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Soils, cultivars and livelihoods in North East Nigeria.

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Soils, Cultivars and Livelihoods in North East Nigeria

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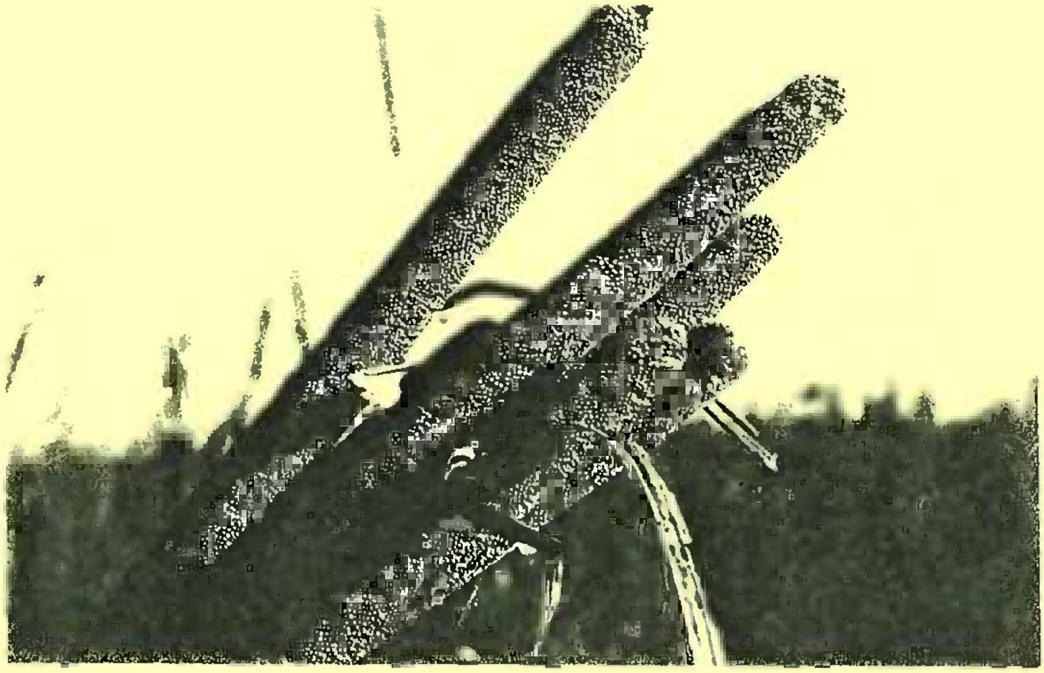

Project ZE0008 (R6051)
Department for International Development
Renewable Natural Resources Research Strategy
Semi-Arid Production System
(Managed by Natural Resources International)

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1 Executive Summary

This Report includes work completed both under the terms of the project *Soils, Cultivars and Livelihoods under Intensifying Aridity in NE Nigeria* (RNRRS Semi-Arid Production System; project no. ZE0008 [until April 1996 R6051]), 1994-199. Where appropriate it also draws data from its predecessor funded by the ESRC (1992-1994, reported in March, 1994), as the two form an integrated five-year study.

The project's purpose is to contribute to the attainment of the ODA's goals of poverty alleviation and mitigation of environmental problems with special reference to semi-arid agropastoral systems in the north-east of Nigeria. The study villages are chosen to reflect a gradient of decreasing rainfall and population density in order to set these goals in the context of climate change, population growth and the degradation scenarios frequently canvassed for the Sahel. The project addresses four constraints that are interlinked in the systems: labour and its management; soil fertility and its enhancement or maintenance; the diversity of genetic resources and their management, with special reference to millet; and household livelihood options and constraints.

Research activities were spread over five years (of which two were funded under the predecessor of the present project, financed by the ESRC), during which field work was sustained in the four villages for four consecutive agricultural seasons. Characterisations of the four farming systems were executed and inventories prepared of technologies, cultivars, soil types and other components of resource portfolios. Land use change over 30-40 years was measured using air photographs. Labour use by members of collaborating households in each village was monitored. In conjunction with rainfall data obtained in the villages, the relations between rainfall and the use of farm labour were mapped. Farm and non-farm labour interactions were measured. With regard to soils, fertility under classified management regimes in each system was investigated by means of field sampling and laboratory analyses (in Nigeria); farmers' methods of fertility management were inventoried and assessed. With regard to cultivars, samples of pearl millet were analysed for genetic diversity (in the UK) and the results interpreted in the light of farmers' methods of managing cultivar diversity. With regard to livelihoods, households' use of options for generating farm and non-farm incomes in the four villages were comprehensively surveyed and related to controlling variables such as food sufficiency and market access.

The management of labour and of technological or economic options by households is the key to enhancing output in these semi-arid systems of low biological productivity. The study has enlarged understanding, not only of these systems, but of how the labour constraint is managed by smallholders through time (within and between seasons, and over the longer term), and in space (labour inputs per hectare). The most intensive system is managed the most sustainably. The linkage, commonly assumed, between population growth and environmental degradation is reversed by this study.

The study's outputs on farming system diversity and on the linkages between rainfall and labour use will be of value to development agencies such as rural development programmes; those on farm and non-farm labour to policy makers concerned with multi-sectoral approaches to rural poverty alleviation; those on womens' farming to designers of interventions on behalf of womens' welfare; those on labour use per hectare to agricultural planners concerned with adaptive planning for systems under transformation; those on soil fertility management to all concerned with environmental policy, including international agencies and research organisations working in the Sahel; those on cultivar management to extension organisations promoting 'improved' varieties; and those on livelihoods to the debate on 'enabling' policy environments.

2. Background

2.1 Researchable Constraints:

The **purpose** of the Department for International Development's Renewable Natural Resources Research Strategy is to 'enhance productive capacity on an environmentallay and economically sustainable basis'. The **goals** of the RNRRS are poverty alleviaton and the mitigation of environmental problems. This project addresses this purpose and goals directly, within the Semi-Arid Production System, in one of the poorest regions on earth, the Sahel.

The Sahel is commonly perceived to be facing crises both in natural resource management and in poverty alleviation. These are linked in a 'nexus' (Cleaver and Schreiber, 1994) of interrelationships among the major factors which include, according to various authors, rapid population growth, low bioproductive potential, environmental degradation, rainfall decline, inadequate infrastructure, social and technological conservatism, inappropriate agricultural policies, international debt, and unfavourable global market trends. Superficial assessment and explanation of the processes of degradation have obscured, rather than clarified an understanding of natural resource management and its dynamics in time. This applies in particular to the process of land use intensification as communities respond through technological change to population and market pressures, and also to the property of adaptive flexibility with which communities defend themselves against risk, emanating from both nature and the political economy. These two cannot be adequately investigated using traditional research approaches such as agricultural economic input-output models, crude correlations between demographic and other variables, or diffusionist analyses of 'improved' technologies.
The project has focused on the following researchable constraints:

climate (both rainfall decline and variability)
labour management
soil fertility
genetic resources
livelihoods

All these are clearly identified and understood by farming households, and hence demand for project comes from grassroots. This project follows a 2-year study funded by Economic and Social Research Council (Global Environmental Change Programme (*Agropastoral Adaptation to Environmental Change in Northern Nigeria*, Project No. L320253001). In particular, it built upon insights developed at a linked ESRC GEC Workshop held in Cambridge in March 1994 on *Agropastoral Adaptation to Environmental Change*. The research grows out of work by M. Mortimore and others (e.g. *Adapting to Drought: farmers, famines and desertification in West Africa*, Cambridge University Press 1989). The present project reflected demand identified through links with researchers in the UK, Europe, Nigeria and elsewhere in West Africa, with development organisations (governmental and non-governmental) in the UK and West Africa which confirmed demand for the present research. However, the chief evidence for demand was in the ideas and opinions of farmers in the Sahel zone of Nigeria themselves.

2.2 The Research Context

2.2.1 Drylands in Crisis: The Threat of Degradation

A vast literature on semi-arid Africa is devoted to the threat both to human life and the quality of life posed by drought and environmental degradation. The concept of 'desertification' has a long history in sub-Saharan Africa, and since the 1970s has had an important place in the thinking of government officials, development planners and researchers (Grove, 1977; United Nations, 1977, Verstraete, 1986). Desertification is now effectively an 'institutional fact' enshrined internationally in the Desertification

Desertification is now effectively an 'institutional fact' enshrined internationally in the Desertification Treaty (Swift, 1996). However, simplistic narratives that portray desertification caused by human and livestock population growth are now being challenged (e.g. Mortimore, 1989; Thomas and Middleton, 1994; Warren, 1996). There is increasing awareness of the complex patterns of past climatic change in space and time, and of that rainfall in Sub-Saharan Africa should be understood in the context of variations in oceanic and atmospheric circulation at a global scale (Glantz, 1992; Hulme, 1996; Nicholson, 1996). Despite the caution that this natural science research might suggest, commentators continue to frame debates about rural Africa in terms of environmental disaster and agrarian crisis (e.g. World Bank 1990; Morgan and Solarz, 1994; but see Watts, 1989).

The impacts of population pressure in sub-Saharan Africa on the environment has become conventional wisdom among many researchers and policy-makers (Leach and Mearns, 1996a). This neo-Malthusian conventional wisdom portrays population growth as the critical forcing factor in relations between people and environment. Population pressure is held to cause increased demands for food by rural producer/consumers and urban consumers, increased cultivated areas, reduction of fallow intervals without compensating inputs, and consequently reduced soil fertility, or 'soil mining'. These changes in turn cause declining yields per capita and per ha, food scarcity for rural people, and costly food import strategies for the urban poor. Environmntaly, these changes are seen to promote soil fertility loss and soil erosion, and wider environmental degradation such as the loss of critical biodiversity.

2.2.2 Degradation and Intensification

Recent research has begun to challenge conventional environmental narratives in Sub-Saharan Africa, including that about anthropogenic reduction of biological productivity and soil fertility (Roe, 1991, 1995; Leach and Mearns 1996b). Evidence from cross-country comparisons that evidence of agricultural 'crisis' is at best exaggerated (Wiggins, 1995). In West Africa, the Club du Sahel's *West African Long-term Perspectives Study* attempts to forecast change within the regional economy (much of which lies outside the formal sector). This work descibes and growing urban-rural and urban-urban interaction with rising population, and forecasts growing synergistic regional economic links between Sahel and coastal regions (Snrech, 1994). An increasing number of studies are focusing on the agency of rural producers as they make decisions and work to deal with difficult economic and environmental conditions. At the farm and village level, studies in the Kano Close-Settled Zone (KCSZ) and nearby areas of Nigeria and Niger (Mortimore, 1989; Mortimore and Tiffen, 1996), and in Machakos District in Kenya (Tiffen, Mortimore and Gichuki, 1994; Mortimore and Tiffen, 1995) suggest that outcomes very different from the standard degradation scenario can occur. Under the right conditions, small farmers can and will invest in their land as populations rise, creating 'landesque capital' such as terraces (Brookfield, 1984; Blaikie do Brookfield, 1987), or adopting technologies that increase production and income per ha. These studies follow Boserup (1965), in emphasising the economic benefits of population growth that counter (to different extent in different places) the problems.

Agricultural intensification may be defined as 'increased average inputs of labour or capital on a smallholding, either on cultivated land alone, or on cultivated and grazing land, for the purpose of increasing the value of output per hectare' (Tiffen *et al.*(1994, p. 29). This definition includes an increase in the intensity of the use of labour, increases in labour inputs per ha, and the creation of landesque capital (for example in the form of soil /water conservation structures or irrigation systems), and but also changes in land management. This defininiton can usefully be expanded to include changes in cultivation frequency (or fallow interval), in the percentage of land cultivated, in the farming technologies used, in the methods used to manage soil fertility, in the crops selected, in the ways in which crops and livestock are integrated, and in the management of rangeland and trees (Mortimore 1995).

It is possible to imagine a model of agricultural ecosystems in which, over time, rising human populations are indeed accompanied by declines in edible primary production and in soil fertility. At low populations densities such declines may not matter (because extensification is an option), and may not be possible to correct (because there is too little labour to invest in intensive agricultural practices). However, at some level of population density it both becomes less feasible to extensify and more possible to intensify. At this point, one might expect agricultural intensification to take place, as farmers make investments in the productive potential of their land.

Historically, intensive agriculture has been relatively rare in sub-Saharan Africa. In *Africans:the history of a continent,* Iliffe (1995), traces the historical struggle rural Africans to cope with (and overcome) the limited supply of labour, and their consequent need to evolve strategies for environmental management and for subsistence that could be effective with low labour inputs.

Formal agricultural development has tended to seek to bring about intensification through planned capital investments in mechanisation, irrigation, integrated agricultural development projects that have been created in rural Africa in successive waves of aid investment. Intensification has been conceived in narrowly-defined technical terms, with machinery and pesticides substituted for labour in cultivation and weed and pest control, and synthesised chemical fertilisers substituted for the labour-intensive use of the local ecosystem and by-products of local agropastoral systems. There are examples of indigenous intensive agriculture in sub-Saharan Africa, for example among the Kofyar on the Jos Plateau in Nigeria (Netting 1968) and the various forms of irrigation (Sutton 1989, Richards 1985, Adams 1992). However, historically, indigenous intensive production has been unusual until late in the Twentieth Century: Sub-Saharan Africa has been land-rich and labour-scarce, and faced with increasing populations and declining yields, most Africans have preferred to move.

2.2.3 Intensification and Risk

Recognition of the skill with which human resources have been deployed in the control of the environment, and with which farming has been adapted to environmental variability, should not lead to the assumption that intensification was an obvious, easy or attractive option. Sutton (1989) emphasises that most extensive cultivation systems were specialised (technologically complex, ecologically sound and flexible) in just the same way as those which were also intensive (indeed, he argues that the extensive stone-lined canals and fields of the Engaruka irrigation systems was over-specialised, hence its abandonment in the Seventeenth Century). He suggests that where agricultural systems remained extensive, it was because they were more efficient in their use of available labour in relation to the returns needed from the land. He suggests that 'To attempt more elaborate, more 'intensive' and laborious methods is always a risk, one sensibly undertaken only if both the needs and the expectation of rewards are overwhelming' (Sutton 1989, p. 100).

Intensification can be both risky and costly. Intensification becomes attractive when the returns to extra labour on existing lands exceed those of acquiring and breaking new land, for example as the 'frontier' closes and new land becomes unavailable, where there are point resources, or where markets dictate (for example in the Kano Close-Settled Zone). Agricultural intensification is a social process, demanding extensive and focused social organisation at either the household or the community level (or both). Decisions about intensification are not made in isolation from wider issues of labour allocation, both within farm work and between on and off-farm activities. It therefore follows that while the process of intensification may be driven by economic factors, these do not determine the same outcomes in different places and at different times.

There is no simple relationship between intensification and sustainability. Agricultural intensification may result in the creation of landesque capital (such as the terraces of Machakos), or the maintenance or enhancement of natural capital in the form of soil fertility (Bayliss-Smith, 1996). However, intensification may not increase the stock of natural capital, and may indeed reduce the natural capital of a farm (notably in the form of soil fertility) if the agricultural ecosystem is squeezed to maximise production in a way that does not invest in fertility maintenance. Such intensification is not sustainable. Moreover intensification may be reversed,as Robert Netting describes in the case of the Kofyar in Nigeria, who abandoned intensive methods when they moved off the Jos plateau to the relatively land-plentiful plains, re-establishing more intensive methods when the new frontier in turn began to close. The sustainability of particular episodes of intensification must therefore be empirically demonstrated and not assumed. Intensification (and degradation) are not processes that occur passively. Niemeijer (1996) suggests that 'in dynamic environments the survivors are those that rapidly adapt, not those who specialise too narrowly' (p. 93). Non-equilibrial environmental systems (c.f. Behnke, Scoones and Kerven, 1993) and externally forced economic change provide a risky and uncertain environment for decision-making.

It would be mistake to dismiss low intensity farming and land use systems as merely the ill-regulated converse of intensive systems, waiting for a critical threshold of population density to prod them into a new course of evolution up an intensification gradient. In the Sahel, the gradient of diminishing rainfall corresponds to that of diminishing land use intensity. Furthermore, the coefficient of variation in annual rainfall is statistically linked to rainfall amount. Thus as land use intensity declines, risk increases. We would argue that an indigenous response to such risk is flexibility, founded on both diversity of choice in natural resource management and in the selection of livelihood strategies. It is this flexibility in response to risk, and in the adoption of intensive agroiculture, that is a particularly importantfocus of work in this research project.

2.2.4 Intensive Agriculture in the Nigerian Sahel

Research on intensive agriculture in northern Nigeria has been carried out for several decades, particularly in the KCSZ (Grove, 1961; Mortimore and Wilson, 1965; Hill, 1977; Mortimore, 1989; Mortimore, 1993a). The intensive agriculture of this ring of densely populated land around Kano city, and its park-like, almost manicured, appearance was noted by Nineteenth Century visitors such as Heinrich Barth (Barth, 1857). By 1913, not more than one third of the farmland was in fallow in any one year. Harris (1996) reports the results of studies on nutrient cycling in the survey village in the CSZ, Tumbau. Soil fertility is maintained by labour-intensive management involving the intagration of livestock and crops (Harris, 1996; Yusuf, 1996). *Taki* (Hausa: compound sweepings or animal manure, especially from small ruminants) is a vital factor in maintaining the physical properties of the soil and in providing chemical inputs (particularly phosphorous), although Harmattan dust and mulch from the unused foliage and stems of intercropped legumes are also important. Harris has analysed the cycling of nutrients through this systyem. The KCSZ is 'an example of a farming system which has reached the point in the intensification process at which all land is under cultivation, all palatable crop resides are used as fodder, and trees are conserved' (Harris, 1996, p. 13).

Agricultural intensification is historically uncommon in SSA, but, given rising population densities in the present century, it provides a forseeable way forwards for an increasing number of poor communities. As outlined at the beginning of this section, this research explores the constraints on production by village households in the Nigerian Sahel (climate (both rainfall decline and variability, labour management, soil fertility, genetic resources and livelihoods, and the factors affecting decisions about the allocation of effort between different livelihood options.

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3. Project Purpose:

3.1 Project Purpose

The fundamental purpose of this project has been to improve theoretical and empirical understanding of decision making with regard to natural resource management in dryland areas. The focus of this study is the household, the constraints on income and livelihood sustainability that are placed by environmental variability and change, and the responses that households make to the threats and opportunities that they face. These responses, and the broader capacity of resource users to innovate and manage their environment and household economy in the face of imposed constraints, represent a significant opportunity for development.

This project has responded to researchable constraints in the following ways:

climate (both rainfall decline and variability)
The project has two objectives. First, to set the study sites in the context of regional climatic change; second, to measure rainfall variability in each village over four years, and relate these variations directly to decisions by farming households about natural resource and livelihood management. The project sought to make these links at the micro-scale of a single village, rather than attempting to relate regional accounts of environmental variability to village-level socio-economic studies.

labour management
The project recognises that under conditions of primarily hand technology, the major controllable constraint on production from natural resource systems is labour (not land, or capital). The project therefore sought to monitor decisions about labour management at the household level under different conditions of ecology and population density over four consecutive wet seasons. Households were selected in such a way that the effects of differential endowments of both labour and land on resource management could be explored by including both larger and smaller households. Under conditions of agricultural change, the impact of labour constraints on technology (e.g. hiring of ox ploughs, choices about fallowing, use of manure or fertiliser) is likely to be significant in identifying development priorities.

soil fertility
Farmers in the Nigerian Sahel recognise that increasing population density (decreasing supply of land) generates an imperative for intensification (as, now, do researchers). This sets a premium on fertility mangement technologies. However, the economic viability of inorganic fertilisers is questionable at current and forseeable input prices (manufacture, transport costs are high, and are likely to remain so), except for high value crops. Therefore, methods of managing and enhancing soil fertility using locally available resources become increasingly critical. Against the paradox that more densely populated systems in the Nigerian Sahel (e.g. the Kano Close-Settled Zone) appear to be the most sustainable, particular attention was therefore paid to the form and success of methods of fertility maintenance.

genetic resources
Environmental variability places a particular premium on the ability of farmers to manage genetic resources adaptively. It is recognised by farmers (and researchers) that local crop types can be closely adapted to particular sets of environmental conditions, or to have other desirable attributes (e.g. phenology, morphology, taste, pest resistance). In view of this, crop diversity is an important resource, and its maintenance is an important longer-term objective farmers. Promotion of the ability of farmers to continue to manage crop divertsity is an important task within agricultural development. The project sought to identify local types of all major dryland crops in the Nigerian Sahel, and explore the

genetic basis for differences between and within locally identified crop types in the most important grain crop, pearl millet.

livelihoods
Resource users in the Sahel draw on a range of different activities to supplement incomes from agriculture, especially when this is threatened by climatic variability or environmental degradation. These activities are constrained by access to markets and temporary employment. They are also constrained by the household's resources of labour and the opportunity costs of income diversification versus crop and livestock production. The balance between farm and off-farm incomes will vary with ecology, rainfall in a particular year and the demographic composition of the household and its resource endowment. The solution to this problem is highly specific to village and household, and the project set out to investigate these specificities.

3.2 Research Questions

The project has adressed the following research questions:

climate (both rainfall decline and variability)
1) what are the agrometeorological implications of climatic change in the Nigerian Sahel?
2) what are the management implications for smallholders of rainfall variability at the local level?

labour management
1) how do smallholders allocate labour between tasks and locations during the course of the agricultural season?
2) how do these allocations reflect rainfall variability within and between seasons?
3) how do these allocations vary between villages with different rainfall amounts and agricultural intensities?

soil fertility
1) what are the indigenous systems for maintaining soil fertility (levels of key soil nutrients) under different levels of rainfall and population density?
2) to what extent are these systems effective in maintaining fertility in conditions?
3) what constraints operate on these systems that might prevent them from maintaining output of crops, livestock and economic biomass (forage, fuel. fruits etc.)?

genetic resources
1) how extensive if the crop type repertoire used by farmers in different envionmental conditions across the Nigerian Sahel?
2) how and why do farmers manage the diversity of seeds and plant materials?
3) what is the genetic basis of crop diversity, and what light can it throw on the ways in which farmers select crop type and their strategies for managing seeds?

livelihoods
1) how do resource users make decisions about allocating labour between agricultural and non-agricultural tasks (off-farm income diversification and livestock production)?
2) what are the implications of rainfall amount (ecology) and season for these labour allocation decisions?
3) what conditions promote effective utilisation of off-farm income sources?

4 Research Activities

4.1 Research Design

In order to fulfil the purpose set out in Section 3, the research project was designed in the following logical steps. (The Proposal document is reproduced as Annex 9 to this Report)

Scale
The household was chosen as the largest unit in which individual decisions can be understood. At the village, district or higher levels of scale resolution, individual decisions are necessarily aggregated, and causal relationships have to some extent to be inferred. At the individual level, on the other hand, collective action tends to be ignored. Households, notwithstanding much evidence for their internal complexity, not to mention the difficulties of defining them, still do operate as coherent management units in many areas of direct relevance to natural resource management - the family farm, the family grain store, the household livestock herd, etc.

Sampling
Depth was chosen in preference to breadth with regard to sampling. The reasons for this were (a) that a high level of collaboration was necessary with participating households, as it was intended to continue observations for several years, and continuity of participation was essential (i.e, separate samples could not be chosen in different years); and (b) that the nature of the information required did not permit a survey approach (relationships were to be analysed on the basis of individual decisions and not inferred statistically). About 48 households were recruited into the study. This decision tended to configure the nature of the enquiries that were made thereafter.

Ecology
In the Sahel, bands of diminishing average rainfall succeed one another northwards, and to take this characteristic into account, four sites were selected, one Sudanian (Tumbau, Kano State), one transitional (Dagaceri, Jigawa State), and two Sahelian (Kaska and Futchimiram, Yobe State) in ecology (average rainfall in 1992-96: 533 mm, 360 mm, 326 mm and 301 mm respectively). All are upland villages, though lowland (wetland) plays a part in two of them (Tumbau and Kaska). These locations are shown in Figure 4.2.

Population density
A gradient of density corresponds inversely to the rainfall gradient, from Tumbau to Kaska (Futchimiram is a little higher). Tumbau, which is in the Kano Close-Settled Zone, has as high a rural density as anywhere in the Sahel (>200), while Dagaceri (>50), Futchimiram (>30) and Kaska (<15) are more representative of other Sahelian areas.

Land use intensity
The four land use systems found in these villages describe a transect as they extend north-eastwards from the highly intensive Kano Close-Settled Zone through progressively drier areas to the extensive agro-pastoral systems of Kaska and Futchimiram. The small study hamlet in Tumbau is a Hausa village where annual cultivation has been carried on since the 19th century or earlier, fallows eliminated, and a high degree of integration between cropping and small ruminant husbandry has been achieved. Dagaceri is a large Manga farming community with a Hausa migrants' section, and its farmlands are increasingly intensively used, and interspersed with enclaves of rangeland under the control of Ful'be livestock owners. The Manga study hamlet in Kaska lies close to the Niger border, an area of complex land systems which supports both rainfed farming on former dunes, which are otherwise grazed, and bottom land cultivation in clay basins. The study hamlet in Futchimiram is a Badowoi community of farmers and livestock owners who maintain enclaves of shifting cultivation within grazed and wooded parkland.

Market access
It was intended to include a gradient of market access in the design, based on increasing distance from the regional market of Kano, but such is the ubiquity of the urban and rural periodic market system in Nigeria that it is doubtful whether such an assumption has validity. It is the nature of market participation rather than its level which changes according to geographical location.

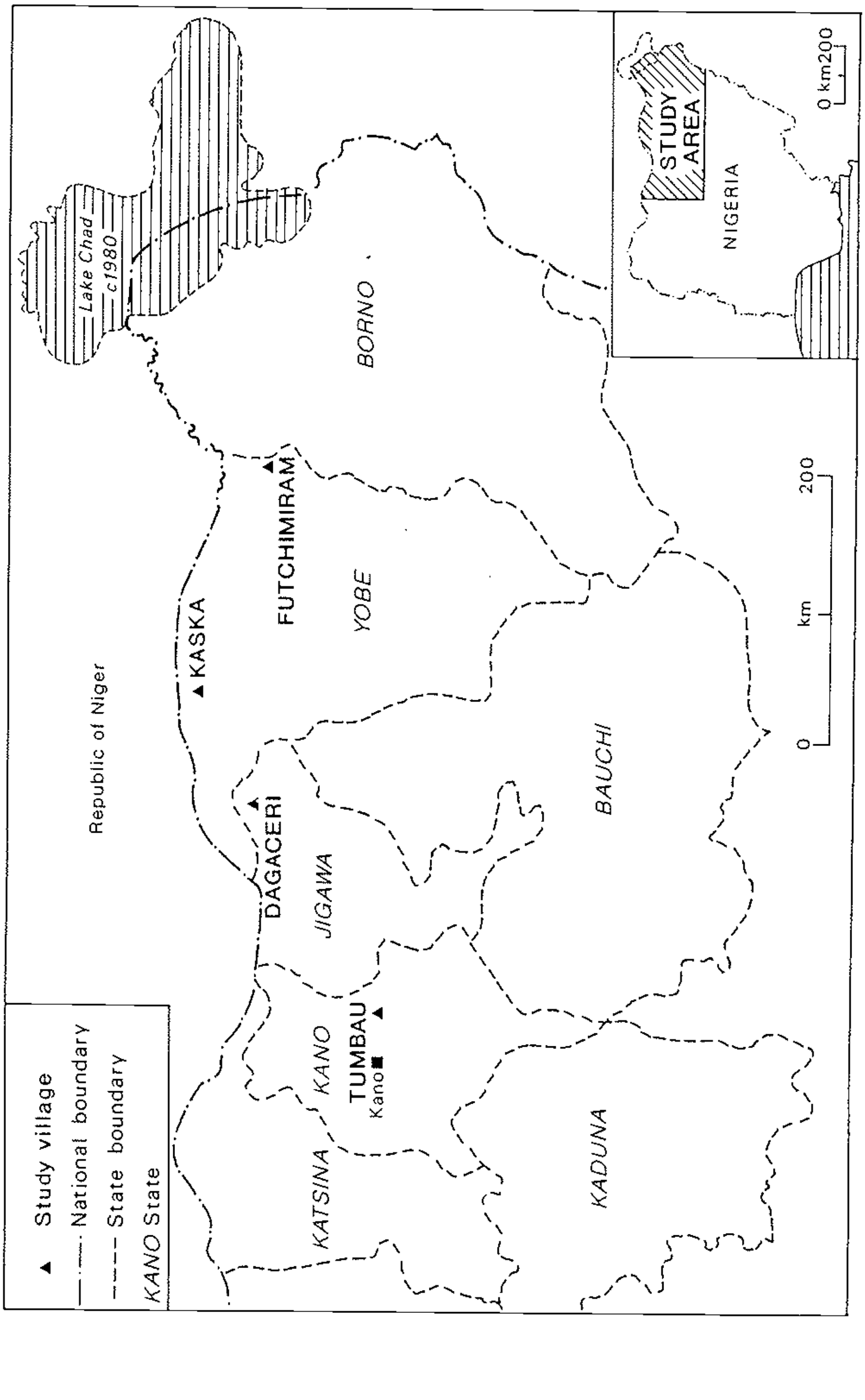
Time perspective
Adaptive management of environmental change must be analysed in a longitudinal framework, and failure to do this has been responsible for many superficial or misleading diagnoses of degradation. Two dimensions of change through time have been incorporated into the study. First, four consecutive years' observations were sustained with the same collaborating households, in order to take account of inter-year variability. Second, greater depth was imparted through archival studies of environmental management in the first 20 years of the century, using colonial records, and through sequential air photo interpretation of land use change since 1950.

