (n) indicates the species being not used for a given purpose.

Local name	Botanical name	Fodder characteristics	Rating				Elevation		
			Fodder	Fuelwood	Timber	Fruit	Aule	Lekh	Total
Utis	*Alnus nepalensis*	m, e, p	3	1	1	n	16	978	994
Dudhilo	*Ficus nemoralis*	a, d, g, k, o, p	1	1	2	n	61	819	880
Ghurmise	*Leucosceptrum canum*	b, d, g, h, o, p	1	1	n	n	1	702	703
Simali	*Vitex negundo*	c, d, p	1	1	n	n	364	0	364
Tanki	*Bauhinia purpurea*	a, d, g, h, o, p	1	2	n	n	289	3	292
Sati bayer	*Rhus parviflora*	c, d, p	1	1	n	1	277	7	284
Chilaune	*Schima wallichii*	m, e, p	3	1	1	n	182	82	264
Dhusure	*Colebrookia oppositifolia*	b, d, p	1	1	n	n	178	18	196
Painyu	*Prunus cerasoides*	m, e, j, k, l, p	3	1	1	n	16	179	195
Rato siris	*Albizia julibrissin*	b, d, g, o, p	1	2	2	n	85	98	183
Mal bans	*Bambusa nutans*	b, d, g, h, o, p	1	3	1	n	92	66	158
Nebharo	*Ficus roxburghii*	a, d, g, o, p	1	*	n	3	2	123	125
Ghangaru	*Pyracantha crenulata*		n	1	n	*	31	67	98
Khotae Salla	*Pinus roxburghii*		n	1	1	n	96	0	96
Gayo	*Bridelia retusa*	c, f, j, o, p	2	1	1	n	92	0	92
Latikath	*Coronus oblonga*	c, d, p	1	1	n	n	0	88	88
Kagati	*Citrus aurantifolia*		n	1	n	1	75	9	84
Ambak	*Psidium guajava*		n	1	n	1	73	7	80

Choya bans	*Dendrocalamus hamiltonii*	b, f, h, o, p	1	3	1	n	2	76	78
Parayang	*Arundinaria spp*	b, d, g, h, o, p	1	n	n	n	0	75	75
Angerii	*Lyonia ovalifolia*	m, e, p	3	1	n	n	52	23	75
Faledo	*Erythrina variegata*	m, e, p	3	*	n	n	59	12	71
Bhimsenpati	*Buddleja asiatica*	b, d, p	1	1	n	n	8	53	61
Badahar	*Artocarpus lakoocha*	b, d, g, h, o, p	1	2	2	1	51	10	61
Darim	*Punica granatum*		n	1	n	1	60	0	60
Asare	*Lagerstroemia parviflora*	m, e, p	3	1	n	n	0	55	55
Mayal	*Pyrus pashia*	c, d, p	3	1	n	1	4	48	52
Keraa	*Musa spp*		n	n	n	1	34	15	49
Gogun	*Saurauia nepaulensis*	a, e, o, p	3	2	n	*	0	48	48
Kutmero	*Litsea polyantha*	c, d, g, o, p	1	2	*	n	21	24	45
Bhayalo	*Rhus succedanea*	m, e, p	3	1	n	n	18	27	45
Mahuwa	*Madhuca indica*		n	1	*	n	42	1	43
Chuletro	*Brassiopsis spp*	a, f, o, p	2	*	n	n	7	35	42
Kaingyu	*Wendlandia exserta*	m, e, p	3	2	n	n	9	29	38
Guras	*Rhododendron arboretum*		n	1	*	n	2	35	37
Kimbu	*Morus alba*	c, d, g, o, p	1	2	n	*	5	31	36