Adaptive labour management
Labour is the major constraint (under the farmer's control) affecting output in a system of hand technology, and this is true in the intensive system as well as the more extensive ones. Therefore labour management forms a proper focus for a study of natural resource management. To pursue this question at the household level called for high frequency monitoring of the sampled households during each agricultural season. The acquisition of this data was assigned a high priority in the execution of the study. In order to relate this data to rainfall, rain gauges in each village were necessary.

Multi-sectoral scope
The household (and village) economy is run as a whole and the interactions between its components (such as crop production, livestock management, marketing, food processing, resource access, migration) involve decisions based on such considerations as the opportunity costs of labour time, cultural practices regarding the division of labour between the sexes, food sufficiency at the household level and many others. An initial target was therefore the characterisation of the farming-natural resource system in each study area.

Components
In relation to natural resource management, and adaptive management of labour, three components of the multi-sectoral household economy were prioritised: (a) soil fertility management, (b) cultivar management, and (c) livelihood management. The interactions amongst these three components, mediated through labour allocative decisions, were expected to generate new insights into natural resource management in these semi-arid systems.

FIGURE 4.1
Location of the study villages



4.2 Methods Used in Data Collection

As a consequence of the three principles outlined in Section 4.1, a range of methodologies was used to handle different kinds of data. In the following section, we describe these with organisational details where relevant.

Rainfall

Regional rainfall data for synoptic stations (Kano, Maiduguri, Potiskum, Nguru) since the beginning of records was provided by the Climate Research Unit, University of East Anglia, and analysed in conjunction with FAO and other data in a special study of the agroclimatological implications of rainfall trends and global warming scenarios, which was commissioned under Phase I (Page, 1994).

Automatic tipping bucket rain gauges supplied by Didcot Instruments were installed in each of the four villages under community care, with a control at Garin Alkali, the headquarters of the North East Arid Zone Development Programme, where a manual gauge is maintained. We collaborated with a NERC TIGGER project on aquifer charge and climate change (British Geological Survey), which provided two of five gauges. Installation on specially built tables was carried out before each rainy season and the loggers were removed after the end of the rains. Supervision and maintenance were done in co-operation with the Department of Geography, Bayero University, where the electronic loggers were downloaded. Blockages by airborne material caused two single-season failures (Futchimiram in 1992 and Tumbau in 1994), and faults caused another (Dagaceri in 1996). The rainfall is recorded in units of 0.1 mm and one minute, which were aggregated to daily totals using the software provided.

Regional desertification

A special study was commissioned in Phase I (Olofin, 1994) to review available literature on soil erosion and degradation in northern Nigeria.

Population density

At the local government (formerly district) level, census data is available for 1952, 1963, and 1991 (total males and females only). No village level data is available after 1952, except for the officially banned census of 1962. A population enumeration was carried out in the Dagaceri study area, covering about 50% of the area mapped for land cover change (see below). Enumerations were not possible in the other study areas, except in the study hamlets themselves. These last were used to derive a density quotient per hectare of compounds plus streets. Using land cover mapping based on air photography, projections were made to estimate the population of all settlements within the mapped areas. These were then converted to densities. As a check on these estimates, 'agricultural population densities' were derived from cadastral surveys of sample households' fields and demographic surveys of sample households' populations.

This range of estimates provides the best available basis for the population density variable which is critically important in relation to land use intensity. An attempt to estimate historical densities using older air photographs was considered but rejected on the grounds of their poor quality or small scale.

Land use and vegetation change

Highly detailed mapping of land cover was required in each study area which would generate compatible data between villages and over time. Unless detail to approximately the field level is obtained, it is not possible to link the remotely sensed data directly with household level field investigations. Earth satellite data lacks both the resolution and the time depth required. Standard vertical air photography contracted originally for topographical mapping was chosen for our purpose. However owing to many reorganisations of government mapping units in Nigeria, locating the older photography proved difficult. The most recent photography (1981 or 1990) was obtained in Kano or

Garin Alkali. The older photography was made available by the Overseas Surveys Directorate of the Ordnance Survey at Southampton, with the permission of the Director of Federal Surveys.

Air photography was obtained as shown below:

Table 2. **Dates and Scales of Air Photography and Size of Study Areas**

	Tumbau*	Dagaceri	Kaska	Futchimiram
Date	2-7 Oct 1950	3-8 Oct 1950	13-25 Oct 1950	Oct 1957
Scale	1:30,000 s	1:30,000 s	1:30,000 s	1:25,000 ps
Corrected Scale	1:29,250	1:29,704	1:29,770	1:24,900
Size (km^2)	102.35	146.38	145.86	170.87
No. dots 4mm grid	8,007	10,639	10,797	17,947
Date	29 Nov 1971	26-27 Oct 1969	7-11 Nov 1969	29-30 Oct 1969
Scale	1:40,000 s	1:40,000 s	1:40,000 s	1:40,000 s
Corrected scale	1:41,250	1:39,704	1:39,770	1:39,900
Size (km^2)	105.28	135.43	144.15	158.91
No of dots 2.7mm grid	9,040	12,531	13,186	14,004
Date	Sep 1981	Sep 1981	Sep 1990	Nov 1990
Scale	1:21,000 mosaic 1:10,000 central area	1:21,000 mosaic 1:10,000 central area	1:25,000 mosaic 1:10,000 south east area	1:25,000 mosaic 1:10,000 south east area
Size (km^2)	115.52	132.25	129.38	135.70
No. dots 5mm grid	7,472	8,389	8,310	8,833

Notes:

1) * = Excluding floodplain
2) s = Stereo cover
3) ps = Part stereo cover
4) Sizes of actual areas mapped are given. These vary as the sheet edges did not coincide exactly.
5) See Turner (1997) (**Annex I** to this Report) for details of methodology and error factors.

Provisional classifications of land cover were evolved in each study area and preliminary maps prepared on the 1981 and 1990 photographs. The work was then transferred to England, where the classifications were revised, integrated and made compatible for use on the different sets of photographs. Final mapping was then carried out at the scale 1:25,000 or 1:21,000 using magnifying stereoscopic viewers where possible.

Each study area of approximately 125 km^2 was mapped for each year (4 x 3 = 12 maps). Land cover classes were measured using a dot sampling technique. Changes in each class between years were measured as simple percentage changes and as compound percentage changes.

Sample households and database

Preliminary demographic surveys were carried out of all households in each study village. They were informally ranked by wealth and size on the basis of the surveys and local informants' opinions. Collaborating households were chosen to represent as far as practicable a range of rankings in each place, but the over-riding consideration was willingness to take part in obtrusive data collecting over several seasons (expected to be two in Phase I, but expanded to four in Phase II). The numbers of households collaborating were:

Tumbau	12
Dagaceri	13
Kaska	14
Futchimiram	8, 0, 4, 7 in successive years

In Futchimiram several households withdrew after the start in 1993, operations were suspended in 1994 owing to the lack of a researcher, the co-operation of only 4 was recovered in 1995, and three more joined in 1996.

A database was constructed containing demographic data on all persons in collaborating households and maintained from year to year.

Cadastral survey and database
A rapid reconnaissance cadastral survey was carried out in each village. The method was a ground survey using 1:10,000 enlargements of the latest air photography, with landmark identification and transect measurements using a 0.1 km tachometer mounted on a cycle wheel. All fields worked by members of the sample households were included in the survey. The fields themselves were not measured, but their boundaries (always visible in the dry season) were marked on the air photographs in the field and later transferred to permanent traces. Each field was registered by user, and additional information was collected on tenure and land use. Sources of information were village heads or their delegates, or sample farmers.

The numbers of fields surveyed and registered in each village were:

Village	*Fields*	*Ha (1996)*	*Date of survey*
Tumbau	90	48.5	February, 1996
Dagaceri	65	142.5	February, 1996
Kaska	53	141.0	1993-94
Futchimiram	32	25.7	February, 1993
Total	240	357.7	

Field areas were measured manually using 0.1 inch squared paper and converted to hectares. The accuracy of these methods is estimated to be adequate to within 15%, which is adequate for our purpose. To have achieved a more accurate data set would have multiplied the cost. Air photographic scale distortion is not considered to be serious since all areas are very flat.

Errors in field identifications have been eliminated as far as possible by repeated checking. Owing to the time-consuming nature of cadastral survey work, annual revisions were not attempted. Final checking planned for 1996 could not be carried out owing to the premature termination of field work. This has contributed to some identification errors. A few fields belonging to sample households which could not be located had area values interpolated statistically.

Each field was assigned a code letter in data collection, and researchers normally referred to them using the farmers' own descriptors. The codes, farmers' descriptors and map numbers of every field are included in the cadastral database.

Farming system characterisation
Inventorying of cultivar types, livestock breeds, technologies, soil types, and household income strategies was commenced in Phase I and continually updated until the end of the study, using open-ended interviews, group discussions and informal observation conducted for the most part by the researchers resident in the villages. This work generated a substantial body of descriptive and qualitative data which was analysed and written up for each farming system according to a standard protocol.

Labour monitoring
For the four farming seasons of 1993-1996, half-daily (morning or afternoon) records were made, for every individual in every sample household, of labour time spent according to work task (or other activity), and field (or other location). These data were collected by researchers resident in the villages. As there was only one researcher available per village, and he could not remain there continuously for the entire season, data for 'periods away' had to be constructed on his return with the help of local assistants.

Location of individuals during each half-day was recorded by field code or, when elsewhere, by other codes (e.g., home, market).

Task done was recorded by a task code according to a scheme evolved inductively during the project in order to reflect as accurately as possible the nature of peoples' activities (a predesigned scheme would have been misleading or incomplete as the range of farm and non-farm activities exposed in the data was very wide). The final list of task codes is given in **Annex 7** of this Report. They are structured heirarchically so that the data can be analysed at different levels of generality (from farm versus non-farm to, for example, foodselling (fish) versus food selling (groundnuts)).

Weights were assigned according to age and sex to reflect approximately the relative importance of contributions to farm tasks.

1.0	Adult male (15 years to elderly)	0.6 morning	0.4 afternoon
0.7	Adult female (15 yrs or married to elderly)	0.4 morning	0.3 afternoon
0.5	Boy or girl (8 to 14 yrs or marriage) Elderly person	0.3 morning	0.2 afternoon
0.3	Child (4 to 7 yrs)	0.2 morning	0.1 afternoon

Weights were updated each year in the database.

Data recording and analysis
Field records were kept in handwritten data books of which copies have been deposited in Kano and in Cambridge. Data input directly on to Excel spreadsheets took place in England (1993 season), and Kano (1994 season), and on to dbase format via coding sheets in Kano (1995 season) and England (1996 season). The sorting and cleaning of so much data (>200,000 records) took a long time and the shortcomings of the cadastral data caused by premature termination of field work added substantially to work which was finally completed for all four years in March, 1997. Analysis is being carried out with Access.

Soils data
Tumbau soils were the subject of a thesis for the M.Sc (Land Resources, Bayero University) under Phase I, and sampling was carried out in 1992-93. In the other three villages, two rounds of field sampling were carried out: reconnaissance sampling in the dry season of 1992-93, and a second round in 1995-96. In each village the soils were classified according to local understanding, roughly mapped, and samples taken from each of a series of management regimes identified with the help of farmers. Four composite samples were taken from the top 20 cm in each regime. Profile pits were dug and described in Phase I.

Analysis of the soils samples was carried out at the laboratories of the Department of Geography, Bayero University, Kano, and the Department of Soil Science at Ahmadu Bello University (Institute for Agricultural Research), Samaru.

Interviews on soil fertility management were conducted with sample farmers and some others in all four villages, under the general direction of the researcher specialising in the Soils Component of the study. These generated a substantial body of 'qualitative' data which together with the analytical results will form the basis for a Ph.D thesis at Bayero University.

Cultivars data
Multipurpose plants in Dagaceri were the subject of a thesis for the M.Sc (Land Resources, Bayero University) in Phase I, and the field work for this study was carried out in 1992-93. Inventories of cultivars were made in all villages in Phase I, and 59 sorghums were subsequently grown out at the ICRISAT station near Kano (failure to obtain funding for further work on sorghum diversity has brought this initiative to a stop). In Phase II, it was decided to focus on millet cultivars.

In Dagaceri sampling of millet cultivars was carried out in 1994 and the materials transported to England, from which selections were made for genetic analysis at the John Innes Institute, Norwich. The selected material was from three farmers' fields, each growing three locally named types, in Dagaceri; and additional samples were obtained from three farmers in Kaska (one type each). The methodology is described in detail in Busso et al. (forthcoming, **Annex 8**).

To support this work, an 'input-output' study of seed progeny from known stock was carried out in Dagaceri in 1996. On 10 x 10 m quadrats in each of three fields belonging to the same farmers as before, seed whose origin was known was sown exclusively in millet-sorghum-cowpea mixtures according to normal practice. The harvested heads were classified according to named types, to quantify the incidence of unwanted progeny as an indicator of genetic diversity and/or outcrossing.

Interviews on millet seed management were conducted with sample farmers and some others in all four villages, under the general direction of the researcher specialising in the Cultivars Component of the study. These generated a substantial body of 'qualitative' data which together with the progeny study results will form the basis for papers, and a Ph.D thesis at Bayero University.

Livelihoods data
Access to farm and grazing land in the Kaska area was the subject of a thesis for the M.Sc (Land Resources, Bayero University) in Phase I. The field work was carried out in 1992-93. Livelihood options were extended from farming and livestock to diversification of incomes in Phase II. Inventories of livelihood options were begun in some villages in Phase I but were incomplete.

The labour monitoring data base contains information on non-farm labour which measures the commitment of households to non-farm tasks and activities. This permits parallel analyses to be carried out on farm and non-farm labour use and inter-task interactions.

Two-weekly interviews were run during 1995 and 1996 with selected households on the level of their food sufficiency.

Price surveys were run on food commodity prices in markets near the study villages during 1995 and 1996.

The impact of four mini-development projects (three community grain banks and a jointly-financed well) was being monitored when field work was prematurely terminated.

Interviews on the management of livelihood options by households in all four villages were conducted with sample farmers and some others in all four villages, under the general direction of the researcher specialising in the Livelihoods Component of the study. These include questionnaire surveys and 'qualitative' interviews with individuals or groups. Linkages with the farming and livestock sectors of the household economy are included in these enquiries. These generated a substantial body of 'qualitative' data which will form the basis for a Ph.D thesis at Bayero University.

4.3 Project Management

Project Organisation
This project ran from April, 1994 until March, 1997, supported by the Semi-arid Systems Programme of the Renewable Natural Resources Research Strategy of the DfID. Co-funding by the (then) Policy Research group at the ODA was sought in 1995. A full funding proposal, whose preparation consumed resources of project time, was, after delay, turned down in February 1996. This project has built directly upon previous research carried out from January, 1992 until December, 1994, funded by a Grant from the Economic and Social Research Council's Global Environmental Change Programme (grantholders M.I.Chisholm and W.M. Adams, *Agropastoral Adaptation to Environmental Change in Northern Nigeria*, Project No. L320253001). This was followed by a Workshop on *Agropastoral adaptation to environmental change* (separately funded by the ESRC), held in Cambridge in March, 1994. The two projects have effectively been Phase I and Phase I of a single five-year research study, and in places in this report are referred to as 'Phase I' and 'Phase II' of this study.

The Senior Research Associate on the project was Mike Mortimore, who was employed 50% time (except for the last month's extension, April 1997). The Counterpart was Dr. J. Afolabi Falola, of the Department of Geography, Bayero University. The grant-holding institution was the Department of Geography at Cambridge University, in association with the Department of Geography, Bayero University, Kano.

Throughout the project, the principal researcher was engaged for 50% of his time only. As three months of each year were spent in Nigeria (usually three visits of 4-6 weeks), this left little time for project activities in the UK. This factor delayed data analysis until the closing stages of the project and in retrospect it can be seen that he was overextended in relation to the planned programme of work.

During the project, close field collaboration was maintained with the projects X 0216 and R 6603, funded by the NRI/ODA (Dr Frances Harris), which worked in Tumbau and Dagaceri respectively.

Work in Nigeria
The linkage with Bayero University Kano (BUK) had the particular support and encouragement of the Vice-Chancellor, Professor Sani Zahradeen (1992-1994). At the informal level, the principal researcher (Mortimore), who was Professor and Head of the Department of Geography from 1979 to 1986, was well known in the institution and in northern Nigeria and this facilitated practical arrangements considerably. The University provided support for the application to the Nigerian Universities Commission for Research Associate status for Mortimore and Adams, and its renewal during the present project, and also facilitated state government approval for the field work.

Three researchers were appointed as Assistant Research Fellows in the Department of Geography at Bayero University for three-years, with effect from January, 1995 (Ahmed Maigari Ibrahim, Salisu Mohammed and Maharazu Yusuf). Arrangements for project management in Nigeria closely followed those developed for the ESRC Project. It proved possible to use the research staffing needs of the project to strengthen institutional capacity for research in Nigeria on land resources and their management in the Nigerian Sahel. In 1992, the three researchers were recruited from the M.Sc programme in Land Resources at Bayero University at the conclusion of their coursework year (although their availability was delayed until September, 1992 by strike action in the Nigerian universities). A training course was held for them in September 1992, which included intensive teaching on research methods and a tour of the proposed field sites, and they were each assigned to a village (Tumbau, Dagaceri, Kaska), where they undertook field data collection. An arrangement was agreed with the Department of Geography whereby they would not only collect data for the project, but also be free to make subsequent use of those data for in writing a Masters Thesis at Bayero University for their M.Sc.

Field data collection was designed and managed by the project's principal researcher (Mortimore), who was also able to collaborate actively with members of the teaching staff at BUK supervising the theses. The theses were submitted, and the degree awarded in 1995. In the present project, the same three researchers, working as Research Fellows, maintained the project's fieldwork programme in the same villages, under the supervision of the Senior Research Associate (Mortimore) and the Counterpart (Dr. J. Afolabi Falola, of the Department of Geography, Bayero University. The researchers also registered for a Ph.D. at Bayero University. Research Fellows took part in designing and each supervising the interview programme on his own 'component', harmonising procedures and monitoring the quality of incoming data. All data collected in the field has been included in analysis in the UK. The work of writing doctoral theses has been developed and managed independently of the project, and the Senior Research Associate has not made any formal input to this work.

Arrangements were somewhat different for fieldwork in the forth village, Futchimiram. A researcher was sought from 1992 from the Centre of Arid Zone Studies, University of Maiduguri. However, the University could not produce a candidate from its own trainee staff, and instead the project recruited a series of staff. The first was a temporary researcher on loan from the Hadejia-Nguru Wetlands Conservation Project (Ismail Hadejia, from September, 1992 to January, 1993); the second a member of the staff of Ramat Polytechnic, Maiduguri (Alhaji Maigana Chiroma, from February, 1993 to June, 1994); the third was an Agriculturalist seconded from the North East Arid Zone Development Programme (M. Isa, from 1995 to 1996). In this way data collection at Futchimiram was completed, with a gap of one year in 1994.

The four Nigerian researchers presented papers at the Workshop held in Cambridge in March, 1994. They subsequently presented papers at the Conference on the North East Arid Zone in Maiduguri in July, 1994; the 3rd National Workshop on Land Resources in Kano in March, 1995, and the Annual Conferences of the Nigerian Geographical Association in Maiduguri and Kano in April, 1996 and May, 1997.

Equipment in Nigeria was confined to previously purchased rain gauges and some camping equipment. The project shared a Land Rover with R 6603 (originally purchased locally second-hand for X 0216), and also maintained and ran a much older Land Rover taken over from the previous project (a very old vehicle belonging to Mortimore). The project financed some soils analyses at the Department of Geography at BUK.

In several ways the project's activities benefited the Department of Geography indirectly. Relations with the Department (and the Head of Department, Malam Kabiru Ahmed) were very good, and the Department made available excellent office accommodation.

Relations with the four village communities were maintained on a very informal level, with the researchers staying in households and establishing strong ties of friendship with members of the community. Difficulties in maintaining the full co-operation of all participating households in Futchimiram were mainly attributable to the discontinuity of staffing. Village heads never ceased to give the fullest co-operation. From this standpoint the project was extremely successful.

The project faced major difficulties with completing the fieldwork due to conditions in Nigeria. There were frequent and sometimes crippling fuel shortages, unjustified obstruction by local government officials on a handful of occasions, some illness, communication problems (in particular, between Kano and the UK), excessive maintenance time on old vehicles, laboratory breakdowns and power or water failures, and other problems caused difficulties in executing the project according to schedule.

However the largest problem faced was the unexpected arrest and deportation of the Senior Research Associate on 22-23 October, 1996 within 24 hours of his arrival for the last major field work programme. His status as a visiting researcher was fully approved by the authorities and he was in possession of a visa and entry permit issued at the airport. He is now a Prohibited Immigrant and so there was no question of repeating the visit. The present Vice-Chancellor of Bayero University has issued no statement on the subject, and neither has the Nigerian Universities Commission. The British High Commission in Nigeria lodged a protest, but the Foreign Office has recently written to report that in the absence of any action on the part of the Nigerian Government, the matter has been dropped.

This development necessitated the abandonment of (a) scheduled work on biomass, (b) the completion of work on the cadastral database, which required revision in Dagaceri and Futchimiram, (c) supervision of the winding up of rainy season field work for 1996, (d) all routine management activities, and (e) end-of-project protocols, data organisation and arrangements for joint analysis. (The disruption extended to R 6603 with which project we had collaborative arrangements for field work.) The major gaps could not be repaired, but the Counterpart succeeded in bringing the other field work to a conclusion and travelled to Cambridge in January-February, 1997 (an unscheduled trip approved by the Semi-Arid Systems Programme manager) to work with Adams and Mortimore on project data. Without his outstanding contribution the extent of damage would have been considerably greater.

Work in the UK

Analysis of the genetics of local millets was undertaken in the UK by the John Innes Institute (Norwich), under a sub-contract with the University of Cambridge. The work was carried out by Carlos Busson, under the supervision of Dr. Mike Gale and Dr. Katrien Devos. Field collection of plant material was carried out to an agreed plan by M. Mortimore, and there were regular joint meetings to discuss analytical strategy, results and joint publication.

Owing to the demands on researcher time in the field, and the tight fieldwork schedule, plans to input the data derived from the monitoring of household labour in Kano had to be dropped. The data for the year 1993 were brought to England for computer input; field data recording procedures were then revised and streamlined, and data for 1994 was entered on the computer in Kano. Data entry was still too slow, so data for 1995 and 1996 were coded in Kano but brought to Cambridge for entry into the database. From October, 1996 until April, 1997 (with an interval), Dr. Kevin Kimmagewas appointed as Research Assistant to prepare the database for analysis using Microsoft Access. Because of the delays in putting in data, and the difficulties with the cadastral data set, this process could not be completed until the end of March, 1997, behind schedule.

The analysis of a large amount of non-quantitative interview data relating to the three Components is still in progress at the time of writing. Duplicate sets of data exist in Cambridge and in Kano. Analysis, being linked to the preparation of theses by the Research Fellows (whose appointments with the Department of Geography end in December, 1997), is expected to be completed by the end of 1997.

Throughout the life of the project, the Department of Geography at Cambridge provided administrative support, for which we are grateful to the Head of Department, Dr. Keith Richards and Andrew Worsdale and his staff. Dr Adams, who worked in Nigeria with the team during 1995, supervised all UK administrative matters and reporting.

5. OUTPUTS

5.1 Characterisation of Basic Parameters

5.1.1 Rainfall

The study limited itself to the modest objectives of (a) setting the farming systems of the four villages in their context of regional long and medium term trends in rainfall, using data from representative stations, and (b) observing daily rainfall during the growing seasons at each village.

Objective (a) is necessary in order to understand contemporary natural resource management as affected by long or medium term declining rainfall in the Sahel. Objective (b) searches for relationships between precipitation events, and/or weekly amounts of rainfall, and farming practice. The growing season was divided into seven-day periods numbered from 1 June.

The agroclimatological implications of rainfall trends and global warming scenarios.
Rainfall trends in the north-east of Nigeria in 1961-90 have been analysed by Hess et al. (1995), using records from four synoptic stations, and lake bed cores show that oscillations have occurred since 5500 BP (Holmes et al., 1997). Changes in rainfall should be seen in agroclimatological context. In a study commissioned for Phase I, Page (1994) investigated the agroclimatological implications of reduced average rainfall in the Sahel and of global warming scenarios, using the FAO's definition of the growing period (when rainfall exceeds or equals 0.5 PET, plus 100 mm stored soil moisture: FAO, 1983). The period when rainfall is equal to or exceeds 1.0 PET is called the humid period. PET values were estimated using Penman's procedure adapted to a spreadsheet format.

Temperature changes predicted in global climate scenarios suggest that a two-degree global warming will raise the PET by about 6 percent in the growing season (*ibid.*, 23-27), reducing the length of the growing period. The model uses a wind factor in estimating potential evapotranspiration (p 23, see Table 5.1.1). Reducing the wind factor, for example by windbreaks on farmland, may compensate partly for the increase in temperature.

TABLE 5.1.1 *Effect of a 2-degree global warming on mean monthly potential evapotranspiration in the growing season, Kano and Nguru* (Source: Page, 1994, Tables 2,3,5,6, pp 24-25)

	Wind factor	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Kano									
PET, mm/month	1	249	254	237	186	158	137	144	179
	0.25	151	164	169	147	134	121	128	139
Increase in PET %	1	3.9	4.1	4.9	5.6	5.9	5.8	6.3	5.9
	0.25	4.1	4.5	5.4	6.1	6.2	6.1	6.6	6.5
Nguru									
PET, mm/month	1	235	263	257	223	184	153	162	179
	0.25	146	162	177	163	147	131	139	140
Increase in PET %	1	3.7	3.7	4.5	5.1	5.6	5.8	6.3	5.7
	0.25	3.7	3.9	5.1	5.7	6.0	6.1	6.7	6.2

The model shows that an excess or deficit of 20 percent above or below the mean rainfall for 1961-90 has a substantial impact on the length of the growing period, thus defined (Figure 5.1.1(a)). The intensity of the growing period, shown by the surplus of rainfall over 1.0 PET (the humid period as defined by the FAO), is even more obviously affected. Of the three stations that represent the study area, Nguru is the most adversely affected by a reduction in rainfall, Kano is less so, and Maiduguri is intermediate.

Subject to the stated assumptions, the model shows the agroclimatological effect of a continuing decline in Sahelian rainfall in the future. While it is impossible to predict rainfall trends (and a reversal of the declining trend of the last 30 years is as likely as its continuation), the model helps to define the adaptive challenge being faced by agropastoralists.

Rainfall in four villages.
Farmers work with variable, not average rainfall, and they usually live far from synoptic rainfall stations. The long term changes modelled in the previous section are paralleled by variability that occurs from year to year in the actual circumstances of agropastoral producers. The coarse distribution of rainfall stations disguises the sharp spatial variability that occurs (Buba, 1992).

Daily rainfall was measured for the four growing seasons, 1992-96, in the four villages. The average was 571.2 mm in Tumbau, 360.0 mm in Dagaceri, 344.8 mm in Kaska, and 375.0 mm in Futchimiram[1]. These amounts, which understate annual rainfall (but insignificantly), are representative of the reduced levels of Sahelian rainfall that have been normal since the 1970s. Figure 5.1.1(b) shows running means for (seven-day) periods. Over the four years, the average rainfall displays predictable spatial trends from Tumbau to the drier villages: a shortening of the rainy season, and a sharper peak in July-August. Rainfall in Futchimiram, however, failed to peak as expected.

The smoothed rainfall curves show that the sites are broadly representative of the Sahel, but give no indication of short-term variability. Standard measures of variability derived from long term data cannot be generated from four years' data collected in the villages. These data, however, more accurately express the behaviour of local rainfall from year to year, and within seasons, to which farmers have to adapt.

Figures 5.1.1(c) and 5.1.1(d) show rainfall by period for each of the four years, 1992-1996, in Tumbau and in Kaska. The contrasting humped and peaked configurations of average rainfall in these two villages are now seen to hide very high variability. This includes variability in the start and end of the growing period, in the distribution of rainfall events and dry spells during the season, between different periods in the same year, and between the same period in different years. The period analysis is used in subsequent sections of this Chapter. (Daily or shorter interval analyses of rainfall have not yet been attempted.)

[1] Rain gauges, which could not be closely supervised, failed in Futchimiram in 1993, in Tumbau in 1994 and in Dagaceri (two gauges) in 1996. The use of Nguru daily rainfall data for 1996 in place of that of Dagaceri was considered. Although satisfactory correlations were obtained for monthly rainfall in the years 1992-95, inspection of the daily data revealed divergent patterns (Buba, 1997). For the purpose of the study, therefore, this option was rejected.

5.1.2 Regional Desertification

The degradation or erosion of soils, the loss or deterioration of vegetation and the decline of surface or subsurface hydrological resources form a large part of scientific orthodoxy on Sahelian natural resource management. This orthodoxy has much influence on national and donor policy. Yet the evidence for desertification continues to be highly controversial, both in the drylands generally (UNEP, 1992; Warren and Khogali, 1992) and in northern Nigeria (Mortimore, 1989a, b). The question has been raised whether the orthodoxy is driven more by an institutional dynamic than by empiricism (Swift, 1996). With respect to Nigeria, two wide-ranging studies of NRM by the FAO (1990) and the World Bank (1992) made extensive use of this orthodoxy, but have never received the critique they deserved either on conceptual or on empirical grounds, as they were classified as 'confidential' documents.

Studies of archival sources, still in progress (initiated by U.Geidam under Phase I), indicate that at the commencement of British rule in northern Nigeria, the official evaluation of the natural resources of the country was uniformly optimistic, which is striking in view of the severe impact of droughts in 1905 and 1913. Assessment and routine reports from the districts contain large amounts of information, including quantitative estimates of demographic and economic parameters. The history of groundnut exports, and to a lesser extent cotton, continued to give support to optimistic assessments until the 1960s. Negative assessments of trends in NRM, usually assumed to be driven by population pressure, are quite recent, and have been escalated since the Sahel Drought of the early 1970s and the UN Conference on Desertification in 1977. The incongruence of these negative assessments with the continuing viability of farming systems at increasing population densities, exemplified most prominently in the Kano Close-Settled Zone (of which Tumbau village is representative), configures the challenge that this study takes up at the micro-scale.

A study commissioned in Phase I (Olofin, 1993) carried out an assessment of soil erosion in the drylands of northern Nigeria, in which published and unpublished site measurements and estimates of sediment yield in rivers were reviewed. The variability of such estimates casts doubt on the validity of estimating procedures or on their wider applicability. Introducing the concept of economic soil life was found to shift the emphasis from erosion (which, given the prevalence of small slope angles, is not expected to be as high as in some areas of Africa) to degradation in the form of fertility loss through nutrient extractions in farming. While this receives consensual support from many farmers as well as officials, there is little empirical data with which to assess its regional significance (Mortimore, 1989b). (Farm level measurements of nutrient flows, and a model of the nutrient cycle under intensive cultivation, have been reported by Harris and Bache (1995) in a project supported by the NRI.)

Preliminary outputs from the present study have been incorporated into a review of NRM in the drylands of sub-Saharan Africa (Mortimore, in press), which advances a thesis of transition from ecologically unsustainable to sustainable forms of management by smallholders, who are adapting to demographic, economic and environmental constraints and opportunities.

5.1.3 Population Density

The population density gradient from Tumbau (the most densely settled) to Futchimiram and Kaska (the least densely settled) village study areas is expected, through its effect on land supply, to be a primary determinant of land use intensity. Density data are not available below the local government level, and as these units can contain a wide diversity of natural conditions and human settlements, they only offer a rough guide to the densities expected in the study areas. Demographic enumerations were not planned for this study and could only be carried out in small parts of the study areas, and had to be supplemented by estimation procedures.

Table 5.1.3 gives three measures of density: (a) average densities for the local government areas (in which the study areas lie) according to the Census of 1991, (b) estimates for each study area based on limited field enumerations combined with area measurements from uncontrolled air photographs, and (c) agricultural population density which combines cultivated land per capita on surveyed holdings with the percentage of arable land.

TABLE 5.1.3
Density of population in the four study areas (per km^2)

	TUM	DAG	KAS	FUT
(a) Census of 1991 (Local Government Area average)[1]	414	66	18	13
(b) Estimates for study areas (appr. 130 km^2) based on enumeration and air photo interpretation[2]	223	43	11	31
(c) Arable land (in ha) per capita (sample households only)[3]	0.46	1.9	1.52	1.29
Arable land (in ha) per capita (all households)	na	1.92		
Agricultural population density, combining arable land per capita with percentage arable[4]	191	29	7	17

Notes:

1 Tumbau: Gezawa LGA; Dagaceri: Birniwa LGA; Kaska: Yusufari-Macina LGA; Futchimiram: Geidam LGA.

2 Enumeration of appr. 50% of the population in Dagaceri study area, and of control samples only in Tumbau and Futchimiram. No enumeration in Kaska. See **Annex 2** for estimation procedures.

3 The number of households is: Tumbau, 12; Dagaceri, 13; Kaska, 14; Futchimiram, 6. Arable land includes cultivated land and short fallow, except in Tumbau, where the amount of fallow is negligible.

4 This figure is obtained from Table 5.1.4, below. The agricultural population consists the members of households having rights to farmland who were present during all or part of the agricultural year, 1996. It should be noted that agricultural population densities are brave projections from small samples of households to entire study areas. The agricultural population density relates the population to the area of arable land currently accessed by these representative households; it takes no account of rights to common access resources nor long fallow under private control.

na not available

Sources: Federal Republic of Nigeria (1992); B. Turner, air photo interpretation; demographic enumerations and cadastral surveys.

5.1.4 Land Use and Vegetation Change

Land use and vegetation change over time provide the historical context necessary for an evaluation of natural resource management and its sustainability. The results of mapping and measuring land cover at three points in time, using air photo interpretation, are summarised in Table 5.1.4 and Figure 5.1.4. In Figure 5.1.4 the major contrasts and changes which have an impact on the sustainability of land use are highlighted. Turner (1997) provides samples from the mapping in each study area and a fuller discussion of the results. This Working Paper attached to this Report as **Annex 1**.

TABLE 5.1.4
Land cover around the four villages

	TUMBAU			DAGACERI			KASKA			FUTCHIMIRAM		
	1950	1971	1981	1950	1969	1981	1950	1969	1990	1957	1969	1990
Arable upland	75.8	87.2	87.7	35.6	56.1	54.6	0.9	0.4	10.0	22.1	22.5	21.7
Arable lowland	1.8	2.1	0.7	0	0	0	14.9	3.8	0.7	0	0	0
Grass upland	12.6	4.1	0.3	57.1	35.4	32.7	62.3	69.9	51.8	46.4	57.5	62.1
Grass lowland	4.8	0.5	0.3	0	0	0	1.6	0.8	1.0	0	0	0
Dense woodland/bush	0.2	0.3	0.6	3.2	1.6	1.0	5.4	4.1	4.6	0	0	0
Open woodland	0	0	0	0	0	0	10.7	17.3	4.8	30.6	19.6	7.9
Degraded/Sparse veg	4.1	3.9	7.5	1.9	5.2	11.1	0.6	0.9	5.1	0.6	0.2	7.5
Active Dunes	0	0	0	0	0	0	0.9	0.9	20.2	0	0	0
Water/wetland	0.4	0.3	0.2	1.9	1.3	0.1	2.5	1.9	1.6	0	0	0
Settlement	0.3	1.6	2.8	0.3	0.4	0.5	0.2	0.1	0.2	0.2	0.2	0.8
Total	100	100	100.1	100	100	100	100	100.1	100	99.9	100	100

Notes:
1) Arable upland includes fallow.
2) Settlement areas do not include dispersed compounds. For more detailed measurements, see Table 5.
3) In Kaska the category shown on the map as semi-dune has been divided into 8.1% active dune and 24.3% grass upland for inclusion in this table.
4) In Futchimiram grass upland includes 45.7% in 1957, 5.1% in 1969 and 15.8% in 1990 on which old field boundaries were visible. Scattered trees occur over most of the grass upland.

Source: Turner, 1997, p 11

Expansion of arable land (cultivated or short fallows) and agricultural population density
Land classified as arable is privately appropriated land under cropping cycles, with or without short fallows, and managed by smallholders. There is a predictable and close positive correlation between the present day agricultural population densities (Table 5.1.3) and the variation in the percentage of arable land between villages. Tumbau, with an agricultural density of 191/km^2, has over 87 % of its surface cultivated annually. Dagaceri, with an agricultural density of 29/km^2, has 55 % under cultivation or short fallow. Futchimiram, with an agricultural density of 17, has 22 % arable, and Kaska, with the lowest agricultural density of 7/km^2, has only 11 % arable. The expected corollary of this, a negative correlation with the proportion of land under grassland and woodland management, is confirmed. There is however *no* correlation between agricultural population density and the proportion of degraded land, a finding that is counter-intuitive.

The changes measured since the 1950s show that the historical dynamic of natural resource management has been quite different in each study area.

Tumbau

In Tumbau, the effective limit on the expansion of annually cultivated land was reached soon after 1950, with the virtual disappearance of grassland. The grassland mapped in 1950 (17%) was mostly upland fallow (13 %) which has subsequently been eliminated from the cropping cycle on smallholdings. The absence of woodland at that time suggests that no land was available for colonisation, except for lowland grassland (5%) which used to be protected from access. There was an increase in the amount of degraded land between 1950 and 1981, to 7.5%. Whether this resulted from the pressure of cultivation under increasing population, or from the drought cycle of the 1970s, cannot be established from this evidence.

Dagaceri

Arable land increased rapidly between 1950 and 1969 but later stabilised. This is believed to have been due to administrative action at the local government level to protect grazing reserves (actually a political settlement between the Fulbe livestock specialists and the Manga mixed farmers, both of whom claimed prior occupation of the area). Dense woodland had already virtually disappeared in 1950, in favour of shrub grassland. Degraded or sparsely vegetated land increased to 11 % in 1981, but as in Tumbau, this category was affected by the droughts of the 1970s. There is no lowland in Dagaceri.

Kaska

In this area, where former dunes, covered by annual grasses, are interspersed with wooded depressions, the figures for arable land show a remarkable reversal between 1950, when almost all of the 16 % then cultivated was found in the depressions, and 1990, by which time cultivation in depressions was confined to irrigated sites and arable had extended on to the upland. In the depressions, dense woodland had remained stable - despite weak official protection - but open woodland, which was found mostly on sites favoured for farming, declined after 1969. On the upland, the grassland, which is managed for year-round grazing, gave way to remobilised dunes which extended from less than 1 % to 20 % between 1969 and 1990.

Futchimiram

There is no evidence that the agricultural population density increased during the period between 1957 and 1990; indeed, some depopulation is reported after the droughts of the 1970s and 1980s. The arable fraction has remained stable at about 22 % throughout, though the location of cultivated fields may be shifted every few years. Trends may, however, have occurred in an increase of grassland at the expense of woodland, and an increase in degraded land. The first of this is obscured by the difficulty of classifying annual grassland with scattered trees as either grassland or woodland on photographs of different quality and scale; and the second by the similar interpretative signatures of bare ground and farmland in this environment. There is no lowland.

Other changes

The area of settlement increased spectacularly in Tumbau (where it was accompanied by a major shift from dispersed towards nucleated forms, driven by a voluntary resettlement programme administered at local government level during the 1950s and 1960s), and substantially in Dagaceri, but the evidence from Kaska and Futchimiram is ambivalent. There are suggestions of a falling water table in lowlands, which is consistent with regional groundwater scenarios. It should be noted that trends in the categories 'dense woodland' and 'open woodland' take no account of trees grown on farmland, which range (*on uplands*) from 12-15/ha in Tumbau through 2-5 in Dagaceri and Futchimiram to zero in Kaska.

The findings from Dagaceri and Kaska generally confirm interpretations of landscape change given in Mortimore (1989a) and Reenberg (1994).

5.1.5 Characteristics of Sample Households

This section describes the sample households and holdings in the four villages.

Household labour

In Table 5.1.5 the demographic characteristics of the sample households are described, and the ages and sexes weighted for the purpose of estimating labour inputs. The households are considered to be representative in each village.

TABLE 5.1.5(a)
Labour characteristics of sample households[1]

	TUM	DAG	KAS	FUT	ALL
Number of households	12	13	14	7	46
Total population, 1996	127	108	101	29	365
males	59	47	46	14	166
females	68	61	55	15	199
children	62	56	55	8	164
Persons per household:					
highest	24	15	14	6	24
average	10.6	8.3	7.2	4.1	7.9
lowest	4	3	1	2	1
Males per household:					
highest	12	8	7	4	12
average	4.9	3.6	3.3	2	3.6
lowest	2	1	1	1	1
Females per household:					
highest	12	12	9	5	12
average	5.7	4.7	3.9	2.1	4.3
lowest	1	1	0	1	0
Children per household:					
highest	12	11	8	3	12
average	5.2	4.3	2.7	1.1	3.9
lowest	2	1	0	0	0
Children per adult	0.95	0.93	0.60	0.38	0.82
Weighted labour available, 1993-1996 (average):					
highest	10.1	5.1	8.5	3.8	10.1
average	4.7	3.2	4.2	2.2	3.6
lowest	2.1	2.2	1.2	1.7	1.7

Notes:

1) Age-sex weightings were assigned as follows: males - 1.0, adults over 14 and under 'elderly'; 0.5, 8-14 years and 'elderly'; 0.3, 5-7 years; females - 0.7, adults over 14 or married and under 'elderly'; 0.5, 8-14 years or 'elderly'; 0.3, 5-7 years. Children under 4 years were assigned a weight of 0.

The data given in this table show unexpectedly clear gradients in each of the following variables:

- average household size (from 10.6 persons in Tumbau to 4.1 in Futchimiram)
- average numbers of males, females and children per household

- average number of children per adult

For average weighted labour per household, highest in Tumbau (4.7 units), Kaska displaces Dagaceri for second place, and the lowest is still Futchimiram (2.2).

The table also demonstrates the demographic variability found among households. Thus average values are misleading as a guide to the labour strategies pursued by real households.

Although many factors intervene between the demographic endowment of households and the mobilisation of farm labour, the distribution of this endowment is nevertheless of some interest. Figure 5.1.5(a) shows a Lorentz curve for the distribution of available labour. At the lower end, 30% of households have only 15% of the total labour available, and at the upper end, 30% have as much as 50% of the available labour. This demonstrates the range of inequality amongst households when they confront the challenge of primary production each year.

The demographic resources available to households also change constantly from year to year, as births deaths and marriages occur, and individuals travel into or out of the community. Figure 5.1.5(b) shows a ranked ordering of all households in all four villages, with inter-annual changes. Households in Futchimiram (coded F) should be disregarded as records were incomplete. Among those in Tumbau (T), Dagaceri (D) and Kaska (K), only four were demographically stable throughout the four-year period. For a production enterprise dependent on labour, this variability is an important characteristic, whether it works as a constraint or as an opportunity.

Farm holdings

In Table 5.1.5(b) the characteristics of the sample landholdings are described.

TABLE 5.1.5(b)

Landholding characteristics of sample households, 1996

	TUM	DAG	KAS	FUT	ALL
Number of holdings surveyed[1]	12	13	14	4	43
Total hectares, 1996	48.54	142.5	140.96	25.7	357.7
Hectares per holding					
highest	11.2	23.8	26.9	9.0	26.9
average	4.0	11.0	10.1	6.4	8.3
lowest	1.2	3.2	1.1	4.3	1.1
Hectares per capita					
highest holding	0.6	3.4	2.6	1.8	3.4
average holding	0.35	1.6	1.3	1.4	1.1
lowest holding	0.1	0.3	0.5	0.9	0.1
Hectares per labour unit					
highest holding	1.0	10.35	8.7	3.1	10.35
average holding	0.7	4.0	2.6	2.5	2.5
lowest holding	0.2	1.1	0.8	1.6	0.2

Notes:

1) Of 241 fields assigned to sample households, 212 were identified in the field and measured on air photographs; for the remaining 29 (4 in Tumbau, 17 in Dagaceri, 6 in Kaska and 2 in Futchimiram), area values were interpolated statistically. The effect of this loss of accuracy is most serious, as the figures suggest, in Dagaceri.

The figures in the table show no generalised gradient from Tumbau to Futchimiram. Rather, Dagaceri emerges with the highest values for hectares per holding, per capita, and per weighted labour unit. The striking contrast between Tumbau and the other three villages was expected. The broad similarity between the values for hectares per capita in the three low density villages (Dagaceri, Kaska, and Futchimiram) is also striking, as population density and other conditions vary, but this similarity is not borne out in the values for hectares per weighted labour unit. In Dagaceri extensive use is made of ox-ploughs, which are little used in Kaska or Futchimiram. About 2.5 ha/labour unit, we imply, is the upper limit for hand cultivation without mechanical assistance. These patterns are shown in Figures 5.1.5(c) and (d).

Landholdings, like household demography, change from year to year, as various methods of transferring rights permanently or temporarily are brought into use. Fallowing in the three extensive systems (Dagaceri, Kaska and Futchimiram) - either planned or imposed on farmers by a labour shortage - affects the area actually cultivated, and such decisons may affect parts of fields as well as whole fields. Thus the idea of the land endowment of a smallholding being immutable, even over a short period of four years, is wholly misleading.

FIGURE 5.1.1(a)

The effect of an increase or decrease of 20% in average rainfall on the length and intensity of the growing period, under a 2-degree global warming scenario, at Kano, Nguru and Maiduguri

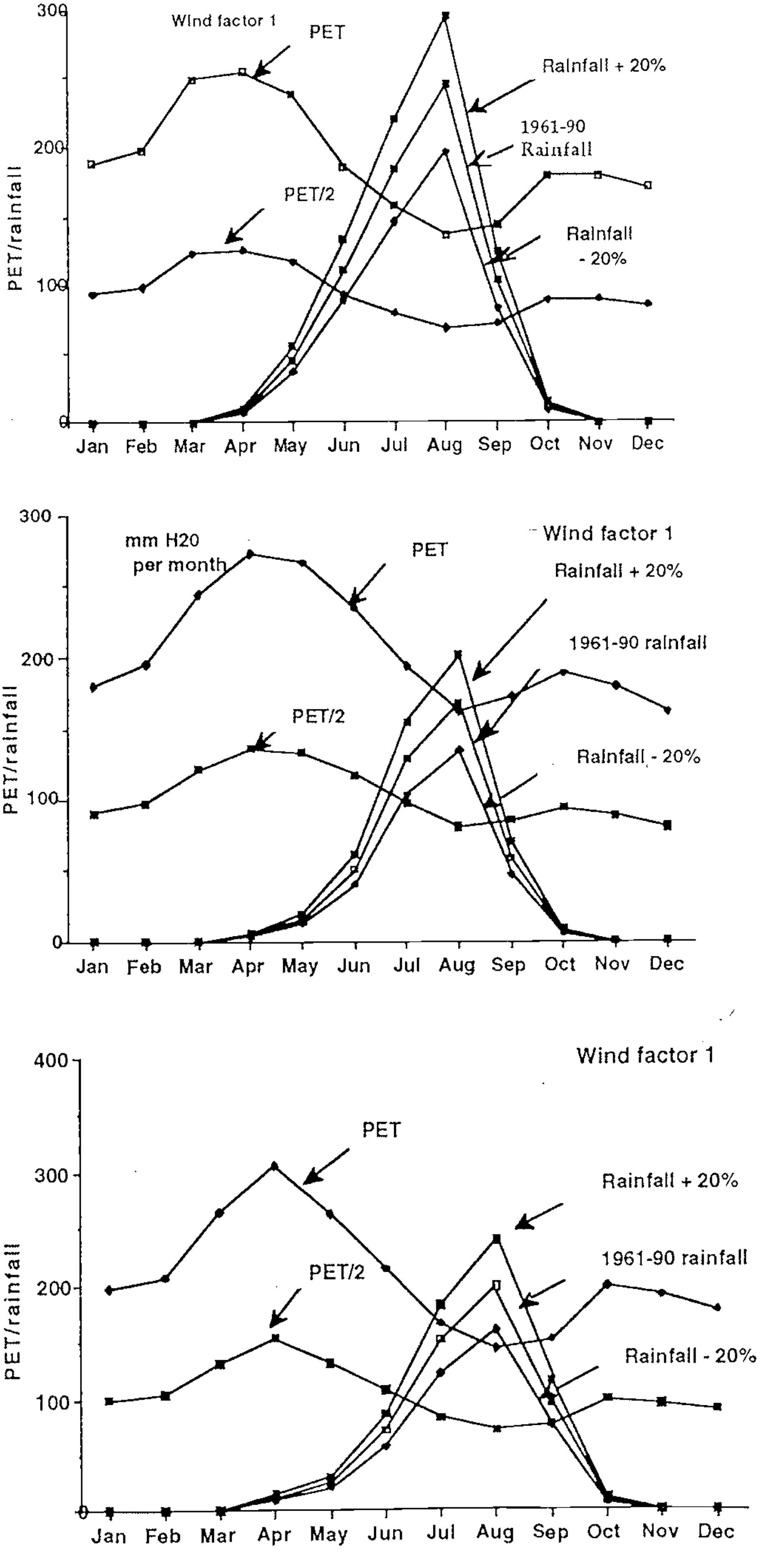


FIGURE 5.1.1(b)