Khirra	*Wrightia antidysenterica*	m, e, p	3	*	n	n	26	10	36
Khasre Khanyu	*Ficus semicordata* var. *semicordata*	b, f, o, p	2	*	n	n	26	9	35
Jayamir	*Citrus jambhiri*		n	1	n	1	24	10	34
Shyalfusro	*Grewia oppositifolia*	c, f, o, p	2	1	n	n	33	0	33
Seto siris	*Albizia procera*	b, f, o, p	2	2	n	n	10	18	28
Bilaune	*Maesa chisia*	m, d, p	1	1	n	n	1	27	28
Aaru	*Prunus persica*		n	1	n	1	9	19	28
Aalcha	*Prunus spp.*		n	1	n	1	12	16	28
Siltimur	*Litsea cubeba*	m, q, i, p	*	3	n	3	4	23	27
Bhogate	?		n	1	n	3	17	10	27
Tooni	*Toona ciliata*	m, e, o, p	3	1	1	n	25	1	26
Rai khanyu	*Ficus semicordata* var. *montana*	b, d, g, o, p	1	*	n	3	12	12	24
Hallaudae	?	m, e, p	3	2	2	n	24	0	24
Gidari	*Premna spp*	c, d, i, o, p	1	2	n	n	22	2	24
Bhakimlo	*Rhus semialata*	c, e, p	3	3	n	3	18	6	24
Musurae katus	*Castanopsis tribuloides*	m, q, p	*	1	*	*	22	0	22
Dhayero	*Woodfordia fruticosa*	m, e, p	3	1	n	n	22	0	22
Amalla	*Embilica officinalis*	m, e, p	3	2	n	1	20	1	21
Keshari	*Lathyrus sativus*		n	1	n	n	0	20	20
Kamle	*Pilea wightii*	c, d, o, p	1	2	n	n	0	19	19
Kadam	?		n	*	n	1	18	0	18

Bakaino	*Melia azedarach*	b, d, p	1	2	n	n	18	0	18
Okhar	*Juglans regia*		n	2	n	2	2	15	17
Tusare	*Debregeasia salicifolia*	c, f, o, p	2	2	n	n	0	16	16
Naspati	*Pyrus cumminus*		n	1	n	1	4	12	16
Jamuna	*Syzygium cumini*	c, f, o, p	2	2	2	2	16	0	16
Sal	*Shorea robusta*	m, f, o, p	2	1	1	n	15	0	15
Lankuri	*Fraxinus floribunda*	m, f, o, p	2	3	n	n	5	9	14
Aap	*Mangifera indica*		n	1	1	1	14	0	14
Guyelo	*Elaeagnus latifolia*	m, e, p	3	2	n	n	13	0	13
Bhalu bans	*Dendrocalamus hookeri*	b, f, h, o, p	1	3	1	n	0	13	13
Simal	*Bombax ceiba*		n	n	n	n	12	0	12
Karam	*Holoptelea integrifolia*	c, f, o, p	2	2	n	n	12	0	12
Kabro	*Ficus lacor*	a, f, k, o, p	2	2	2	3	4	8	12
Chuthro	*Berberis asiatica*		n	1	n	n	0	11	11
Chamlayo	?	c, f, o, p	2	2	1	n	8	3	11
Sigoure	?	m, f, o, p	2	1	n	3	6	4	10
Hardae	*Morinda citrifolia*	m, q, p	*	2	n	n	0	10	10
Khayer	*Acacia catechue*	b, d, o, p	1	1	n	n	9	0	9
Hadchur	*Viscum articulatum*	c, f, o, p	2	2	2	n	8	1	9
Tatola	*Oroxylon indicum*	c, q, o, p	*	3	n	n	8	0	8
Suntala	*Citrus nobilis*		n	1	n	1	8	0	8
Sindurae	?	m, e, p	3	2	n	n	3	5	8
Dhalne katus	*Castanopsis indica*	m, q, p	*	1	*	*	7	1	8