7 week weighted average rainfall in individual villages 1992-1996

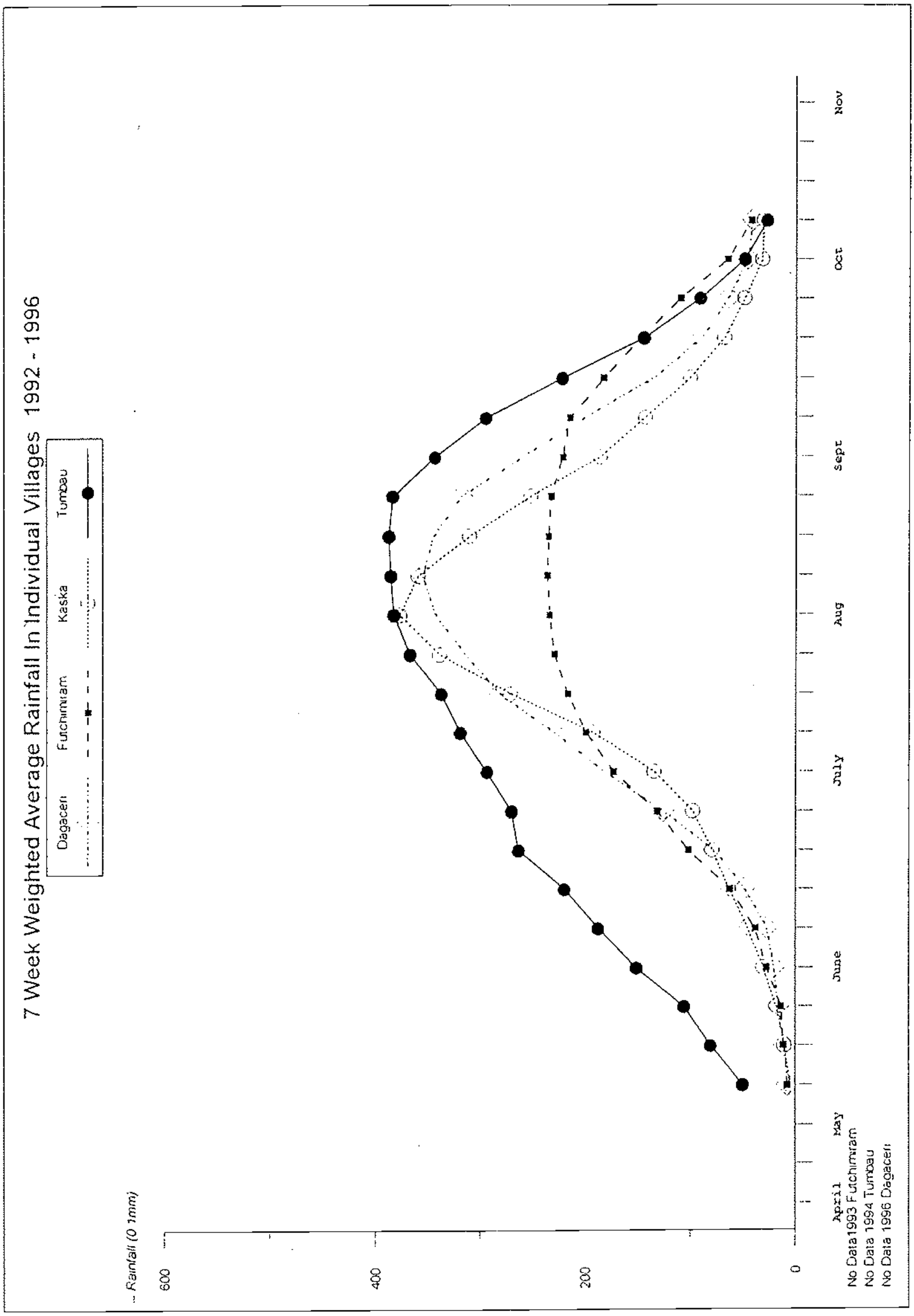


FIGURE 5.1.1(c)
Tumbau rainfall, 1992-1996

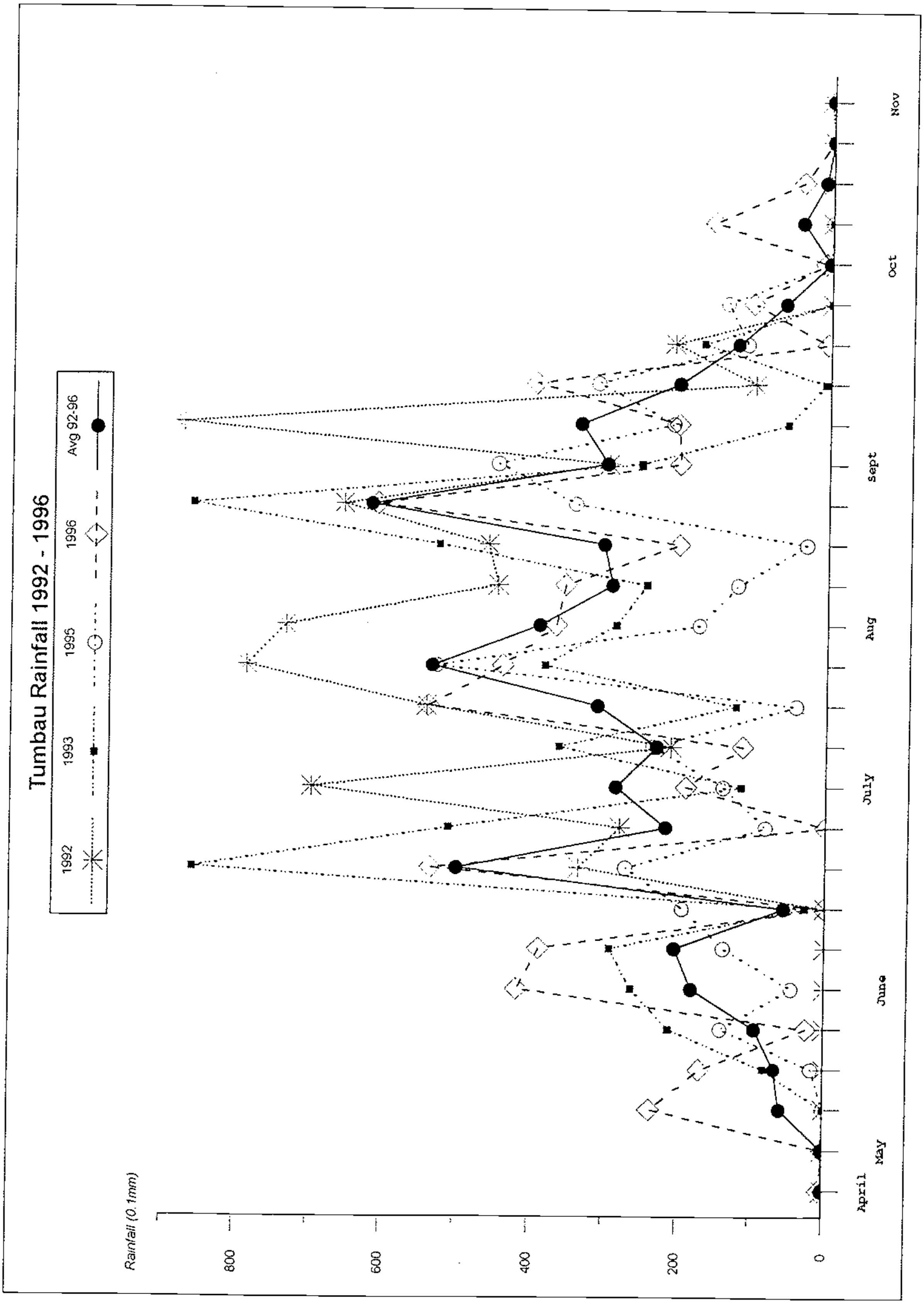


FIGURE 5.1.1(d)
Kaska rainfall, 1992-1996

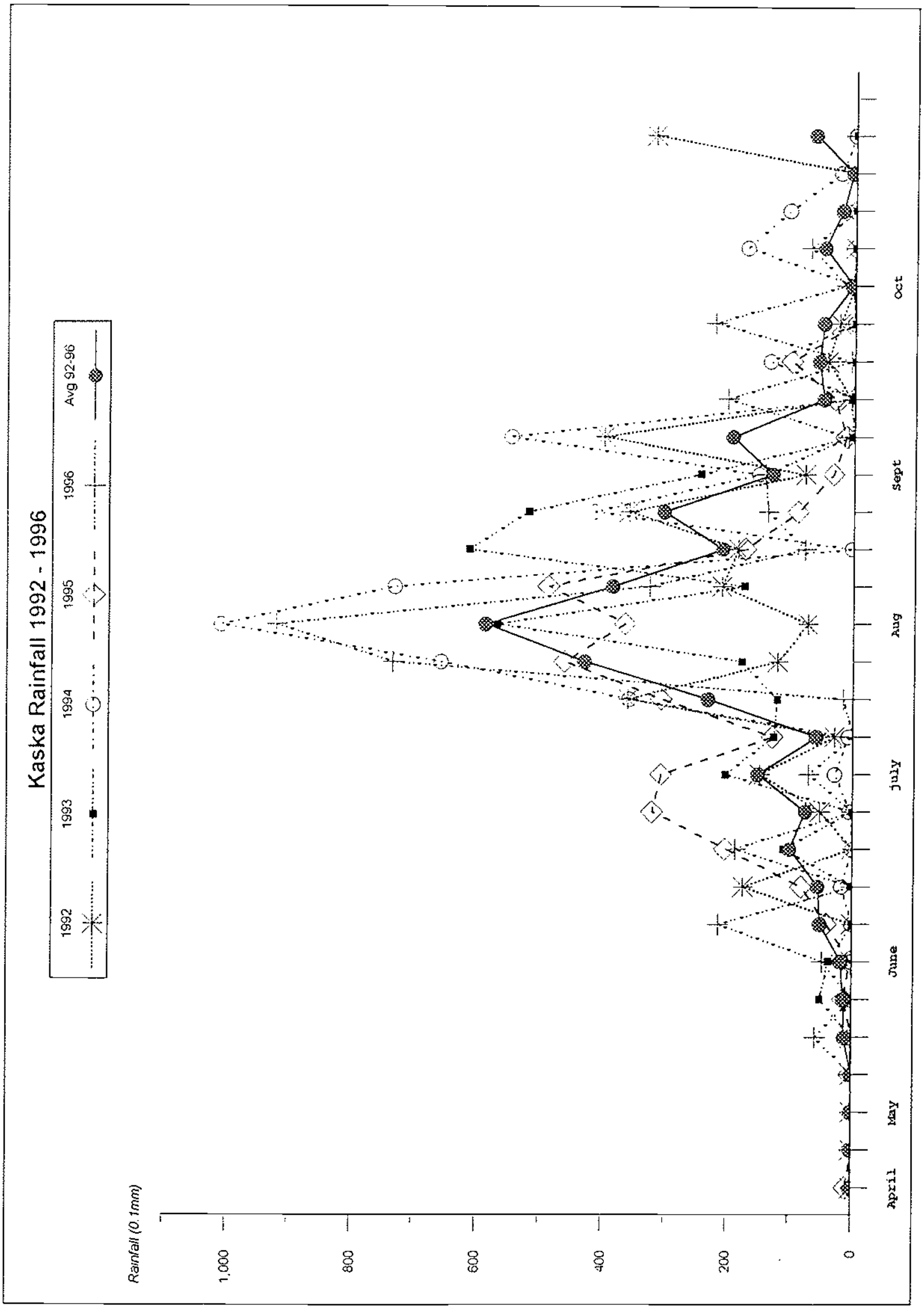


FIGURE 5.1.4
Changes in the major categories of land use

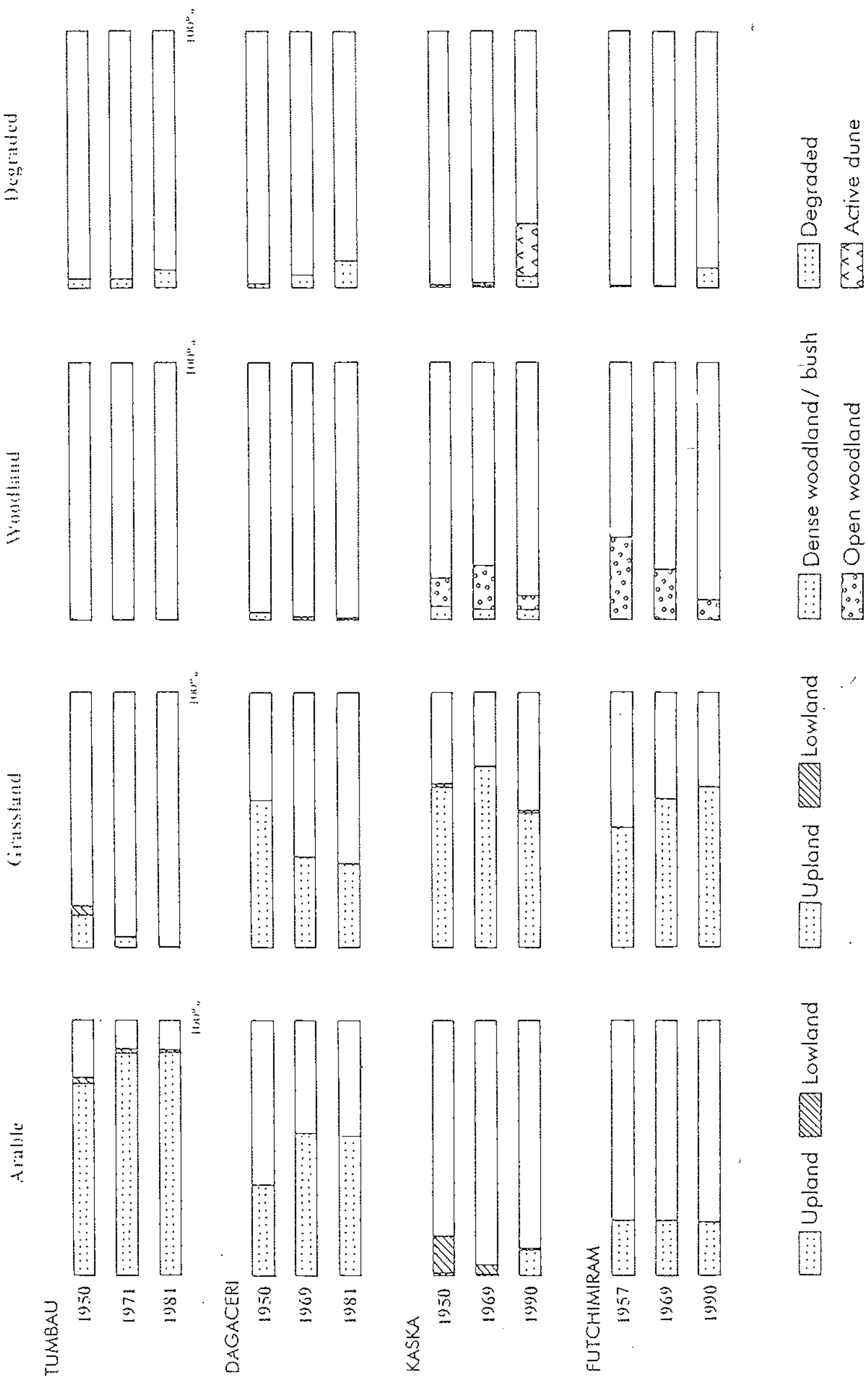


FIGURE 5.1.5(a){9.A.5.2}
Distribution of available labour in four villages, 1995

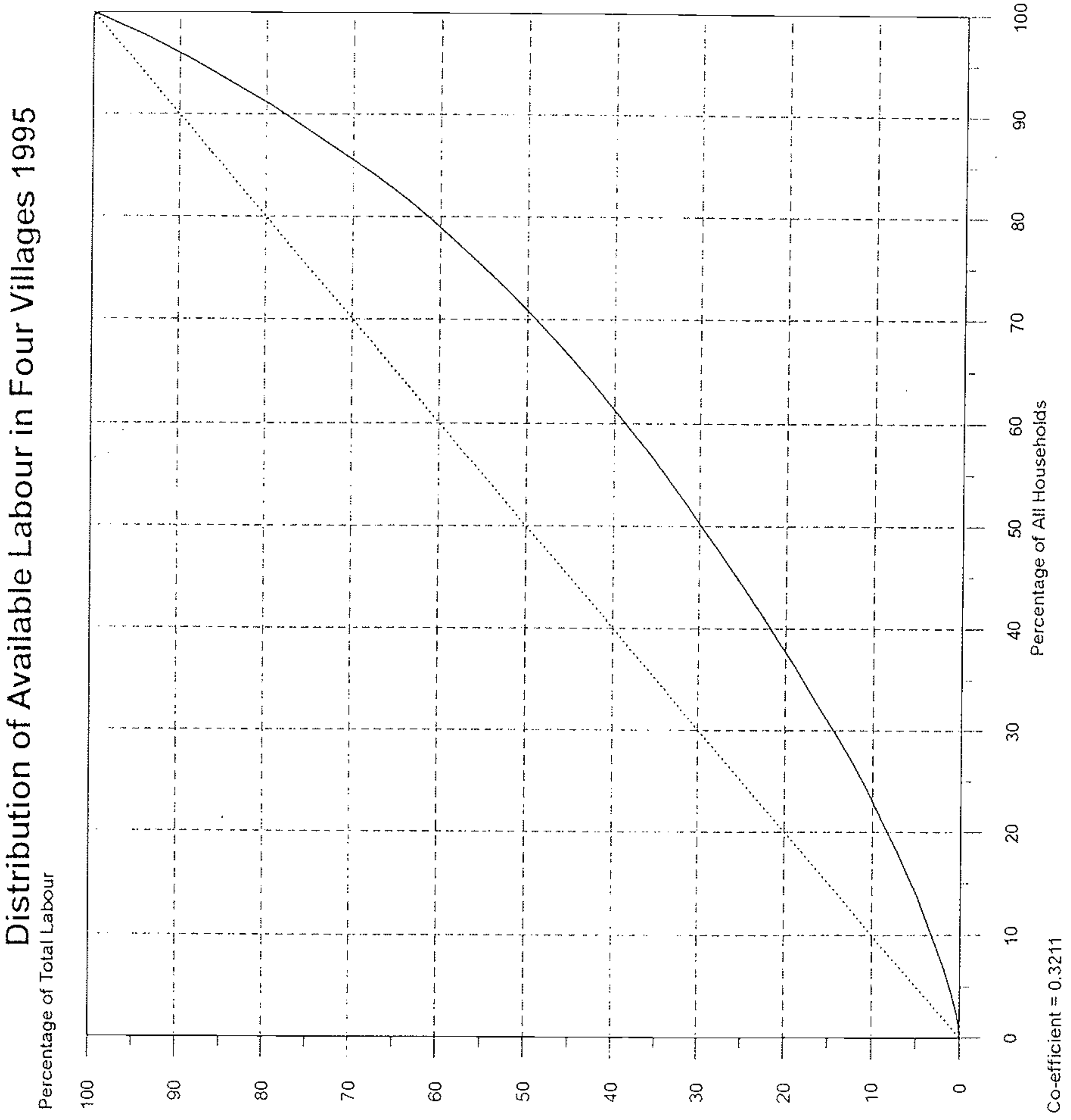


FIGURE 5.1.5(b)

Total household labour availability, 1993-1996

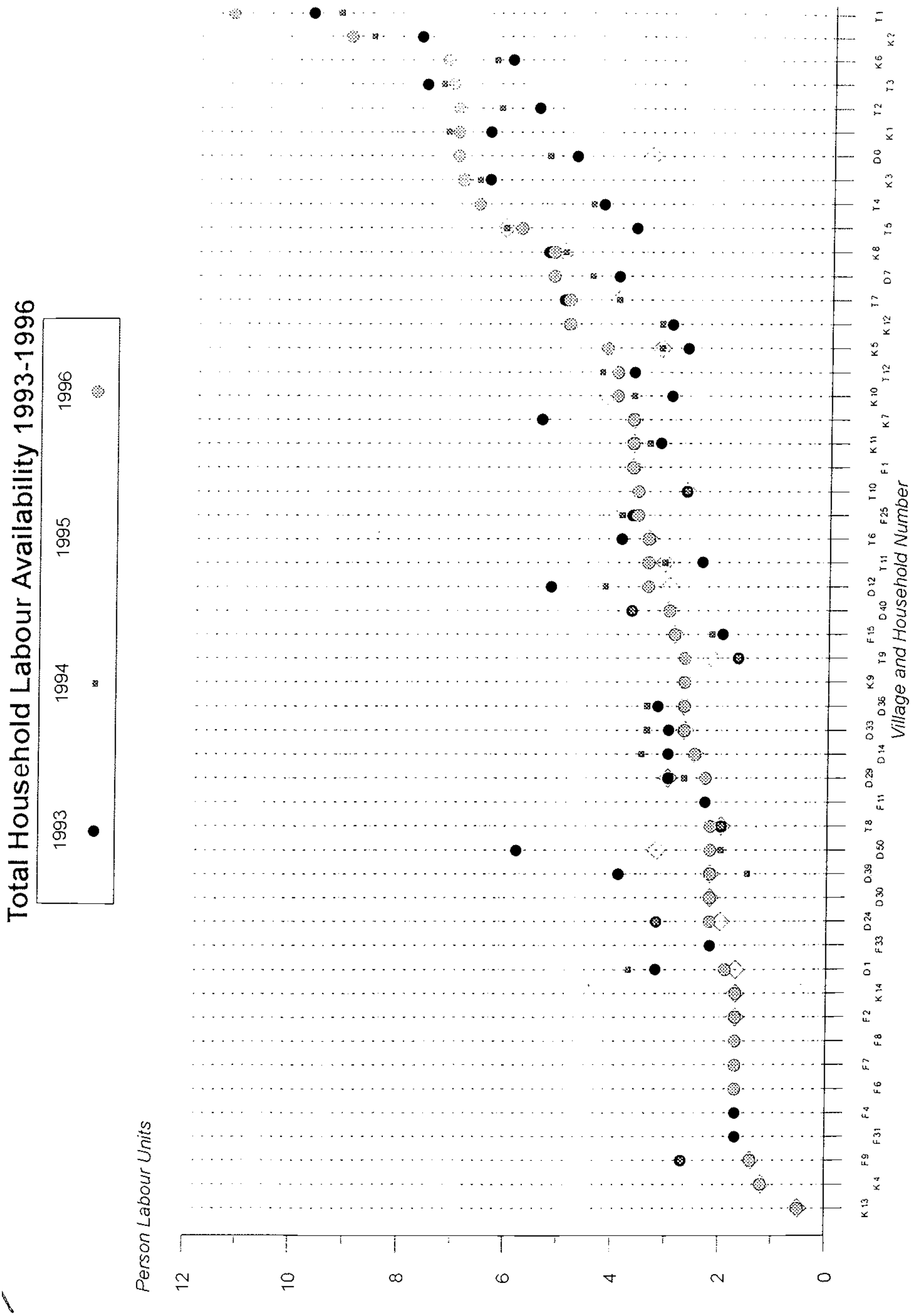


FIGURE 5.1.5(c)

Household land-labour relationships in four villages, 1996: per capita

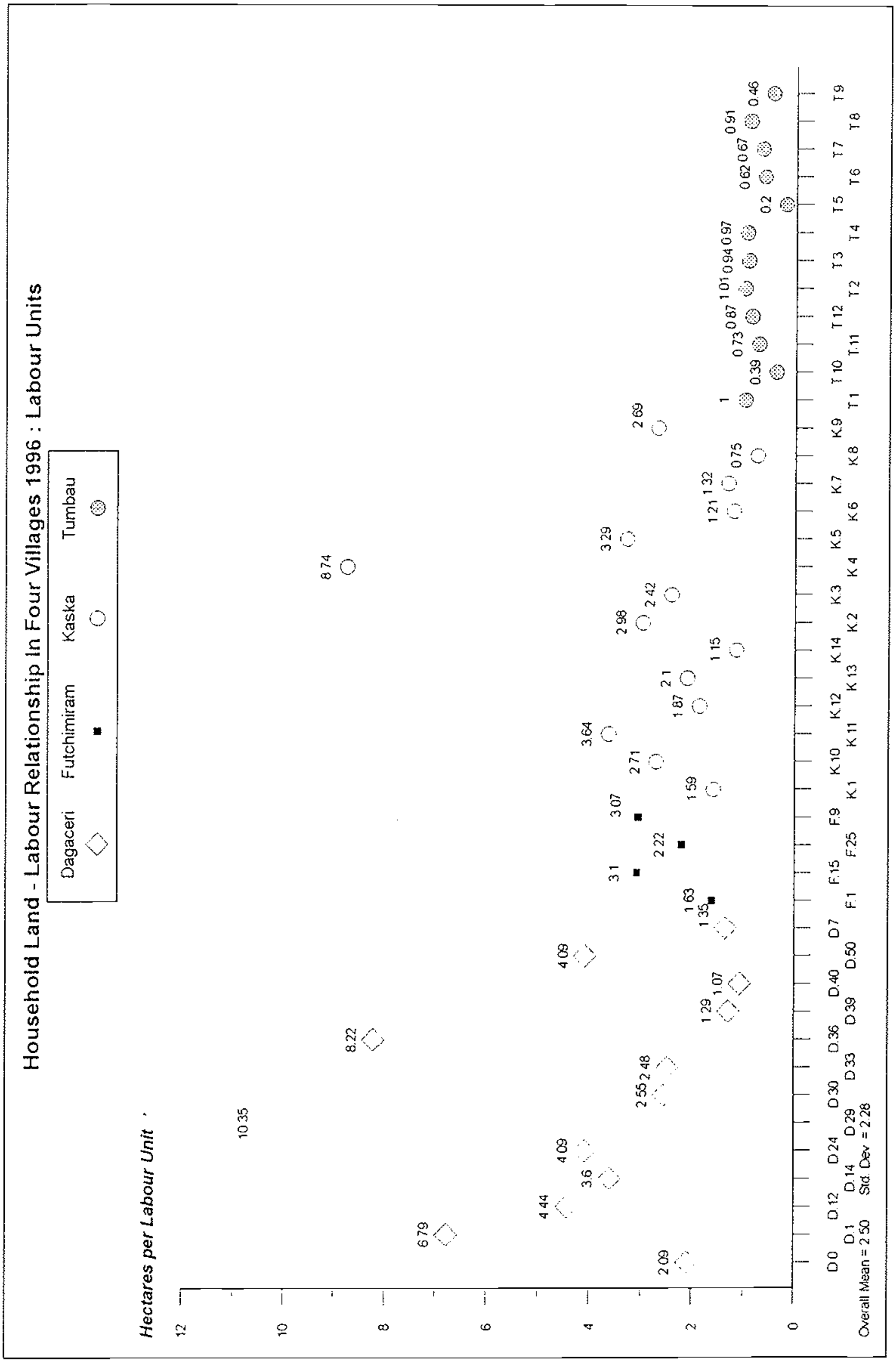
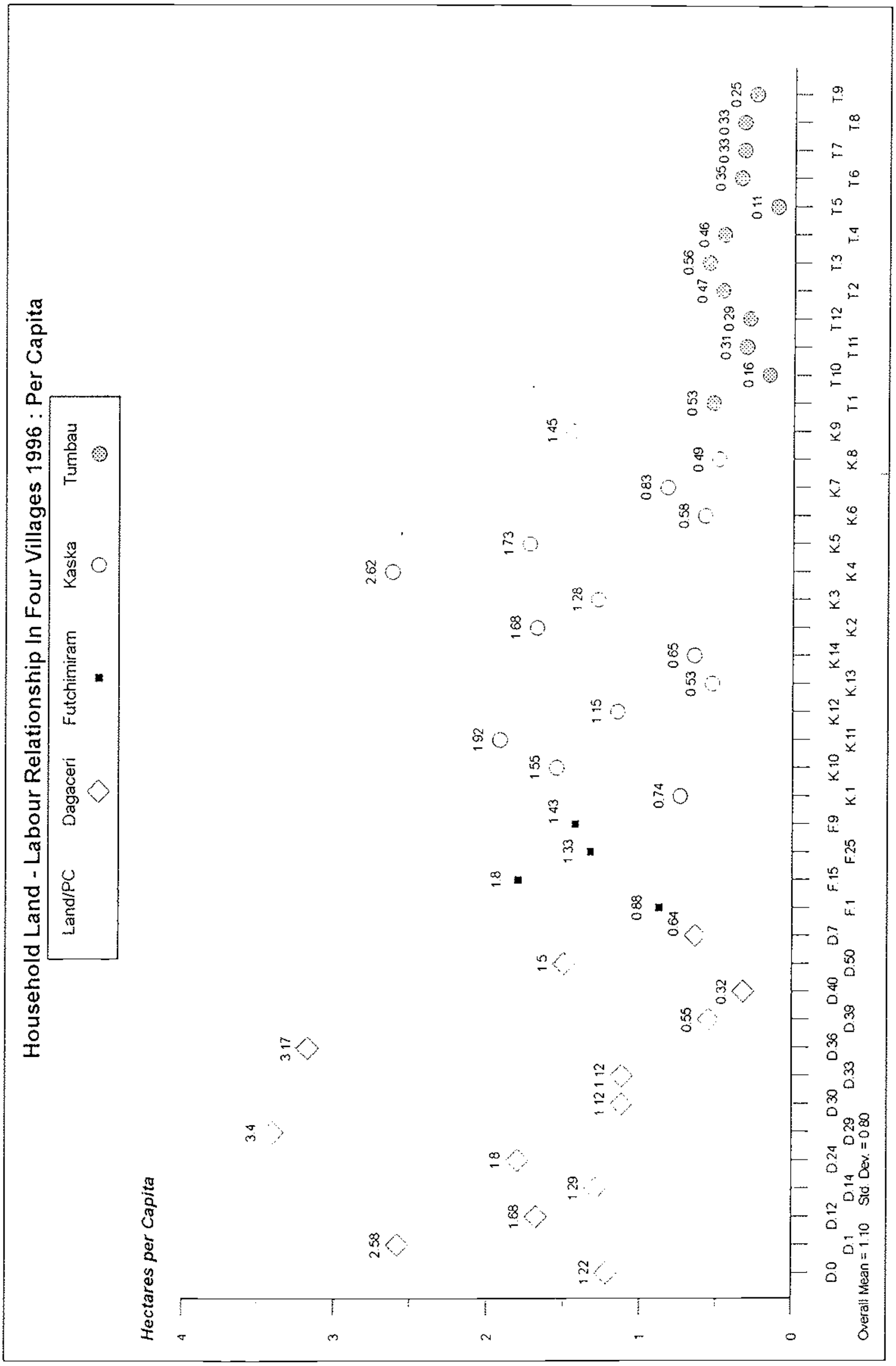


FIGURE 5.1.5(D)

Household land-labour relationships in four villages, 1996: labour units



5.2 Farming and Livelihood Systems

5.2.1 Introduction

The design of the research, with parallel investigations across four villages on an environmental and socio-economic gradient on decreasing rainfall, farming intensity and population density, has been described in Section 4.1 above.

A major output of the project has been a detailed description of the farming system of each of the four villages. These *Farming Systems Reports* have been published separately, and disseminated to researchers in the UK and West Africa, and to development agencies in Nigeria (Yusuf 1996, Mohammed 1996, Ibrahim 1996, Chiroma 1996). These accounts draw on the extensive qualitative research materials obtained through fieldwork in the study villages. They provide an almost unique resource for researchers and policy-makers not only within Nigeria (where ignorance of the lives and environments of the rural poor is profound), but also in the West African Sahel more widely, where a small number of previous case studies from northern Nigeria are used repeatedly to make generalisations over large areas. These accounts form the basis of the quantitative analyses reported elsewhere in this part of the *Final Technical Report*, and will also underpin further dissemination of the project's results. The accounts of farming systems are, however, voluminous, and do not meet well the guidelines on the *Final Technical Report* that emphasise the need for brevity. The *Farming Systems Reports* have therefore been summarised as Annexes to this report (Annexes 3-6). This section is in turn a very brief summary of the material in these Annexes, without which the material presented in sections 5.3 to 5.6 will be robbed of its vital context. Each village is described in turn.

5.2.2 Tumbau

Tumbau is in the inner Kano Close-Settled Zone where intensification of small scale agriculture is highest in the whole of Northern Nigeria (Mortimore 1967, 1989). The farming system is highly diverse in terms of cropping, technology and fertilisation. The rural population density is high, and the average arable land per head is small (Mortimore, 1993). Tumbau lies in the central parts of the Kano plain. Natural vegetation has been removed in this area through fire, cultivation, browsing, grazing and cutting for fuelwood, and is now replaced by cultural vegetation which is referred to as farmed parkland. This consists mostly of economically useful trees such as baobab, *Parkia biglobosa, Mangifera indica, Tamarindus indica, Ceiba pentandra,* valued as sources of food and fuelwood.

The main food crops are millet (early and late), sorghum and cowpeas. Early millet is the main food crop. Late millet is the first to be sold for cash, and some sorghum may be sold . Early and late cowpeas are mostly intercropped with grain and are both consumed and sold (as are the crop residues for livestock feed). About a third farmers grow cassava. The main cash crops are groundnuts (whose residues are also important for penned livestock). Peppers, bambaranut, benniseed, okra, sweet potatoes and tomatoes are also grown, as is rice in a few water-logged pockets and in the reaches of River Kano.

Most farms in Tumbau are ox-ploughed which makes thinner and narrower ridges than hand-ridging. One ridge is usually left after planting grain in one or two ridges and planted with cowpeas later. Cropping systems are complex and highly diverse in terms of pattern and intensity. The overall pattern is intensive-mixed cropping, with at least two major crops and 2 to 3 minor crops in a single plot. The pattern is determined by the needs and interest of the farmer and also the fertility status of the farm. Patterns of intercropping can be simplified into three main categories, grain main farms (*gonar hatsi*), groundnut main farms (*gonar gyada*) and those farms in which a portion of a farm is devoted to cassava, okra, benniseed, etc.

Crop rotation, mainly between grain main mixtures (sorghum and millet) and groundnut main is popular as a deliberate strategy to maximise yield and conserve fertility. Rotation may be after one year or two years. It is considered that grain main mixtures can be rotated with groundnut-main mixtures with no regard for the fact that early millet or sorghum was grown as an intercrop with the groundnuts in the previous year. So a typical rotation might be as follows:

1st year - Groundnut mixed with either sorghum, early millet or cowpeas.
2nd year - Early millet mixed with cowpeas or sorghum with cowpeas.

Tumbau has supported a high population density for centuries. Smallholder farming is highly intensive and the farmlands are under continuous cultivation. In order to maintain fertility and yield, the system has developed diverse agricultural management practices in terms of cropping, fertilisation and technologies. Twelve distinctive management practices based on fallowing, farming technologies, fertilisation and agronomic practices were identified in the area (Yusuf 1996). These 12 practices fall under four headings, Fallowing (2), Fertilisation (4), Cropping (4) and Technology (2).

Soil fertility is chiefly maintained by applying different types of animal manure, notably small ruminant pen manure; cattle manure; domestic refuse, ash, and burnt gathered leaves and crop residues. Inorganic fertiliser is in high demand but only a few farmers can afford to purchase it in adequate quantities. It is largely applied to grain (sorghum and millet) when available and affordable. Generally, the application of some form of fertiliser is necessary for a reasonable harvest. Therefore, farmers do all they can to supply manure and fertilisers to their farms.

The most important source of manure is from penned domestic animals, especially small ruminants. There is no family in the area that does not keep some small ruminants, and their function in providing manure is second only to their role as a pool of savings. Those who have few livestock borrow small ruminants from relatives or friends so as to pen and feed them in order to get manure. Farmers feed the livestock with all sorts of leaves, grasses, crop residues and browse. Collection is time-consuming, especially in the last part of the rainy season (August). Domestic refuse and ash are thrown into the livestock pen. In the dry season when the livestock are released for free grazing, the farmers remove and pack the manure to the farms on donkeys (about 75%); ox-drawn cart (20%) and by head, especially to home farms (5%).

The farming system in the area ensures a cycle of nutrients. Manure is needed to produce crops and crop residues are used in feeding the livestock which produce manure that is taken back to the farm to improve soil fertility. The cycle is fairly efficient though some nutrients are lost by taking some harvested crops away from the area. Nevertheless, this is compensated by the browse and leaf litter from the trees that exploit nutrients from the bottom of the soil horizon, and also by the application of chemical fertilisers brought from outside the system. Nutrients are transferred among the three subsystems: livestock, crops and soils (Harris 1996). The farmer knows that the soil cannot produces significant yield without manure, and the survival of his livestock depend on the crop residues and farm grass weeds. Though there are a number of leaks and some inflow of nutrients from other sources they are insignificant on a larger scale.

The first rain in the Tumbau area usually comes in late May to the first week of June, and the rain lasts until late September. Distribution and frequency of rain within the season determine the growth of individual crops and the overall crop harvest rather than the amount of rain recorded.

Planting starts from the first day of the rain to July. Grain crops (early millet and sorghum) are mostly planted within the first two weeks, whereas cowpea planting lasts up to July. The first ridging begins with rain and lasts to about four weeks, and the second ox-ploughing and plough-weeding last up to the last part of August. Weeding starts immediately after the re-growth of grass weeds and continues to October after the rain.

Crop harvests start with early cowpeas, usually from early September and continue to late November for sorghum which is the last crop to be harvested in the farm. Packing and storage of grain is usually delayed until after the rain (October), especially for early millet which is harvested in September. The reasons are that the high humidity of the wet season is likely to damage the grain, and also around that time a farmer may not have space or a granary. Moreover, the materials (*gamba* grass) for making a granary may not be available by that time. Most farmers with more than 15 bundles keep their early millet in the farm (covered) until after the rain.

Hand ridging has been overtaken by ox-ploughs which were introduced into the area about 25 years back (1970s) but became more popular in the last 8 years (from 1985). Because of the heavy capital investment involved, few families own ploughs (about one in 25). Yet these plough teams are sufficient to cultivate their own and other people's farms on hiring, though there are queues and delays in the first three weeks of the rainy season for non owners, and some may not have money to hire in time. The prime ambition of most farmers in Tumbau is to possess an ox-plough, both as a means of saving labour and a means of maximising crop production.

Weeding and crop harvesting are the most labour-demanding tasks. Labour shortage during weeding is filled by hiring labour from those who either have little farms or are in need of cash. But during crop harvesting this gap is filled by community labour during which the farmers extend their working time to afternoons. The main labour source for farm work is the male members of the household aged from 10 - 60 years. The household head who decides on what operation is to be done every day, and in which farm. Women (especially young married women aged 15 - 40), are confined to domestic compound work, although some married older women do work in their own farms, this depends on the number of working males in the family and the well being of the family as a whole. The head of the household in a *gandu* family (an extended family system) controls the labour of each member of the household in the morning operations, while the allocation of labour in the afternoon is decided by individuals, who may work their own personal farms or hire themselves for cash.

Livestock play an important role in the farming system and the economy of the area. Most cattle in the Tumbau area are kept by semi-sedentary Fulbe. Hausa farmers keep cattle for fattening and traction. Two thirds of ruminants are small stock. Hausa keep sheep for breeding and fattening and they tether them especially in the wet season whereas the Fulbe keep sheep for breeding and graze them alongside their cattle. Small ruminants are penned in the rainy season under a hut in the compound and released for free ranging after the harvest in the dry season. A few households own donkeys for transporting manure, farm produce, bricks and clay for building. A considerable number of livestock (sheep, goats, and cattle) are kept for fattening are not released for free grazing but penned throughout, consuming a large amount of stored hay and straw. Settled Fulbe in Tumbau participate fully in rainfed farming, and only some members of the family move south with the cattle in the dry season in search of pasture. Generally the Fulbe are finding it very difficult to graze their herds in the area; the only available spaces for them in the wet season are the cattle tracks, which are becoming narrower every year as farms encroach on them, and some strips along the major streams (the reaches of the River Kano in particular). Some nomadic herders pass through the area from Niger Republic in November, December and January and do a lot of damage to the farm-trees by unscrupulous lopping without the consent of the owners, and this is becoming a serious problem and a source of conflict. In the dry season Hausa-owned livestock stock range freely, and most livestock management (watering, tethering for the night) are done by women. Scarce stored feeds (hay and straw) are kept to feed stock in the first part of the rainy season before the growth of farm weeds. Small ruminants released in the dry season are penned in the first week of rainfall (May/June). Grass and weeds (collected from farms in the afternoon or early evening) form the major feed until after the harvest of all crops in the last part of November.

The elimination of the natural vegetation in the northern savanna and its replacement by cultural vegetation or farmed parkland has effectively domesticated all the trees and other plants. There are over 40 different useful farm trees in the area, most of them multipurpose. All farm trees are in one way or the other used for fuelwood, many provide fodder and a number of them provide economic fruits and timber). Trees are more numerous near the village, while shrubs are more numerous further away. There are over 43 useful tree species and a number of shrubs in the Tumbau area. Almost all trees and shrubs have some economic importance. Fuelwood is mostly harvested from living trees rather than from clear felling, this kept the tree density in the Kano Close-Settled Zone reasonably stable. Trees are used intensively and contribute greatly in feeding livestock and providing fuel wood whose end product (ash) is subsequently taken to the farms as manure. Most of the trees in the area are multi-purpose providing 2 to 4 different uses. There is not much planting or transplanting of farm trees, possibly because few trees are clear felled. The most conscious effort in raising and planting trees is for shade and timber in the villages. Most farm trees regenerate by chance and the farmers leave them and nurse them to maturity. Some trees like *dorawa, mangwaro, dabino,* and *rimi* need to be fenced in the dry season to protect them from the free grazing livestock. Other trees grow from shrubs which the farmer leaves to grow. The fact that fuelwood may not be taken from other peoples' economic trees this protects them from unscrupulous lopping.

5.2.3 Dagaceri

Dagaceri lies between latitudes 12° 45'N and 12° 50'N and longitudes 10°05'E and 10°. It is a hamlet (Dagaceri Karaguwa) within Mungurun Village Area, Birniwa Local Government, Jigawa State (Appendix 4). It includes of three different ethnic groups: Manga, Hausa and Fulb'e. Hausa and Manga live within the village while the Fulb'e community live outside in the grazing lands. The vegetation of the study area is a secondary or degraded woodland comprising widely spaced trees, lots of shrubs and a continuous ground cover of herbs.

Crops in the study area include sorghum, pearl millet, cowpea, groundnut, benniseed, and 'cow melon' *guna (Citrulus lanatus).* All the crops are grown under rainfall alone. Millet is the major source of food, although sorghum is also important. There are seven different varieties of millet and seventeen different varieties of Sorghum. Cowpeas are cultivated as a staple and for cash, usually intercropped with either sorghum or millet. In the nineteen sixties and early nineteen seventies, groundnuts were the major cash crop in the area, but in recent years, groundnut cultivation has almost disappeared (because drought in 1970s and 1980s, and rosette disease). Presently groundnuts are not grown in commercial quantity and few people grow them for local consumption. *Guna* is presently one of the major cash crops of the area, grown for its oil-bearing seeds that are rich in fat and protein. It reappeared as a market crop in Dagaceri after 1972 due to an increasing demand (Mortimore, 1989:106). It is planted towards the end of the rainy season to grow under residual moisture, and is popular because of its economic value and low labour requirements. Benniseed is a major cash crop whose continuous cultivation has been inhibited in recent years by its being very susceptible to grasshopper attack. With high market value, it is intercropped with either sorghum, millet or cowpea. Bambara Groundnut is grown largely by women in small farms and more for domestic consumption than for cash.

The major cropping patterns identified in millet main-farms are millet with sorghum minor (*gonar hatsi mai sarnon dawa*), millet inter-cropped with cowpea (*gonar hatsi mai sarnon wake*), and sorghum inter-cropped with cowpea (*gonar dawa sarnon wake*). Farmland in Dagaceri consists of manured infields (fertilised with livestock dung, ash heaps and compound sweepings) and unmanured outfields. Manured farms are seldom fallowed. Mortimore (1989:104) reported consecutive cultivation of 25, 30 and even 50 years on manured farmlands close to the village. Unmanured outfields are fallowed, but few farmers do so systematically.

In Dagaceri, some fields are ridged, and others cultivated flat On flat farmland planting normally starts after a heavy rainfall with the long handled planting hoe (*sungumi*). On ridged fields, ridges are made with the plough and in a few cases by tractors hired from Birniwa (the local government headquarter). Planting on ridges is done without the use of the long handled planting hoe or any other implement. Ridges may be left unplanted for later relay crops (e.g. cowpea). Planting is easier and faster on ridged than on flat land.

Labour shortage is not a problem at the onset of the rains because the dry planting has already taken place before the onset of the rain, planting is among the easier farming operations in which all household members participate (even children of 8 to 9 years old), and because hired labour is available and cheap at this time. However, labour is critical during the weeding period because it is seen as the hardest of the farming operations, and it coincides with the period of labour scarcity, and hired labour is expensive. Farms in interdunal depressions where water collects grow weeds and need more labour than those on dune tops. Manure or fertiliser encourage the growth of weeds and need more labour. Women are responsible for household activities such as cooking, washing of plates and clothes of children, fetching water from the well or boreholes, threshing grain and many others, while smaller children cannot work fully on the farms.

Cattle are mostly held by the Fulbe community in Dagaceri, although some Manga and Hausa households have cattle. In some cases these are managed by Fulbe herders. The Manga community keep bulls for use in traction and transportation. Both Manga and Fulbe keep sheep and goats. Sheep, are an important sources of income to the villagers in festival periods. Prior to the 1970s and 1980s drought, almost every compound in Dagaceri owned at least one horse, and many had donkeys. Presently very few households own either.

There are two patterns of livestock rearing in Dagaceri. Manga and Hausa farmers' sheep and goats are managed by someone appointed in the village as a herdsman. In the dry season, the village herdsman take the animals to harvested farmland (without *guna* in it) and fallow land. In the rains, grazing is restricted to uncultivated grazing lands and fallow lands. The animals prefer fresh grasses. The Fulbe in Dagaceri move with their cattle, sheep and goats in search of pasture and water. In the farming season, they are restricted to grazing areas such as cattle tracks, grazing lands and fallow fields found at the edge of the village. At the beginning of the dry season, the Fulbe move to fallow land and harvested farmland. Access to farms where *guna* is grown is only possible by negotiation, and only after it has been harvested. During a prolonged dry season, when fodder is scarce, and stored feed exhausted, the animals graze on shrubby plants and lopped branches of trees such as *Faidherbia albida, and Combretum glutinosum.* Grazing lands (grazing reserves and cattle tracks) are open access areas where grazing is not controlled, but crop cultivation is normally not allowed. Livestock graze these lands in both the dry and rainy seasons. There are disputes over stock damage to growing crops on private farmland.

People know and use 118 non-domesticated plant species in Dagaceri, 62% of them herbs, 28% trees, and 9% shrubs. These plants occurred widely, on fallow fields (37%), grazing land (25%), on cultivated fields (23%), cattle tracks (11%) and around settlements (4%). They were used for a variety of purposes, the most important of which was medicine (32% of species). Villagers are aware of the significance of vegetation and they have taken various strategic measures for its management. The local government has made free distribution of exotic *Azadirachta indica* seedlings and other introduced and indigenous species. Fuelwood comes from dead wood, dry woody shrubs such as *Guiera senegalensis, Boscia senegalensis,* and *Acacia ataxacantha,* and crop residues such as millet stalks, sorghum. Various economic products are harvested from trees, such as the leaves of the baobab (harvested in both rainy dry seasons), leaves of *Faidherbia albida* (harvested in the dry season for livestock) and leaves of *Combretum glutinosum* (cut for livestock in the dry season). Fruits of *Hyphaene thebaica, Ziziphus spp., Balanites aegyptiaca, and Tamarindus indica* are harvested in the dry season.

5.2.4 Kaska

The Kaska study area lies within Yusufari Local Government Area of Yobe State (latitude 13° to 13°25' North and longitude 10°50' to 11°30' East). To the north it extended up to the border with Niger Republic (Appendix 5). Kaska lies on an undulating plain with stabilised dunes forming the upland *(tudu)* which are interspersed by interdune depressions *(faya)* and *kwari* (low land) depressions which form the low lands.

The lowland depressions, generally surrounded by huge stabilised sand dunes, contain the big water bodies in the area called *tafki*. The *tafkis* in the past retained water for years and supported aquatic life like fish, hippos, and crocodiles. In the dry season when the surface water dries, the *tafkis* produce potash (*kanwa*) and locally processed salt *(manguli)*. Rice, wheat, sugarcane, maize, onion and cassava are grown around the *tafkis*. *Tafkis* have gradually dried up, stopped yielding potash and the aquatic lives which were once supported have totally disappeared. The moist soil, however, in some *tafkis* supports the cultivation of crops and potatoes through small-scale irrigation, *garka*.

The vegetation was formally Sudan savanna, characterised by tall *gamba* grass *(Andropogon gayanus)*. The ecology of the area has gradually changed to a more Sahelian type of vegetation over the past 25 years. The dominant gamba grasses have almost disappeared and been replaced with *karangiya (Cenchrus biflorus)* and other species. The few trees found on the stabilised sand dunes and inter-dune depressions are *Commiphora africana (dashi)*, *Calatropis procera (tumfafiya)* and *daniya*. The dominant tree in the low land depression now is the *Hyphaene thebaica (goriba)*. There is high pressure on the exploitation of *goriba* shrubs *(kaba)* by the people in the area for mat-making

The major crops include: millet (six varieties), cowpea (nine varieties), sorghum, cassava, okro, tomatoes, *guna*, and green vegetables. Date palm are also important. There is no fixed farm calendar in Kaska due to the nature of rainfall which fluctuates between years. Currently, field clearing starts around April to May, dry planting *(bunne)* is June, wet planting from mid June to early July. Weeding covers the period between mid July to early September while harvesting and storage take place from mid October to November. The period between mid December to early April is normally devoted to small scale irrigation on *garka* plots in low-lying land and own farm and off farm activities like mat weaving, small scale trading, and short term mobility *(cin rani)*. *Garka* cultivation is mainly for commercial purposes; 91% of the households of Ngammiya village own *garka* plots in which cassava, potatoes, sugarcane, vegetables and economic trees like dates, mangos, lime and guava are grown. *Garka* plots are usually fenced against animal incursions and demarcated by economic trees, dug pits or channels

The topography of the area has produced three major categories of farm lands. These are lowland depressions (*kwari* H), interdune depression (*faya* H) and stabilised sand (*tudu* H). Until about 15 years ago, *kwari* was preferred for cultivation. The soil is black clay in nature and rich in potassium, phosphate and plant nutrients. The major crops are sorghum, wheat, rice, cowpea, millet, sugarcane, cassava and potatoes. The prevalence of drought has made the cultivation of *kwari* areas difficult as the soils are difficult to manage when dry. Thus most of the *kwari* farms are undergoing long fallow and some are abandoned and grown into bush dominated by young dum palm trees *(Hyphaene thebaica)*. Around the *tafkis* where the soil is moist and the water table is shallow, small-scale irrigation is conducted. Wells and dug pits provide the main sources of water for the irrigation. Cassava is the major crop grown in the *garka* plots. Economic trees like date palm, mango, and lemon are also planted in some of the *garka* plots.

The interdune depressions (*faya*) are now the most intensively cultivated areas around Kaska. The soil is sandy, mixed up with a little clay. It has a high moisture retention capacity but is easily managed compared with *kwari* clay soils. Thus farmers in the area now prefer the *faya* farm land to the *kwari*. Crops like sorghum, millet, cowpea, *guna* and benniseed are grown. The *faya* fallow duration is usually between 2 and 5 years. Presently, there is no left over *faya* land that is not under cultivation or has no title attached to it.

Due to the scarcity of the *faya* farm lands and the failure of the *kwari* farm lands, cultivation is now being extended to the slopes and tops of unoccupied sand dunes. This practice started about 9 years ago during the *banga-banga* drought (1983-1985). Millet, sorghum and *guna* are grown. Farmers cultivating *tudu* areas are facing the problem of crop damage by the livestock. As most of the *tudu* areas are unoccupied, pastoralists graze their animals there. Animals wander into the tudu farms and destroy the growing crops, thus resulting in conflicts between the farmers and the pastoralists.

Unlike the other study villages, economic trees are not an integral part of farms. However, attention is geared towards small date palm plantations (especially among the Manga farmers). Reliance on date palm plantations for the supply of economic products and income adds to the sustainability of the farming system in the area.

Soil fertility is generally low, and respondents suggest that soils cannot withstand more than 5 years of cultivation without loss of fertility. Manga maintain soil fertility by short fallows (2 to 5 years) and the application of organic manure, mainly obtained by inviting the pastoralists in their neighbouring settlements to fertilise the soil through livestock droppings in exchange for crop residues or friendship.

Agricultural systems among both Manga and Fulbe communities in the study area are a form of mixed farming. The Manga practice a rotational bush-grass fallow system of cultivation usually in conjunction with permanent cultivation. The fallow period ranges from 2 to 15 years depending upon the availability of labour, population pressure, and physical factors such as farm location (low land depression or interdune depression), the fertility regaining capacity of the soil, and drought. Under the fallow system, the Manga grow millet and sorghum (usually for subsistence, although when there is a surplus or a social or health problem they are sold). Fulbe farmers practice a semi-permanent system of cultivation with no fallow at all, or with fallow at long irregular intervals (e.g. during the droughts of 1983 and 1985 when some Fulbe migrated temporarily to wetland areas). Organic manure obtained from their livestock sustains long periods of cultivation. One respondent's farm land has been under cultivation for over 50 years without fallow. The Fulbe cultivate mainly the subsistence crops, millet and sorghum. They do not participate in commercial crop production, *garka*, cowpea or *guna* cultivation.

Regenerating shrubs and the remains of crop residues scattered in fields are normally cleared before planting. Cleared materials (shrubs and crop residues) are usually collected in heaps and burnt to ashes. Fields are not ridged. Ridges could expose moisture in the soil to the sun and affect the growing crops; the soil (especially in *faya* and *tudu* areas) is also too loose to make firm ridges, and is easily flattened by rain splash or wind once dry. Moreover, in large holdings (of 2 to 4 hectares) it would be labour-demanding to make ridges and would take a long time and delay planting. Weeding is carried out twice during the growing period. The first weeding operation is usually started 4 days to a week after germination, and can last up to a month or more. Both Manga and Fulbe use the *Ashasha* (H) for weeding. Second weeding is started when necessary. When the crops grow tall and are not easy to weed with *ashasha,* a hoe is used in carrying out the second weeding, especially in *kwari* areas. Crop thinning may be done when crops reach 15-20cm tall, and the plants removed may be transplanted if there is adequate moisture to support their growth, otherwise they are left on the fields to decay. Harvesting is the most time-consuming of all farm operations, usually lasting a month or more, with an average of seven working hours per day. Men cut crop stalks and arrange them in lines on the ground. Either men or women may remove crop heads from the stalks. Harvested crops are given constant inspection and temporary cover before storage to guard against pests. Crops are stored in granaries made with *Andropogon* grass, usually obtainable from the patches protected in cultivated fields and woodlands.

Manga farmers obtain labour obtained from family members, communal assistance or hire. Field clearing, granary building and crop storage are entirely managed by men while threshing is handled by women. Planting, weeding and harvesting are carried out jointly by men and women. Female participation in farming operations in many families is almost equal to that of males. It is a common practice for women to hold and manage separate fields. The Fulbe consider farming as a male affair. Women rarely participate in planting and harvesting. However, in a desperate situation women do participate in weeding.

Both Manga and the Fulbe graze their animals on stabilised sand dunes and the abandoned or long fallowed *kwari* farms which are the major grazing areas. The Manga keep small ruminants (mainly sheep and goats) in small numbers. Some Manga own cattle (8% of households in Ngammiya), which are managed by neighbouring Fulbe in exchange for payment. Horses and donkeys are mainly used for human transportation and carrying loads respectively while small ruminants are kept as assets (28% of the households own horses and 19% own donkeys). The Fulbe at Kwarin-Isa keep large herds of cattle (on average between 15 and 25) and large herds of small ruminants (30 to 50 sheep and goats). Many Fulbe own camels for transportation just like horses and donkeys.

Respondents reported that the population of livestock in Kaska (particularly of cattle) was high around 1960 (almost five times that of the present) but that had fallen drastically and changed in structure since: there are more goats than sheep, and fewer cattle, horses, donkeys and camels. These changes were said to be due to lack of fodder and water. Furthermore, the ownership of livestock has changed. Around 1970 Fulbe held about three-quarters of the livestock population in the area, but now most animals belong to Manga. The Manga have a source of income in dry season *garka* cultivation that has meant they have not had to sell their livestock as the Fulbe have to get food and fodder, and to meet to other social obligations. Grazing land on the other hand is open to Manga, Fulbe and strangers.

Neither the Fulbe nor the Manga prevent one another, or strangers, from grazing on available pasture. The Fulbe in the study area appear to be able to prevent the neighbouring Manga farmers from extending farm cultivation into their traditional grazing lands acquired through first settlement, by intentional crop destruction, and verbal or open combat.

During the wet season (June to September) Fulbe livestock are confined to rangeland, but after harvest (October through November to early December), grazing is extended to farmland, especially where free crop residues are available. Around March, when the nearby fodder starts diminishing, livestock are moved to wetland areas until June. The sedentary Manga farmers confine the movement of their small ruminants within less than 2 km of the village. In the dry season, small ruminants owned by Manga in Ngammiya are managed by one or two groups of people who get paid on a monthly basis. In the wet season, however, when every adult is busy with farming, animals are managed by boys and girls between the ages of 8 and 10 years from individual households.

Fuel in Kaska comes from trees, mostly in and around the lowland depressions (*Hyphaene thebaica, Acacia sieberiana,* and *Piliostigma thoningii*) and around settlements (*Azadirachta indica, Balanites aegyptiaca*) and on uplands (*Faidherbia albida*). *Hyphaene thebaica* and date palms provide poor fuel, but due to measures taken by the local government authority against cutting live trees, only stalks of date palms are used for domestic burning. These are usually fetched by women. Dates and dum palm shoots *(kaba)* are the major commercial tree products in the area. Date palms are privately owned while palm shoots are open access resources. *Kaba* is harvested throughout the dry season from November to June by adult men.

5.2.6 Futchimiram

The village of Tatukuturi is located about 2km north-east of the larger village of Futchimiram (Lat. 12^0 45'N and Long. 12^0 25'E), Geidam Local Government, Yobe State (Appendix 6). It is inhabited predominantly by Badowoi, a Kanuri dialect group. The area is a flat to very gently undulating plain at 300m above sea level. The vegetation is a parkland savanna, with natural vegetation consisting mainly of thorny drought-tolerant trees (e.g. *Balanites aegyptiaca, Faidherbia albida* and *Acacia* spp.) and *Leptadenia* shrubs. The most prominent grass species are *Cenchrus biflorus, Dactylectenum aegyptiacum* and *Digitaria debilis*. The area is mainly used for grazing and is only cultivated around villages.

Millet (three varieties) is the dominant crop because of its adaptability to drought coupled with its ability to grow under low fertility. Sorghum is common, but a secondary crop in Futchimiram, primarily produced as livestock feed. Groundnuts (4 varieties) are the most important crop after millet. The introduction of an early maturing (upright bunching) variety about 10-15 years ago, made the higher yielding spreading variety less popular. Groundnuts contribute more to the total farm income than any other single crop. The shelled kernels can be bagged and sold in the market, the oil from the kernels can be extracted and sold as vegetable oil to be used in frying or in stew making, the leftovers from the processed kernels made into groundnut cake and eaten or sold, and the crop residue itself may either sold or reserved for use as livestock fodder. Most women who own farms independent of their husbands devote all their land to groundnuts (this is possible because it is not their responsibility to provide for the food needs of the family). Cowpeas (5 varieties) are the second cash crop, although they are also eaten, and the shoots are sold or fed to livestock fodder, particularly small ruminants, during the dry season. Pests and diseases are a problem; a recent outbreak of cutworms (*noctuids*) discouraged many from growing the crop and few now devote much lands to it. The farming system is characteristically rainfed subsistence farming of annual crops with some production for cash. All crops are planted with virtually no prior land preparation. The loose sandy nature of the soils makes ridges short-lived, and the labour implications of farming ridges using hand held hoes also discourage many farmers from planting on ridges, so crops are generally grown on the flat. Systematic use of pesticides or fungicides is an uncommon practice owing to their scarcity and high cost.

Animal traction for cultivation is uncommon because of problems associated with the procurement of farming implements such as ox ploughs, whose current market price is beyond the reach of many farmers. Manuring has become an integral part of the farming system, and many farmers collect manure for use on their farms.