Nigalo	*Arundinaria intermedia*	b, d, g, h, o, p	1	n	n	n	0	6	6
Bel	*Aegle marmelos*	c, q, p	*	1	n	2	6	0	6
Anar	*Punica spp*		n	1	n	1	6	0	6
Tilke	?	c, d, o, p	1	1	n	n	5	0	5
Kholme	*Symplocos spp*		n	2	n	n	0	5	5
Khasreto	*Ficus hispida*	c, f, o, p	2	*	n	n	5	0	5
Kharane	*Lindera pulcherrima*		n	1	n	1	4	1	5
Jhigane	*Eurya acuminata*	m, e, p	3	2	n	n	0	5	5
Dhupi	*Juniperus wallichiana*		n	n	n	n	2	3	5
Champ	*Michelia champaca*	m, q, o, p	*	2	1	n	1	4	5
Barro	*Terminalia belerica*	c, f, o, p	2	2	2	3	5	0	5
Aat	?		n	*	n	n	5	0	5
Syaau	*Pyrus malus*		n	2	n	1	1	3	4
Malledo	?	m, q, p	*	2	n	n	0	4	4
Hoksae	*Citrus grandis*		n	2	n	1	4	0	4
Darimpate	?	c, e, p	3	1	n	n	4	0	4
Pipire	?	c, f, p	2	3	n	n	2	1	3

Pipal	*Ficus religiosa*	m, f, o, p	2	*	n	n	3	0	3
Maleto	*Macaranga pustulata*	m, e, p	3	2	n	n	1	2	3
Junar	*Citrus spp*		n	1	n	1	2	1	3
Harro	*Terminalia chebula*	c, f, o, p	2	2	2	1	3	0	3
Dabdabe	*Garuga pinnata*	c, f, o, p	2	2	3	n	3	0	3
Bokae timur	*Zanthoxylum armatum*		n	2	n	1	3	0	3
Tejpat	*Cinnamomum tamala*		n	n	n	n	0	2	2
Saj	*Terminalia tomentosa*	c, e, o, p	3	2	1	n	2	0	2
Ritha	*Sapindus mukorossi*		n	2	n	1	2	0	2
Katahar	*Artocarpus integra*	m, e, p	3	1	n	1	2	0	2
Dudhae lahara	?	c, d, g, o, p	1	n	n	n	0	2	2
Datharum	?		n	*	n	n	2	0	2
Bains	*Salix spp*	m, q, p	*	3	n	n	0	2	2
Babis	?	m, e, p	3	2	3	n	0	2	2
Arkhaulo	*Quercus fenestrata*	m, e, p	1	1	n	n	1	1	2
Somi	*Ficus benjamina*	m, q, o, p	*	3	n	n	1	0	1
Silange	?	m, q, o, p	*	2	n	n	0	1	1
Patpatae	*Leycesteria formosa*	m, q, p	*	2	n	n	1	0	1
Padori	*Stereospermum personatum*	c, f, o, p	2	2	3	n	1	0	1
Odal	*Sterculia villosa*	c, f, o, p	2	2	3	n	1	0	1
Nibuwa	*Citrus lemon*		n	1	n	1	1	0	1
Mewa	*Carica papaya*		n	n	n	1	1	0	1
Lapsi	*Choerospondias axillaris*		n	1	3	1	0	1	1
Koiralo	*Bauhinia variegata*	c, e, j, o, p	3	2	n	n	1	0	1
Khari	*Celtis australis*	c, d, g, o, p	1	1	n	n	0	1	1
Kaulo	*Machilus odoratissima*	c, d, o, p	1	1	n	n	1	0	1
Kafal	*Myrica esculanta*		n	2	n	1	0	1	1
Gohore	?		n	2	n	n	1	0	1
Char chare lahara	?	c, d, o, p	1	n	n	n	0	1	1
Bandrae	*Cynocardia odorata*		n	3	n	n	0	1	1
Baar	*Ficus bengalensis*	c, f, o, p, i	2	3	3	3	1	0	1
Archal	?	m, e, p	3	2	n	3	1	0	1