In Futchimiram, strip fields that extend from each household in either direction. The eastern field is only a fraction of the one on the west. These fields, known as *kulo fatoye* (home farms), are those of the first settlers and have been under continuous cultivation since then without fallow. These fields include one big farm devoted to millet and a few smaller ones devoted to groundnut, cowpea and sorghum. Continuous monocropping of rainfed crops is common with virtually no inter-cropping. Rotation and fallow are introduced whenever soil fertility drops too low. Continuous cropping of the same crop type for up to 10 - 15 years is common on newly opened fertile fields or home farms enriched with organic manure (*taki*). In the absence of sufficient manure, farmers preferentially fertilise the home fields (*kulo fatoye*) and rely on fallowing to maintain the fertility of more distant outfields. Each household has its cattle alongside the house and often stations them at the nearby home farms in the dry season for manuring. Rotation is usually practised between cereal crops (millet and sorghum) and legumes (groundnut and cowpea), although the frequency of rotation varies.

Crop cultivation starts with land clearing in June (task done by men); planting of millet and Sorghum commences in July shortly before the rains. Groundnut and early cowpea are planted with the main rains in August whereas late cowpea are not planted until late August. Plough-users plant earlier (with the first rain). Weeding starts immediately after groundnuts are planted and continues to early November when the rains have ceased. Crop harvesting starts early in September with the early cowpea varieties (which have to be harvested before pods shatter) and continues up to late November. Late varieties of cowpea and sorghum are the last crops to be harvested. Carrying and storage begin with early cowpeas in September and end with grain crops in December.

Severe farm labour demands can limit the area that can be cultivated, and labour availability is recognised as a more important production constraint than land (just over 20% of the area is presently cropped). The major constraint in clearing new fields is the cost of labour. Since the onset of drier conditions in the 1970s, farmers have cultivated large areas to maintain production in dry years, but it is not uncommon to see sizeable portions of land abandoned to weeds. Male labour migration is quite low. Except for those females that own and manage lands independently of their husbands, women generally assist their husbands in most farm operations including planting, weeding and threshing/shelling. One strategy is voluntary co-operative work *sarwa*, by which household units whose family labour cannot cope with farming labour demands solicit assistance from well wishers without monetary returns. Inter-household linkages are crucial to the sustainability of this practice. A few farmers hire ox-ploughs from neighbouring villages, saying that it is cheaper than human labour. Labourers also have to be fed, and supervised. Most labourers insist on basing their charges on hours worked. Since farms tend to be scattered, it is not always easy to provide supervision, and this discourages farmers from hiring labour.

Although the Badowoi are basically crop cultivators, they also own some livestock (camel, cattle, sheep and goats). Cattle are kept for breeding, milking and manuring, and by a few farmers for fattening and sale. Cattle owning for traction is not common. Most Badowoi see livestock as a security against eventualities (low crop yields) and social commitments (weddings, naming ceremonies, etc.). During the dry season when fodder is low in quantity and quality, only pack animals (camels, donkeys and horses) and small ruminants are fed on cereal grains or legume residues. Cattle are placed on crop residues (cereal straws and stovers) which are very low in protein and energy content. The Badowoi neither like nor encourage migrant Fulbe in the area.

In the dry season, cattle are left with the options of grazing on crop residues, cereal bran, browse, and the grasses available. The feed resources may be low in protein and energy content, leading to loss of body weight and reduced milk production. Only lactating cows and old, sick and young cows receive priority in the provision of high energy supplements such as cereal grains, legume residues and cotton seed cake. The nutritional stress often encountered by cattle also renders them more susceptible to opportunistic infections and even death if the dry season prolongs. In the rainy season between crop emergence and harvest, cattle, sheep and goats are herded in the day time (by children 7 - 15 years, or hired labour) and penned in the night for fear of crop damage. In the dry season, livestock range freely.

The distribution of trees is affected by cultivation, fire, grazing by animals, and the drought that has become a persistent feature in the area. The Badowoi do not plant trees to replenish those destroyed. The dispersed population of species seen in the fields are not planted but are useful volunteers. Tree felling has been reduced over the last 5-6 years. The law states that trees on farmland may be cut, but in the bush *(kara'a)* only branches may be cut, and then not to the extent of endangering the life of the tree. The law applies to all trees however small they may be. A majority of farmers claim that the law is effective and is leading to an increase in the woody vegetation. Women, often assisted by children, collect fuelwood, particularly dead twigs and branches. They may fell dead trees by setting them on fire.

5.2.7 References

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5.3 Adaptive Management of Farm Labour

5.3.1 Nature of the data

The objective of the field labour monitoring was to record, during the four farming seasons of 1993-1996, the allocation of all labour, whether family or external in origin, by individual, by field (or other) location, and by task, activity or technology. This was achieved, with the two qualification (a) that it was not thought necessary to identify the individuals contributing non-family farm labour, and (b) that data collection was suspended in Futchimiram during 1994 owing to a staff shortage. The resultant data set is as follows:

Number of individual records	>200,000
Number of villages	4
Number of years	4 (except in Futchimiram)
Number of households	46
Number of persons, 1996	365
Number of landholdings	43
Number of fields	254
Number of tasks recorded	99

The data is stored on a Microsoft Access database at the Department of Geography, Cambridge University, and copies of the field books are retained at the Department of Geography, Bayero University, Kano (steps are being taken to transfer data files in accessible software to Kano).

Owing to the size of the database, and length constraint in this report, only part of the possible range of analyses is reported here.

Persons

All activity, including domestic work, rest and sickness either in or outside the village was recorded in half-day units (morning and afternoon) and entered into the database in fractions of a day. A weighting system was used, intended to differentiate farming inputs according to sex and age. All entries to the database have been thus weighted. In the subsequent analysis, time-periods of seven days (referred to hereafter as 'weeks'), beginning on 1 June in each year, have been used, but the data is capable of analysis on a day by day basis, except during periods when the researchers were absent from their villages and aggregate data were sometimes collected. In including both children (aged 4 years and over) and the elderly, weighted appropriately, the contributions of all family members to all productive activity are recognised.

Tasks

The 99 separate sub-tasks are grouped into 15 task categories which in turn can be grouped into major affinities such as farm and non-farm tasks.

Farm	Land clearance	*Business*	Foodselling
	Fertilizing		Manufacturing
	Planting		
	Transplanting	*Domestic*	Domestic work
	Weeding and thinning	*Resting*	Resting
	Irrigation	*Sickness*	Sickness/incapacity
	Harvesting		
		Off-farm	Outside activities
Unclear	Unclear/unknown	*Livestock*	Tending animals

The classification of tasks was evolved inductively as the study developed, rather than imposed at the outset, in order to be fully responsive to the multiplicity of activities found. The major limitations affecting this data are (a) that male adult informants may have represented the activities of females or children inaccurately at times, and (b) that tasks occupying less than a morning or afternoon, especially when repeated daily (such as milking or tying up animals) were merged with the major tasks recorded in the field.

A full listing of tasks is given in Annex 7.

Field or other location
Every field had a code assigned on the basis of the farmer's own field name, and this was used in data collection. Entries in the database include these codes. Where field codes were not assigned, for any reason, at the point of data collection, a standard code was used; as this happened frequently in some villages and some years, labour data is only analysed in relation to specific fields where and when a clean set is available.

Activities carried on outside the family farm and household (such as working on other peoples' farms, or visiting markets) are identified through the task code system.

5.3.2 Adapting farm labour to rainfall along the ecological gradient

Total agricultural labour and rainfall
Total agricultural labour includes the farm tasks listed in the previous section. Plots of labour use superimposed on rainfall, all in weeks, have been generated for each village and each year (n = 15). They show a number of predictable characteristics which are illustrated in the plot for Tumbau (1996), which is reproduced as Figure 5.3.2(a). These characteristics are:

- a discontinuous (in timing) and erratic (in amount) distribution of rainfall;
- a sharp beginning to the labour season, reflecting a need to respond swiftly to the beginning of the rains;
- a fluctuating curve of labour use, suggestively linked to that of the rainfall, but inexactly so; an
- a pronounced tail in this curve as labour use is extended beyond the end of the rainy period.

All of these characteristics can be recognised in all villages in all years.

Agricultural labour by task and rainfall
Agricultural labour breaks down into six task groups of which three - planting, weeding/thinning, and harvesting - account for the bulk of time spent. Figures 5.3.2(b) - (e) allow a comparison of the four villages to be made, along the rainfall gradient from Tumbau to Futchimiram in 1996.

In a rainy period of 20 weeks in Futchimiram, the three labour curves for planting, weeding/thinning and harvesting were separated distinctly. Planting began abruptly with the first rainfall in week May 4, and declined rapidly.The crop repertoire is limited to short cycle millet, groundnuts and cowpea all of which must be planted quickly given the expectation of a short growing period in relation to the 90-day growing cycle of millet and an erratic distribution giving, in that year, the wettest week as early as week June 3. Weeding began within days of first planting, rapidly attained a peak in week June 2, and maintained this level for 11 weeks without a significant break until week August 4. However as soon as early millet is ready for harvest, labour must be allocated to that. This transition took place in weeks September 1 and 2, and weeding fell off to zero. There were two harvest peaks, the first reflecting millet (weeks September 1-3) and the second groundnuts (October 1-3). The farming year came to a conclusion in week November 3.

Although slightly longer (22 weeks), the rainy period at Kaska was extremely erratic with eight weeks, two of them successive, having negligible rainfall. In contrast to Futchimiram, rainfall peaked in week August 1, having been extremely poor for the first 10 weeks. Nevertheless, the configuration of the three curves for major agricultural tasks has the same features: an abrupt start and rapid end to planting; a sustained though shorter (6 - 7 weeks) weeding cycle, a sharp transition from weeding to harvesting in weeks August 3 and 4, and a multi-peak, though lower and longer harvesting curve not ending finally until week November 4.

This graph also shows land clearance operations associated with the preparation of irrigation plots on lowland sites, and renewed planting and weeding activity on these plots. The continuation of the dry season *garka* cultivation extended beyond the observation period. This demonstrates the labour implications of having an alternative farming option with which to respond to the risks imposed by such an erratic rainfall distribution.

Over 20 weeks, rainfall in Dagaceri, after an uncertain start, reached a high level in week June 4 which, following the end of planting activity, precipitated a sharp increase in weeding and thinning. However the configuration of this curve was quite different from those of Futchimiram and Kaska, fluctuating for 13 weeks from June 4 until September 3 -4 when the transition to harvesting took place. In this year, the extension of rainfall throughout September with some late showers up till week October 2 provided an incentive for late planting of sorghum and, after the end of the millet harvest in week October 1, the re-planting of millet fields with the dry season crop *guna* or cow melon. There is no lowland in Dagaceri. Such late season activity (continued until week November 4) on upland fields is an opportunistic adaptation to a beneficial configuration of the rainfall pattern.

The rainfall began only slightly earlier in Tumbau, though in some years four or five weeks can separate it from Dagaceri, and continued for 23 weeks without serious break. The configuration of the planting, weeding/thinning and harvesting curves were quite different from those of the other three villages, however, and reflect Tumbau's normal experience of a longer rainy period. First, there were three planting peaks in weeks May 3, June 1 and June 4, reflecting short cycle millet and sorghum, later cowpea and groundnut interplanting. Second, planting continued after weeding had commenced in week June 1. The length of the sustained weeding period thereafter (13 weeks) was similar to that found elsewhere, and it terminated with the beginning of millet harvesting in week August 4. After the early millet was harvested, weeding climbed to a second peak in September 3-5, showing that it is the priority of the harvest and not the end of weed growth that brings weeding activity down. A second transition occurred in week October 1, followed by a cowpea harvesting peak in October 3 and of sorghum and other late crops in November 2-3.

The plotting of temporal patterns of labour use demonstrates that labour allocation is (a) responsive to rainfall and (b) subject to the opportunity costs of competing demands and alternative opportunities. These four graphs indicate the diversity found between individual farming systems operating with different amounts and distributions of rainfall and ecological site factors.

Comparisons between years

Figures 5.3.2(f) and (g) demonstrate the impact of differential rainfall on labour use in farming, at Dagaceri. 1994 was a good (though by no means wet) year, with an adequate total, a normal monthly distribution with a peak in August, and a late fall in week October 3 to encourage *guna* planting. 1995 was a poor year, with a low total, a hesitant start, a failure of the August peak and a prompt end in week October 1 after a dry September.

The impact of this contrast on biomass production may be deduced from a comparison of the levels of labour use during the weeding/thinning and harvesting periods. For this purpose we introduce the variable, *percentage of available labour used* (Table 5.3.2(a)). Available labour is defined demographically as the sum of weighted family labour in a household. It takes no account of the many factors (custom, incapacity, non-farm commitments for example) which intervene in the mobilisation of this labour for farm tasks. Nevertheless, the percentage of available labour used has been found to mirror quite precisely the curves of total labour used during the season; and it makes labour curves of differing magnitude compatible between years or between villages.

TABLE 5.3.2(a)
Percentage of available labour used in agricultural tasks, Dagaceri

Month	1994 Rainfall (mm)	1994 Labour (%)	1995 Rainfall	1995 Labour
June	25.2	no record	17.0	no record
July	83.9	50.5	104.2	25.6*
August	151.3	53.6	97.9	33.1
September	98.0	55.5	98.3	28.0
October	44.8	49.4	4.6	28.7
November	0	44.4	0	17.7
December	0	47.6	0	4.9

Notes: * Weeks 8 and 9 only

The utilisation of available labour varied between a monthly average of 50.2% in 1994 and one of 23.0% in 1995. This suggests that (a) labour use and biomass productivity are positively correlated in the farming system, and (b) the concept of the labour bottleneck in smallholder agriculture is rainfall-dependent, and labour supply is more likely to constrain output under *good* rainfall than under *bad*.

A second demonstration of the effect of variable rainfall is given in Figure 5.3.2(h), for Kaska, which should be compared with Figure 5.3.2(c). The harvesting labour curve, but not that of weeding/thinning, was massively higher in 1994 than in 1996. The weeding/thinning curve of 1994 correlates positively with the distribution of rainfall, having been prolonged by substantial rainfall in September, but that of 1996 appears to contradict it, declining just as the rainfall improved in late July and August. By then the rain was too late, and the damage had been done to the millet whose reduced output was reflected in the lower harvesting labour curve of 1996.

The comparison of the harvesting curves supports the hypothesis that biomass production may be expected to correlate with labour inputs, and in fact the farmers received a much superior harvest in 1994. The comparison of the weeding/thinning curves does not, however, support it. The high input of labour to weeding/thinning in 1996, notwithstanding the very poor rainfall in the first part of the season, reflects a need to remove *all* weed competition under dry conditions. At this time there is a crisis, as farmers may throw increasing amounts of effort into preserving diminishing amounts of output. The small labour input in harvesting in 1996 shows that these efforts, to a considerable extent, failed. It is not surprising that labour invested in the alternative option of irrigated *garka* plot preparation - in renewed planting and weeding after the rainfed harvest - was lower in 1994 than in 1996.

A third demonstration of the effects of variable rainfall on labour use is given in Figures 5.3.2(i)-(k), which show the percentage of available labour used in the four villages in each year, 1993, 1994 and 1995.
The complexity of the inter-annual and inter-village variability which is shown graphically in these Figures can be summed up in the following observations (see Table 5.3.2(b)):

- Tumbau uses a smaller proportion of its available labour than the other three villages, on average, in all years. This is consistent with its higher population density and smaller holdings; however, the difference in the use of labour is much less than the differences in density and size of holdings.

- Tumbau uses its labour less variably through the season than the other three villages, where labour use fluctuates sharply. In this respect, labour use fluctuates less in Dagaceri than in Kaska and Futchimiram. This is consistent with an increase in rainfall variability and risk along the ecological gradient. It also reflects the multiple cropping and complex labour requirements of the farming system in Tumbau.

- The effect of an increase in seasonal rainfall in 1994 (which was not recorded at Tumbau owing to a gauge failure but is known to have occurred) was to raise the level of labour use in Dagaceri (by 17% on average) but to lower it in Tumbau (by 4% on average). This finding is contrary to expectations, as biomass production in Tumbau was greater in 1994 (Harris and Bache, 1995). In Kaska, the period data shows a reduced level of labour use early in the season, owing to late rainfall, but a sharp increase in the mid-season and later.

- The effect of very low rainfall in 1995 on labour use was less in Tumbau than in Dagaceri. In Kaska, an apparently small decrease in average labour use hides extreme fluctuations. In Futchimiram, a large drop in average labour use, especially at the end of the season, reflected a major drought. Again the limited response of the Tumbau system to rainfall variability is to be understood in terms of its greater complexity.

TABLE 5.3.2(b)
Rainfall and the use of available labour in agriculture, 1993-1995

Village and year		Seasonal rainfall (mm)	Rainfall as % of 1993	Labour use in agriculture (%)	Labour use, % of 1993
Tumbau	1993	564		29.0	
	1994	na	na		- 4.4
	1995	373	- 34		- 2.2
Dagaceri	1993	381		39.1	
	1994	403	+ 6		+17.4
	1995	326	- 14		- 7.6
Kaska	1993	296		43.3	
	1994	435	+ 47		- 0.7
	1995	317	+ 7		- 1.9
Futchimiram	1993	444		41.3	
	1994	na			
	1995	209	- 53		- 10.9

Harvesting labour
If we follow our ecological gradient from Futchimiram (drier) to Tumbau (wetter) and disaggregate the labour category 'harvest' by major crop, the implications of a changing rainfall regime for labour management can be demonstrated. See Figures 5.3.2(l) - (o).

Futchimiram
Two distinct harvest labour peaks are recorded: for short cycle millet (weeks September 1 to October 1), and for groundnuts (weeks September 5 to November 1). No sorghum is grown in this system, and although cowpeas are usually planted, the crop failed in 1996. It is noteworthy that groundut harvesting, which involves pulling, drying, separating the pods from the haulms, storage and removal of both (for sale or for fodder respectively), used more labour in 1996 than the harvest of the staple food crop.

Kaska

Three harvest operations are discernible in this system. Those of short cycle millet (weeks August 4 to September 5 with a break in the middle that had little to do with rainfall or agronomy factors) and of sorghum (weeks September 5 to November 3) are separated. But the harvest of cowpeas, which in this climate must necessarily be short cycle types, is almost synchronous with that of millet; yet, owing to the higher priority placed on millet and the somewhat greater flexibility of cowpea, labour used in cowpea harvesting had an inverse relationship with that used in millet. There was some late millet harvested in weeks October 1 and 2. In labour terms, possibly the most valid criterion for prioritising the major crops, the ranking is: 1, millet; 2, cowpeas; and 3, sorghum.

Dagaceri

Further complexity is added in the Dagaceri system with the division of cowpeas into two - short and long cycle - crops. A very early harvest of cowpea in week August 1 is consistent with the use of an early planted variety claimed to mature in 40 days (the planting rains began 7 weeks earlier). Later planted cowpeas continued to be harvested at a low intensity until week October 1. Then there was a peak in labour used for harvesting late cowpeas in week December 2. A pronounced gap occurred between the millet and sorghum harvests (weeks October 2 to November 1); data for 1994 shows that this gap was then used for harvesting grass fodder from fallows for storage. Substantial late rain (up to week September 5) ensured a very good sorghum crop. The result was that labour used in harvesting sorghum (weeks November 2 to December 2) was greater than that used for millet (weeks September 2 to October 1). The ranking in Dagaceri in 1996 was: 1, sorghum; 2, early millet; 3, cowpeas, with early cowpeas spread out and late cowpeas concentrated. The long rainy season in 1996 was partly accountable for these characteristics.

Tumbau

A substantially larger number of important crops increases the complexity of harvesting operations in Tumbau. There are two millet harvests: early millet was secured about two weeks earlier than in Dagaceri (weeks August 3 to September 3), and late millet (week December 1) after sorghum (weeks November 1-4). The groundnut harvest (groundnuts are recovering fast in the Kano region, after being in recession since 1975) was inserted between the millet and sorghum harvests (weeks October 1 to November 1), with a tail extending for several weeks that reflects the use of late varieties as well as competition for labour. The peak in the groundnut harvest coincided with a smaller one for rice (weeks October 2 to November 1) - this is the only one of the four study villages where localised soil and water conditions permit upland rice to be grown. Finally, the cowpea harvests here were clearly separated into early (weeks September 1 to October 2) and late (November 1-4). The importance of securing all economic biomass in this intensive system is indicated by the harvest of crop residues at the end of the season (weeks November 2 to December 4). To rank the crops on the basis of their harvest labour use might be misleading, as competing demands in October and November had to be reconciled.

The data for 1995 show how the Tumbau harvest system can be modified by lower rainfall. Figure 5.3.2(p) shows lower labour use for harvesting sorghum than in 1996 and possibly also for millet (which is obscured by the presence of a combined category, 'harvesting millet and cowpea'). Early cowpea harvest labour (weeks September 3 to October 3) was similar in scale to that in 1996, and the beginnings of the sorghum and late cowpea harvests were recorded just before data collection ceased in week November 2. Harvest work on groundnuts was significantly lower in 1995 and there was no rice. Added to this figure is the labour used in harvesting fodder, which in all weeks save two, exceeded or equalled that spent in harvesting economic crops. Again this strkingly reinforces the priority given to livestock management in this highly integrated system.

Conclusion

In this section, period data has been subjected to a preliminary analysis in order to show the structure, dynamics, and variability in space and time of labour use in four Sahelian farming systems. The variability in rainfall defines the challenge for adaptive agriculture; and the patterns of labour use, described here for the first time, show the response. The major implication is that Sahelian farming is critically concerned with adaptive labour management, and technologies must fit into this framework.

The above analysis is not exhaustive and is limited to week-period data. The database is also capable of analysis on the basis of day-periods. Whether a closer correlation exists between rainfall and labour use at this periodicity, either total or by task, has not yet been investigated.

5.3.3 Farm and non-farm labour

It will not have escaped notice that the percentage of available labour used in agriculture (farming), even at the peak of the season, rarely exceeds 70 and is usually much lower. The *average* in Tumbau is of the order of 30% and those of the other villages only about 10% higher. The signficance of this fact can now be investigated in the light of other demands for family labour whose opportunity costs and social benefits must be weighed against those of field work. The hypothesis is that, during the growing season, households work with a constrained supply of labour, and allocations among competing demands (which are arrived at by a mix of authoritarian decisions, individual initiatives, and negotiations amongst members) represent a balance of costs and benefits. Flexibility is constrained (through time) by the rainfall pattern, and its effects on crop production.

The following analysis uses the seven major task categories of farm work (the subject of the preceding section), domestic work (men or women), livestock (tending or management), business (manufacturing or selling), off-farm (which includes work on other farms and time spent outside the village), resting, and sickness. Labour use was plotted for each village and year (n=15).

Inter-village comparisons
Four important functional relationships are shown in Figures 5.3.3(a)-(d), which portray labour time by major task category in 1996. They show that each village has a distinct mix of patterns which reflects its basic social and ecological characteristics.

Farm work and livestock work
There are two patterns discernible:

- In Tumbau, time spent on these two activities is negatively correlated and animals consume a large amount of time (Pattern A). In the intervals between the weeding and harvesting labour peaks, an increased amount of time is spent on livestock work. In Tumbau, all animals must be fed in pens with gathered fodder throughout the cropping season, and each household therefore looks after its animals independently, consuming a great deal of time. Much of this is womens' and childrens' work (and they often own the animals). Pattern A can therefore be said to characterise an intensive, highly integrated system, based on small ruminants. Cattle, if any, are contracted out to transhumant graziers.
- In the other three villages, time spent on livestock is much lower and rises significantly towards the end of the cropping season (Pattern B). Under this system, the village flock of small ruminants is managed collectively, greatly reducing the labour needs, and grazed out each day on accessible fallows and rangeland. Relatively little work is required in collecting fodder for use in the night pens, except for horses and donkeys. Cattle, if any, are contracted out to local specialists (Ful'be). The time saved is available for farm work. This pattern characterises an extensive and less integrated system.

Farm work and domestic work
Two patterns are again discernible:

- In Tumbau and Dagaceri, domestic work consumes more time than farm work virtually throughout the farming season (Pattern A). This is primarily womens' and childrens' work (major sub-tasks being carrying food to the farm, housework, food preparation, threshing, and fetching water). (Gender roles will be reported below.) This pattern reflects a relatively low level of participation in

field work by women who are, in theory, secluded; but an observed difference between Tumbau and Dagaceri in the strictness of seclusion is not reflected in the numbers.
- In Kaska and Futchimiram, the relationship is quite different. Farm work is overwhelmingly dominant in the first half of the season, and falls gradually to meet a rising commitment to domestic work during the second half (Pattern B). The participation of women is highest in Futchimiram, where it is customary for all Badowoi wives to farm their own fields, and the two curves do not intersect there until after the end of the harvest. In Kaska, the gap separating the curves is narrower and they intersect earlier, during the millet harvest.

Business and off-farm activity

Business includes food selling (often by women or children) and manufacturing (often by men); off-farm activities include working on other peoples' farms for hire or communal groups, attending markets, school and travel (and is a very miscellaneous category calling for analysis in greater detail).
- in relation to the other categories, both are highest in Dagaceri - with off-farm activity consuming rather more time than business - and remain steady throughout the season. Dagaceri is a large village, offering scope for small scale business, and relatively well integrated into markets. Farming does not displace these activities, though the commitment to them increases during the dry season.
- in Tumbau, relative to farming, both activities are much lower. This is surprising in view of the fact that Tumbau is the most accessible of the four villages to markets, the most densely populated, and expected to be the most diversified economically. But it is small settlement and women are restricted in their activities outside the house. Part of the explanation seems to lie, as before, in the demands made by the complex and intensive farming system and livestock management during the growing season.
- in Kaska there is very little business in the small hamlet studied, but a high level of off-farm activity, which is mostly travel by men, who maintain involvement in several markets notwithstanding the considerable distances involved. This area has a tradition of long distance trading based on the salt, natron and date palms of the natural *ngor* depressions.
- in Futchimiram, all non-farming activity is remarkably suppressed during the first half of the season, but off-farm activity slowly rises during the second, mostly market attendance. Business is almost non-existent as the size of the settlements is small and cash is spent usually on livestock.

Resting and sickness

Resting occupies a significant amount of time in all four villages, with a tendency to be suppressed by the weeding peaks (most noticeably in Futchimiram, where it rises somewhat during the harvest period). The need to rest must be understood in relation to the energy requirements of hand farming under very high temperatures, especially in the three drier villages, where large cultivated areas often push the labour force to its biological limits. Sickness, which includes malaria, typhoid, and a range of other diseases, tends to rise during August and September, and there is an apparent increase in mortality at these times, which can affect household farm production very adversely. In 1995, a close correlation was recorded between labour incapacity and rainfall at Tumbau (Figure 5.3.3(e)).

Comparisons between years

The patterns displayed in each village in 1996 were consistent with those of earlier years. However, a comparison of labour use by major task category in Tumbau in 1995 (a year of poor rainfall) and 1996 (a better year) is instructive (Figure 5.3.3(f), which should be compared with Figure 5.3.3(a)).

The following observations may be made:
- Pattern A linking farm with livestock work is recognisable in 1995, but a slight lowering of farm work is complemented by a small increase in livestock work, which causes the two curves to intersect, or nearly so, at three points in August and October. No more graphic demonstration could be found of the importance given to animal husbandry in this farming system.
- Pattern A linking farm work with domestic work is also verified in 1995, but domestic work is significantly lower at about 130 instead of 160 person labour units per week.
- Business and off-farm activities were not significantly different in 1995.

- Resting was higher in 1995, by an average of about 10 labour units/week, and sickness was significantly higher, with a peak of nearly 30 labour units in week September 1.

The stability of the 'Tumbau labour use pattern' between years suggests that we have identified significant discriminators between the villages which help place the use of labour in the farming system into its broader context of household labour management. Labour is the chief resource of Sahelian communities, and a holistic analysis can reflect and qnatify the trade-offs which have to be made by households.

5.3.4 Division of labour

The contribution of females to agricultural labour varies between villages and between years. The data collected on female participation is likely to err on the conservative side as women may work either on their own or on mens' fields, and only in Futchimiram are wives' fields usually substantial in size and expected to make a major contribution to household production. In the other villages, women may have small fields on which they may have worked unrecorded. Girls' labour is included in the data.

TABLE 5.3.4
Agricultural labour by gender/origin (%)

Village and year		Planting			Weeding/thinning			Harvesting		
		female	male	h/u	female	male	h/u	female	male	h/u
TUM	1993	11.7	86.0	2.3	9.8	84.7	5.5	9.9	77.2	13.0
	1995	11.3	87.5	1.2	11.5	82.6	5.9	19.0	76.2	4.8
	1996	8.4	88.6	3.0	4.5	87.7	7.8	19.3	74.6	6.1
	mean	**10.5**	87.4	2.1	**8.6**	85.0	6.4	**16.1**	76.0	8.0
DAG	1993	38.2	54.5	7.3	30.4	53.6	16.0	28.2	67.8	4.0
	1995	20.8	71.9	7.3	6.8	78.0	15.1	20.8	71.9	7.3
	1996	20.8	74.8	4.4	4.2	77.8	18.0	8.2	75.5	
	16.31									
	mean	**25.4**	66.9	7.7	**13.8**	69.8	16.4	**19.1**	71.7	7.7
KAS	1993	31.0	69.0	0	18.1	65.5	16.4	13.2	74.9	11.9
	1995	nd	nd	nd	35.0	60.7	4.3	30.6	66.1	3.3
	1996	26.4	72.0	1.5	38.0	61.0	1.0	24.8	73.4	1.8
	mean	**28.7**	70.5	0.7	**30.4**	62.4	7.2	**22.9**	71.5	5.7
FUT	1993	43.2	56.8	0	25.3	57.8	16.9	26.2	73.3	0.5
	1995	nd	nd	nd	39.4	60.6	0	44.6	55.4	0
	1996	60.3	39.7	0	37.6	62.4	0	29.3	70.7	0
	mean	**51.7**	48.3	0	**34.1**	60.2	5.6	**33.4**	66.4	0.2

Notes: 1) nd: no data; 2) h/u: hired or unattributed

Contribution of women to agricultural tasks

Table 5.3.4 gives data on the contribution of women relative to men and hired or unidentified persons (almost always male) to major task categories by village. Owing to the variability found between years, it is considered least misleading to use average values. 1994 is excluded because of very high 'hired/unattributed' values.

The mean values show a rising gradient from Tumbau to Futchimiram in the percentage of labour contributed by women in each of the three major task categories, planting, weeding/thinning, and harvesting, and therefore also in total agricultural labour. The clarity of this gradient is striking. However, the differentiation between villages is not constant.

- In *planting*, Dagaceri women contribute twice as much labour as Tumbau women, Kaska women a similar percentage to Dagaceri women, but Futchimiram women contribute twice as much again as Dagaceri women.
- In *weeding/thinning*, Tumbau and Dagaceri women contribute in a similar order of magnitude, but Kaska and Futchimiram women contribute more than twice as much as those of Dagaceri.
- In *harvesting*, the contribution of women rises slowly from Tumbau through Dagaceri to Kaska, but Futchimiram women contribute twice as much labour as those of Tumbau.
- The women of Futchimiram are committed to farming to a substantially greater extent than those of any of the other three villages.

These differences are strongly influenced by cultural determinants. In the Hausa community of Tumbau, it is a man's responsibility to feed his household, and seclusion of women is more likely to be practised than in the other villages. Although the participation of women in farming may be increasing slowly (there are no data), the small size of all landholdings releases households from the need, felt in the other villages, to mobilise women for field labour. However, some women inherit land. The sample households in Dagaceri and Kaska (with one exception) are ethnic Manga, whose attitude to seclusion is more relaxed. The largest landholdings amongst our four villages are found in Dagaceri, where men aspire to grant land to their wives and many women have inherited fields. In Kaska, whole families work together in the household fields. In Futchimiram, Badowoi men may grant large parts of their land to their wives, and work their own fields separately (though this practice is not universal). A large commitment to livestock, including cattle, on the part of almost every household, calls for additional labour in watering and grazing. The Futchimiram household is more stretched than in any other village with regard to meeting labour commitments.

The use of female labour is related therefore to the percentage use of available labour (see Figures 5.3.2(i)-(k)), which is lower in Tumbau than in the other villages, and fluctuates less sharply during the season. A link with rainfall regime is clearly possible. The shorter the season, the more concentrated and episodic the peak demand periods for labour become, and the greater the need to mobilise women as well as men. While individual operations may be just as urgent in Tumbau, in aggregate, levels of demand are lower and can be handled by skillful management of a continuous, mostly male, labour force.

The pressure on women to contribute labour is shown in Figure 5.3.4(a) in terms of the percentage of available female labour used in the major farm tasks. Weeding and thinning stand out as the most important category for female participation. Futchimiram and Kaska stand out as the villages making the most use of their female labour force in agriculture.

Timing of female contribution to farm labour

Figures 5.3.4(b) and 5.3.4(c) allow a comparison to be made between the seasonal patterns of male and female agricultural labour (though it should be noted that the years are different). Male commitments ranged widely between 30 and 60% during the rainy period (July-September), and then embarked on a declining trend towards the end of the harvesting season in December. Although they fluctuated much less in Tumbau than in Kaska and Futchimiram, the average levels achieved in the four villages were of a similar order of magnitude.

On the other hand, female labour commitments discriminated sharply between villages. In Dagaceri and Tumbau, they remained below 10% throughout the rainy period, rising (in Tumbau only) to over 20% during the harvest period. But in Kaska and Futchimiram, hugely greater commitments were maintained during the rainy period, of the same order of magnitude as those of males (50-60% at the peak of the weeding period in June-July). They then fell to 25% or less, converging on the other villages, in the harvest season.

5.3.5 Household Differentiation

For a preliminary analysis of household differentiation, households in each village were ranked on the basis of available weighted labour, and three selected in each:

- the household with the highest average available labour in 1993-1996,
- the household with the lowest average available labour in 1993-1996, and
- the household nearest to the average in available labour in 1993-1996.

It is hoped that this exercise will show whether more formal analysis of differentiation is justified with this data, and where the important thresholds are.

Total agricultural labour in small, medium and large households

In Tumbau, Futchimiram, and Kaska, the selected households conformed to expectations in committing a percentage of their available labour to agriculture that was inversely related to their size, that is, large households used the smallest proportion of their labour in agriculture, and small households the largest. Also as expected, the fluctuations in labour use during the season were greatest in the small households and least in the large. The same patterns were observed in 1994 and in 1995. Figure 5.3.5(a) provides an illustration from Kaska. Dagaceri, however, did not conform to expectation in either year; and, since each plot shows only one household, this may have no significance.

Labour by category in small, medium and large households

The selected households were analysed for all major task categories. In Tumbau (Figure 5.3.5(b), the small household used relatively more labour in farm and livestock tasks, and less labour in domestic, off-farm, business activities and in resting than the large and medium households; the large household used substantially less labour for farm and livestock activities but more in domestic and business activities. A similar pattern was observed in Futchimiram, though weaker, but not elsewhere.

The small sizes of the samples of households in each village do not justify a statistical analysis of differentiation, especially when disaggregated into even smaller sub-samples on the basis of the size of the available labour force. The major differences between the four villages forbid amalgamating the samples into a single population of 46 households; it is likely, for example, that all the Futchimiram households will cluster at one end of the scale as the average household size there is small. Differentiation on the basis of landholdings is discussed below. However, the labour data for individual households will be used to back up the qualitative analysis of livelihood strategies (Chapter 5.7).

5.3.6 Labour use per hectare

The amounts of arable land (which includes both cultivated and short fallows) used per capita and per available labour unit were presented in Table 5.1.5(b). In this section, we analyse labour used per hectare, as a prime indicator of the intensity of the farming systems.

Labour use per hectare in 1996

TABLE 5.3.6(a)
Labour per hectare by agricultural task, 1996[1]

Village:	TUM	DAG	KAS	FUT
Hectares[2]	*45.69*	*116.4*	*132.2*	*25.7*
Average ha/capita	*0.35*	*1.6*	*1.3*	*1.4*
Average ha/labour unit available	*0.7*	*4.0*	*2.6*	*2.5*
Land clearing and fertilizing	4.76	0.98	0.11	na
Planting[3]	5.51	3.14	2.24	1.41
Weeding and thinning	31.55	8.38	16.20	21.35
Harvesting	35.11	3.99	3.51	11.19
All agriculture	**76.89**	**16.48**	**22.07**	**33.94**

Notes:

1) Periods of monitoring: Tumbau, weeks May 3 - December 4; Dagaceri, weeks June 1 - December 3; Kaska, weeks June 2 - November 4; Futchimiram, weeks May 4 - November 3.
2) The numbers of hectares given in this table differ from the total hectares given in Table 5.1.5(b) (except in Futchimiram), owing to the omission of some fields for which area values were interpolated statistically or for which labour use values are unreliable in one or more years.
3) Planting labour could be incompletely recorded if (a) dry planting (before the rains begin) was practised in Dagaceri, Kaska and Futchimiram, or (b) the 'planting rains' arrived before the commencement of monitoring (up to one week in Tumbau and Kaska in 1996).

The table establishes the supremacy of the Tumbau system in terms of intensity.

- much higher inputs per hectare in land clearing and fertilizing reflect manure applications which are carried out during the growth cycle of the crops, on a plant-by-plant basis. There is some manuring in Dagaceri; otherwise, in the other three villages, this category mainly reflects uprooting or cutting down naturally regenerating vegetation.
- higher inputs in planting reflect the high planting densities used in Tumbau, and the multiple cropping, which sustains activity for several months. Late planting of sorghum and *guna* raises planting labour in Dagaceri.
- higher inputs in weeding and thinning reflect a larger number of weeding cycles in Tumbau - three or even four against two or even one and occasionally none (owing to labour scarcities) in Dagaceri and Kaska.
- much higher inputs in harvesting reflect higher biomass production in Tumbau and multiple harvesting operations (see Figure 5.3.2(o)).

There is a close correspondence between the number of labour units used/ha and the number of hectares available per capita in Tumbau, Dagaceri, and Kaska, but Futchimiram is anomalous, as the following ratios show:

	TUM	DAG	KAS	FUT
Hectares/capita	1:	4.6:	3.7:	4.0
Hectares/labour unit	1:	5.7	3.7	3.6
Labour used/ha	1:	0.2	0.3	0.4 *(reciprocal 1: 4.6: 3.5: 2.3)*

Explanation can be found in site-specific factors, as follows. In Dagaceri, the local administration reserved grazing areas for the Ful'be in about 1972, which put a stop to the expansion of privately held arable land by Manga farmers (see Section 5.1.4). Prior to this, and possibly anticipating such a restraint, farmers had been appropriating large areas, which were subsequently subdivided among their heirs. As free land was no longer available (the Manga had a tradition of shifting cultivation), fallowing became internalised within the boundaries of private farms. Today, whole fields may be fallowed, or (more usually) parts of fields. The meaning of fallowing is not necessarily as a strategy to enhance soil fertility, but as often a failure to mobilise enough labour for its cultivation. This operational concept of fallow explains why Manga farmers frequently plant larger areas than they can later weed, having to abandon millet after one weeding, or even none at all. All extensive systems under hand technology are constrained by labour. The need to maintain rights of access to as much land as possible has internalised the frontier of cultivation.

In Futchimiram, on the other hand, shifting cultivation is still practised (see Section 5.1.4). It is not practised, by and large, by individuals, but by groups of farmers. This is because the Badowoi keep large numbers of cattle and small ruminants (whereas among the Manga, cattle keeping is largely restricted to the Ful'be) and they continue to graze the rangelands (which are, in effect, long fallows) during the cropping season. Livestock are kept off the crops by means of thorn fences constructed from branchwood which is produced by pollarding mature trees standing on the farmland when it is brought into cultivation. Fencing is more economical if fields are grouped. Furthermore, the permission of the village head (*Zanna*) of Futchimiram is necessary before a new clearing is made. This permission, which is given to the community, is dependent on vegetational indicators of soil fertility having adequately recuperated since the last cycle of cultivation. Thus, in this system, fallowing is largely externalised (although it sometimes occurs on large, private fields, almost always due to labour shortages).

Another difference between the Dagaceri and Futchimiram systems is that plant spacing is far wider in Dagaceri fields - a metre or more separating stands of millet - than in Futchimiram fields, where stands are commonly about 0.5 m apart. Furthermore, groundnuts are grown in Futchimiram in small patches at very high densities, in order to minimise weed growth. These patches can be moved around the farm from year to year. Thus the system of Futchimiram can be characterised as a 'mobile intensive system' whereas that of Dagaceri is a 'stationary extensive system'.

Kaska is closer to the Dagaceri than to the Futchimiram model, as the numbers show. Shifting cultivation, and shifting settlements, continued until recently according to air photographic evidence. Two factors appear to be bringing such mobility to a stop. First is, rather than an overall shortage of land, a shortage of superior farming land in *faya* depressions, which it is unwise to vacate for fear of losing claims. Second is intensified competition with the Ful'be for the use of uplands, which before the 1980s were little used for farming. There has been, therefore, a rapid increase in privately appropriated upland farms. There being no materials in these grasslands for fencing, such fields need to be adjacent to one another and grazing supervised.

These findings indicate that the use of labour inputs per hectare of arable can be a misleading guide to intensity unless the system is understood holistically. The same objection applies to the use of 'agricultural population density' (Section 5.1.3). Our transect has exposed some of the diversity which exists and the dangers of using a simple indicator which assumes *ceteris paribus*. Further progress in analytical measures of intensity is still, however, necessary as the one prediction that can be made with confidence is that people:land ratios are going to continue rising.

Peak intensity of labour use per hectare: inter-year comparisons
To replicate Table 5.3.6(a) for the years 1993-1995 would be misleading because monitoring, always difficult to begin in time for the first (unpredictable) rainfall, and sometimes withdrawn before the end of the harvest season, did not cover all agricultural labour in all villages in every year. This is not simply a result of imperfect execution of research design: *some* agricultural work goes on after the harvest of economic crops (contrary to the myth of the 'idle' dry season), notably manure distribution (in Tumbau), harvesting of residues, cutting of grass fodder, lopping of trees, harvesting and

processing of *guna*, clearing new fields, and of course animal husbandry. The extent of such unrecorded or under-recorded agricultural work cannot be estimated accurately from our data.

An alternative measure of labour intensity in agriculture is peak labour inputs in major operations when the labour force is most stretched. Variations in labour intensity from year to year are here analysed by comparing the averages of the five highest weekly inputs/ha in each village and year, for the two major tasks: weeding and thinning, and harvesting. Of these, the first is the more important, as everyone agrees that output is determined first by rainfall, second by weeding efficiency. See Table 5.3.6(b).

TABLE 5.3.6(b)
Peak intensity of labour/ha, 1993 - 1996

		Average of five highest weekly values			
		TUM	DAG	KAS	FUT
Weeding and thinning	1993	2.72	1.03	1.68	?
	1994	2.23	1.10	1.61	na
	1995	2.51	0.57	1.85	na
	1996	2.38	0.55	1.77	1.81
Four-year mean		*2.46*	*0.81*	*1.72*	*?*
Maximum departure from mean (%)		*10.6*	*35.8*	*7.6*	*?*
Harvesting	1993	2.41	0.63	1.31	?
	1994	2.10	0.95	1.61	na
	1995	2.58	0.47	1.25	na
	1996	2.77	0.36	0.51	1.35
Four-year mean		*2.47*	*0.60*	*1.17*	*?*
Maximum departure from mean (%)		*15.0*	*58.3*	*56.4*	*?*
Average ha/labour unit available		*0.7*	*4.0*	*2.6*	*2.5*

As each value represents the total labour input of all the sample households on all of their landholdings during one seven-day period (the average of five peak periods), quite small differences are operationally significant.

- Variability in the use of labour was greater, in all villages, in harvesting work than in weeding/thinning. This was expected, as the economic value of the harvest determines labour time spent in gathering it in, and rainfall (which is not under the farmer's control) is the primary determinant of production. But earlier in the season, outcomes are not known; and a primary determinant of production (which is under the farmer's control) is weeding efficiency.
- Variability in peak intensity labour use is least in Tumbau and greatest in Dagaceri and Kaska, if we take both operations together and ignore the surprisingly low variability between years in Kaska in weeding/thinning labour use. This was expected in view of our emerging characterisation of the Tumbau system as relatively invariable, inflexible, complex and intensive, and of the Dagaceri and Kaska systems as variable, highly flexible, less complex and extensive.

- The absolute differences between Tumbau, Dagaceri and Kaska are broadly consistent with the average hectares of arable land per available labour unit; the more land there is, the more thinly labour effort must be spread. In Tumbau, the sample households achieved peak levels of labour use exceeding 3.0 units/ha/week on several occasions in all years except 1994.

FIGURE 5.3.2(a)

Tumbau, 1996: agricultural labour and rainfall (total seasonal rainfall, 000 mm)

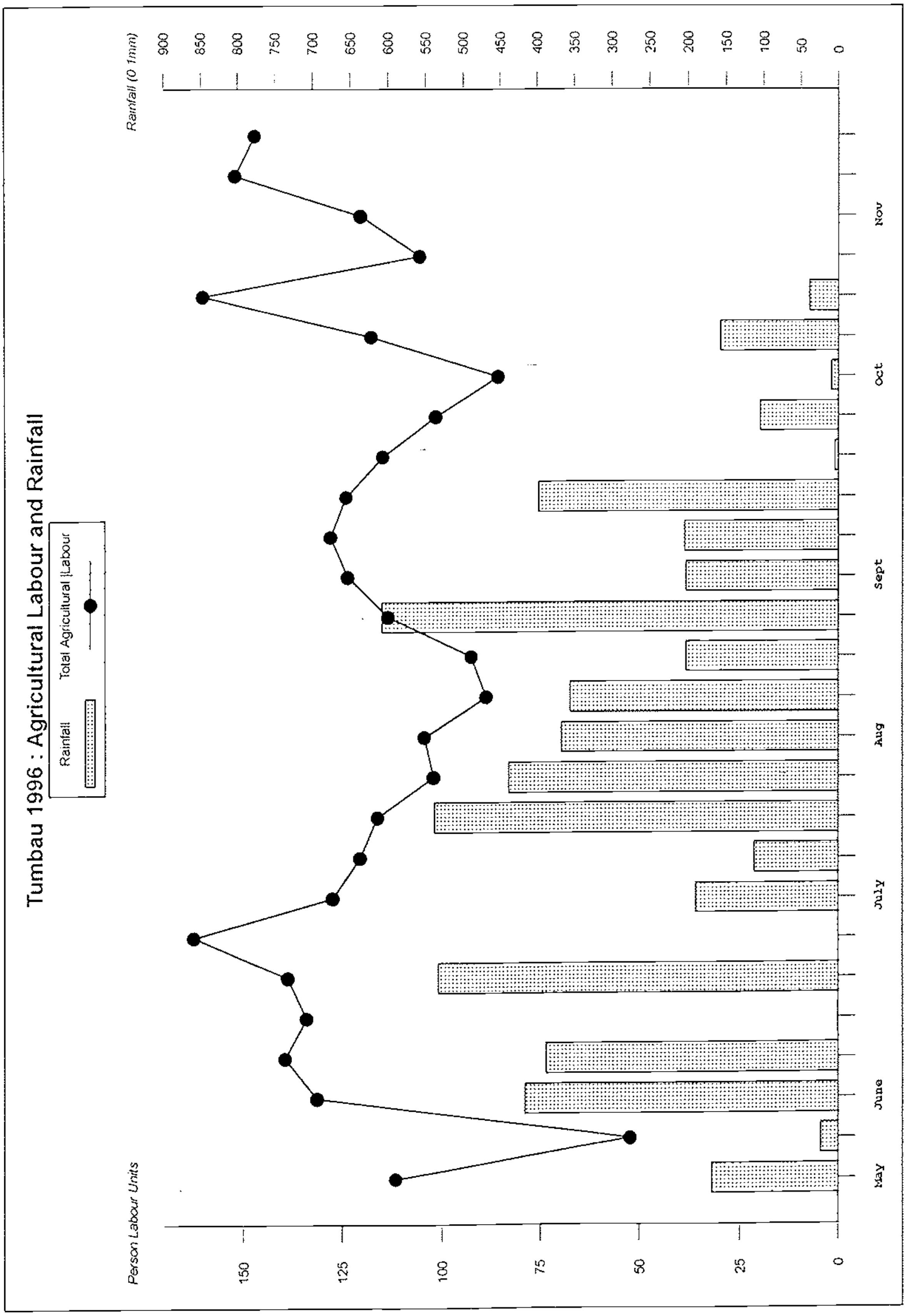


FIGURE 5.3.2(b)

Futchimiram, 1996: Agricultural labour and rainfall (total seasonal rainfall, 000 mm)

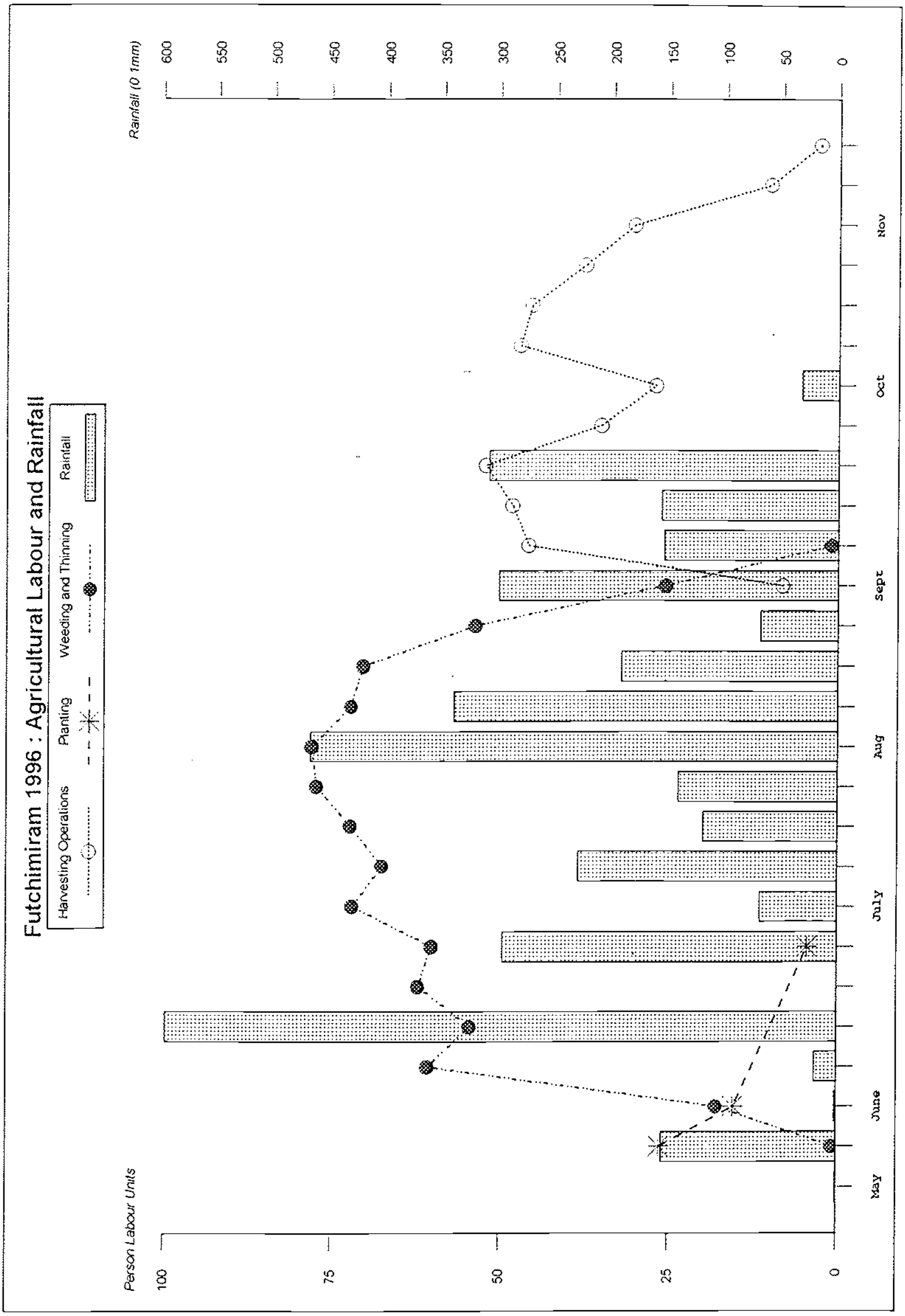


FIGURE 5.3.2(c)

Kaska, 1996: Agricultural labour and rainfall (total seasonal rainfall, 000 mm)

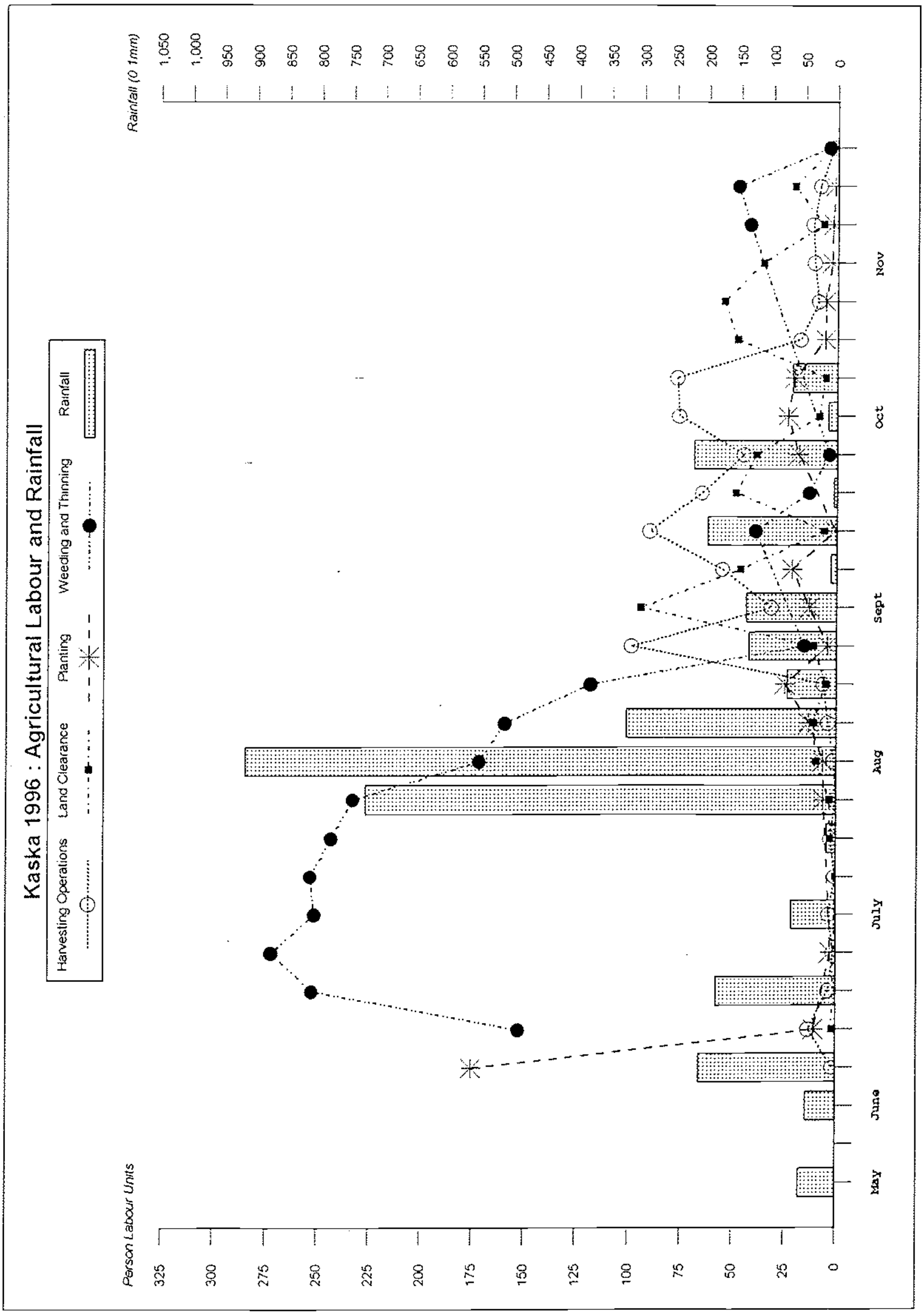


FIGURE 5.3.2(d)

Dagaceri, 1996: Agricultural labour and rainfall (total seasonal rainfall, 000 mm)

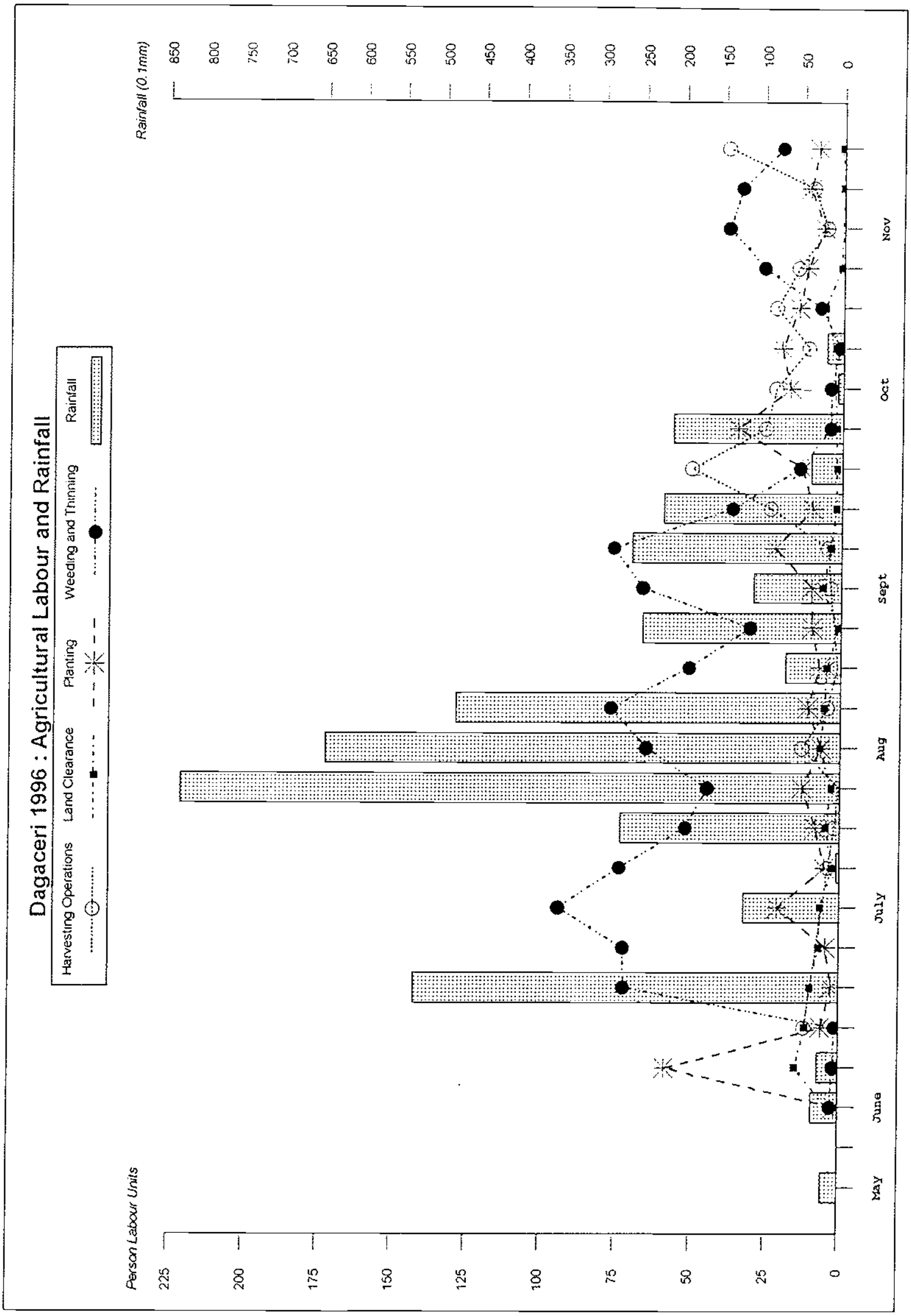


FIGURE 5.3.2(e)

Tumbau, 1996: Agricultural labour and rainfall (total seasonal rainfall, 000 mm)

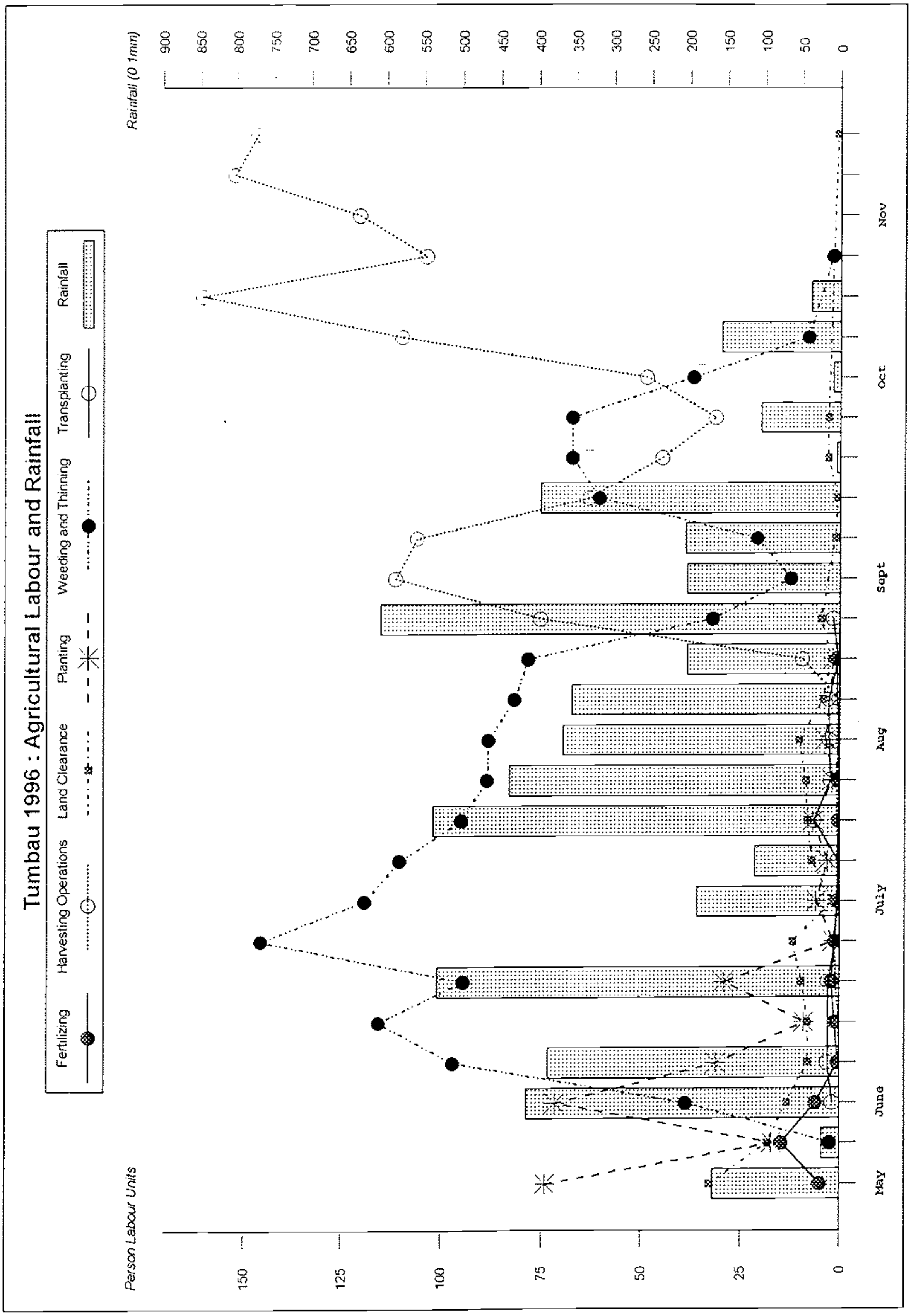


FIGURE 5.3.2(f)

Dagaceri, 1994: Agricultural labour and rainfall (total seasonal rainfall, 403 mm)

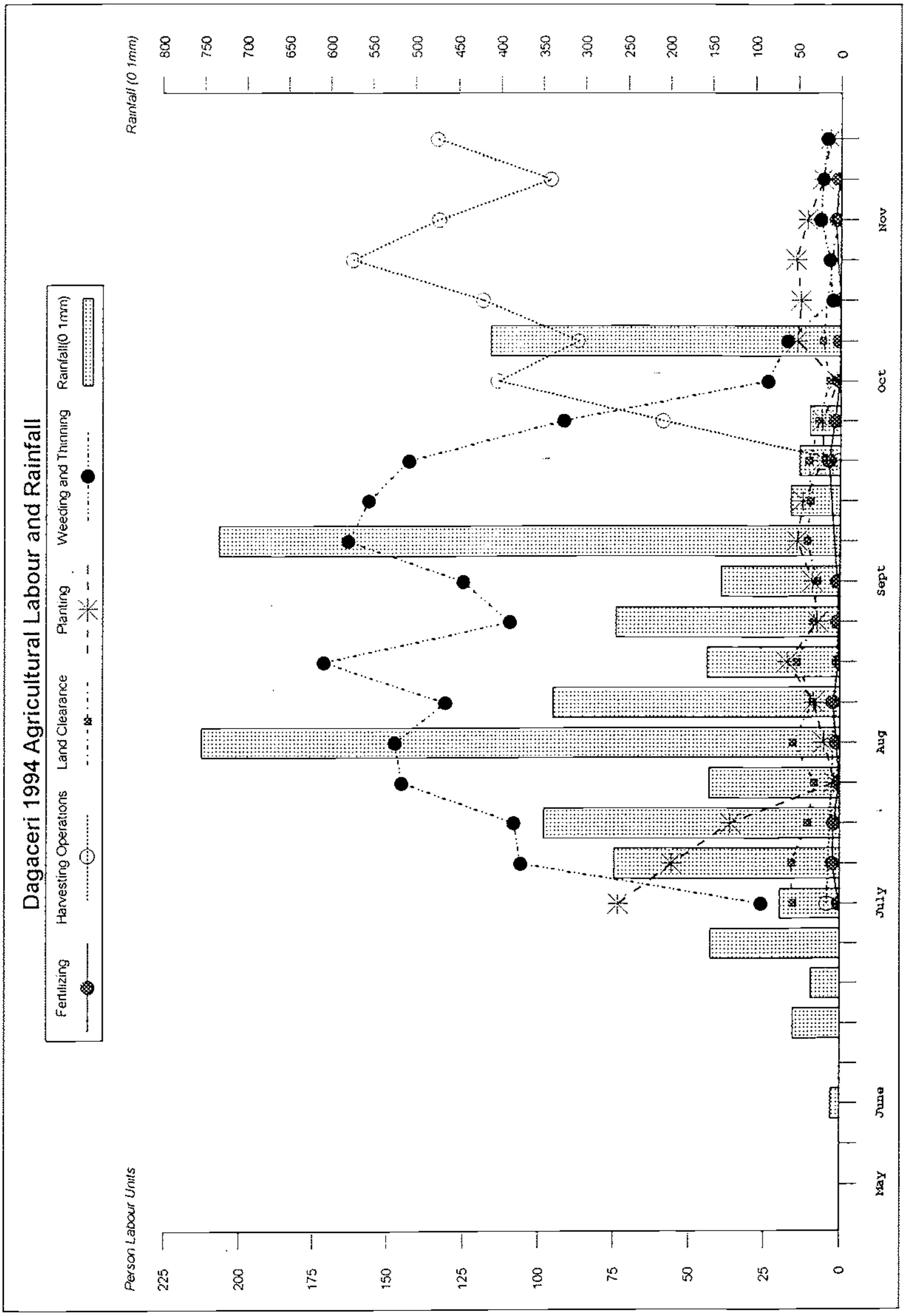


FIGURE 5.3.2(g)

Dagaceri, 1995: Agricultural labour and rainfall (total seasonal rainfall, 326 mm)

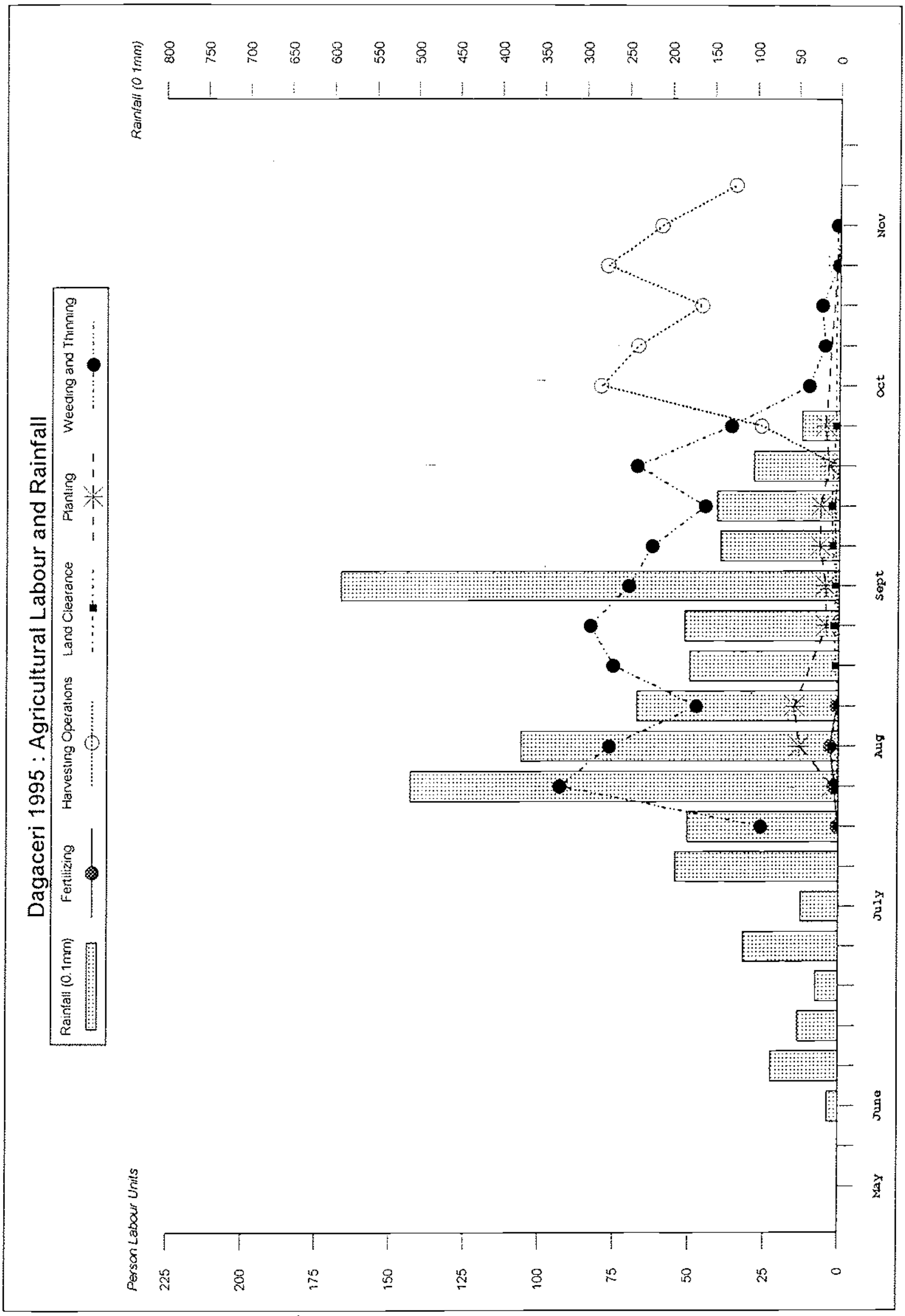


FIGURE 5.3.2(h)

Kaska, 1994: Agricultural labour and rainfall (total seasonal rainfall, 435 mm)

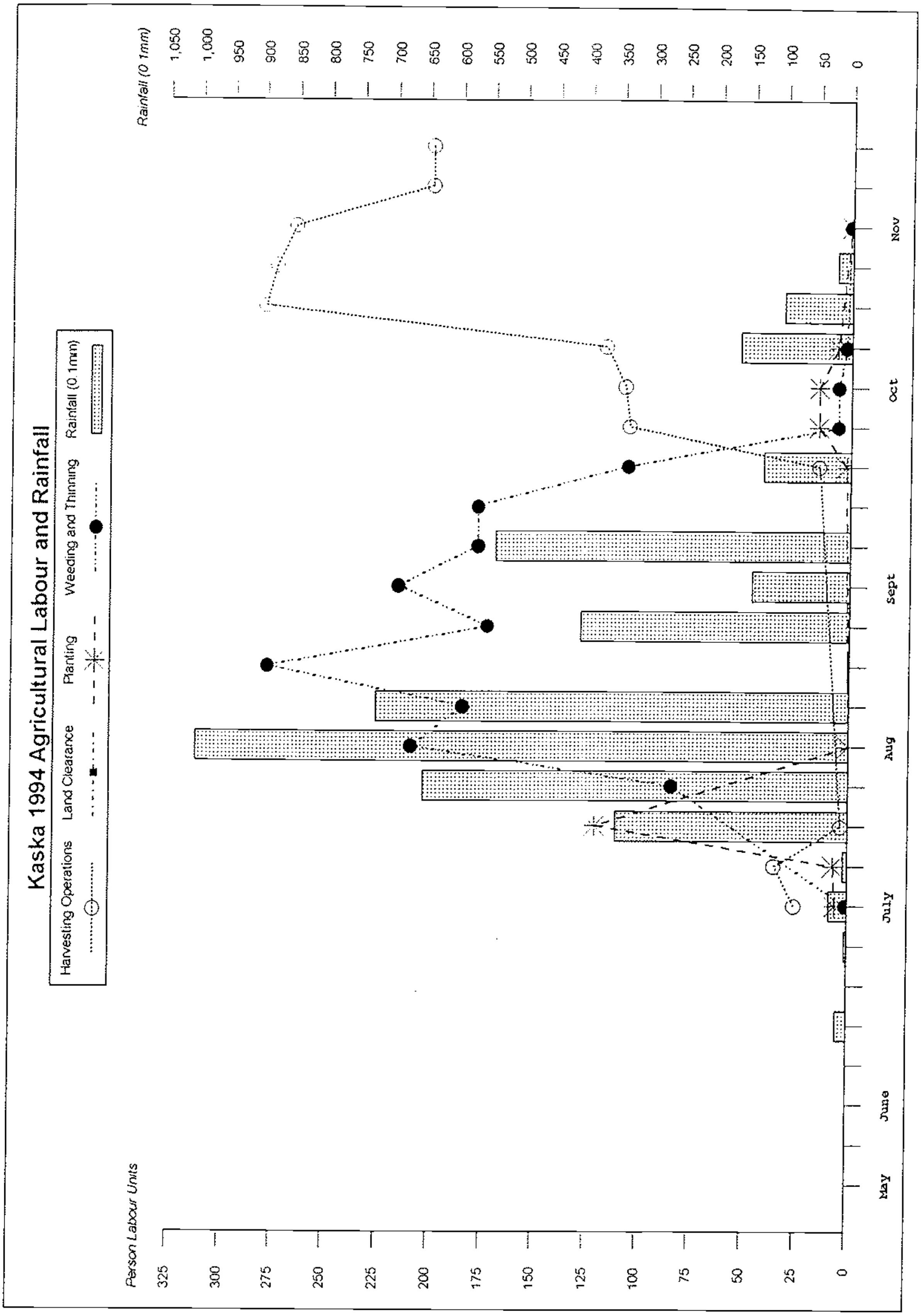


FIGURE 5.3.2(i)

1993 Agricultural labour: percentage of available labour used in agriculture

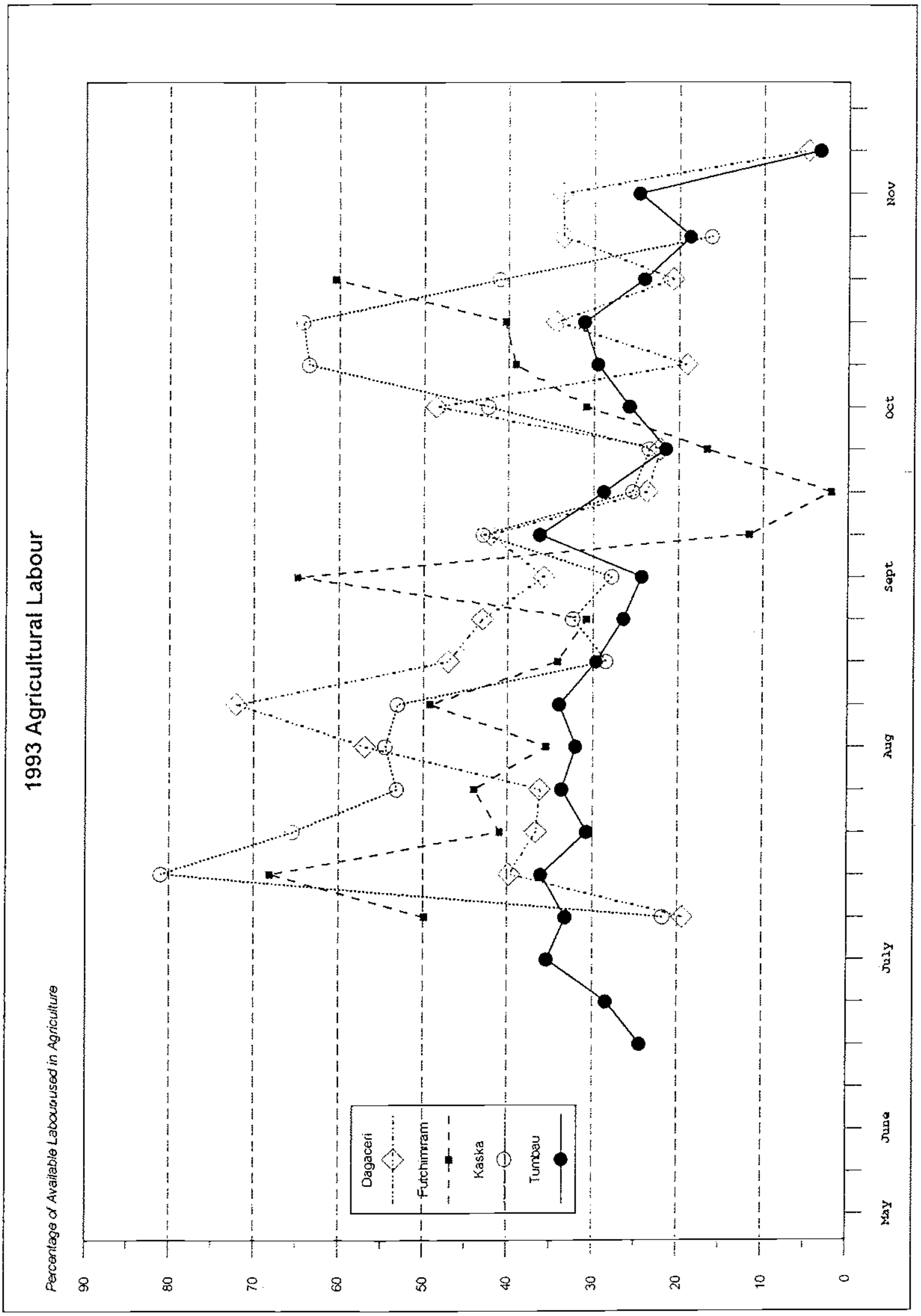


FIGURE 5.3.2(j)

1994 Agricultural labour: percentage of available labour used in agriculture

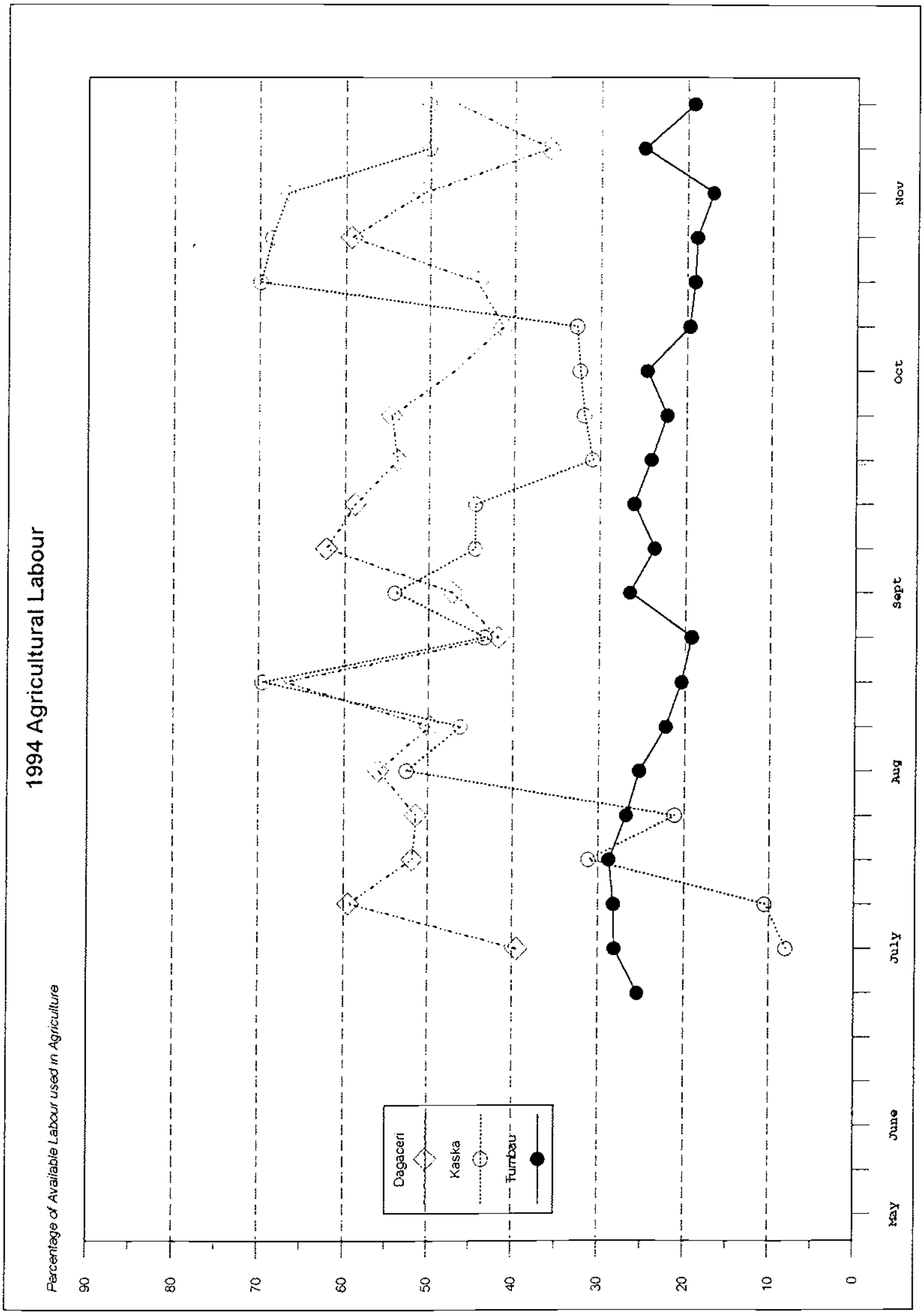


FIGURE 5.3.2(k)

1995 Agricultural labour: percentage of available labour used in agriculture

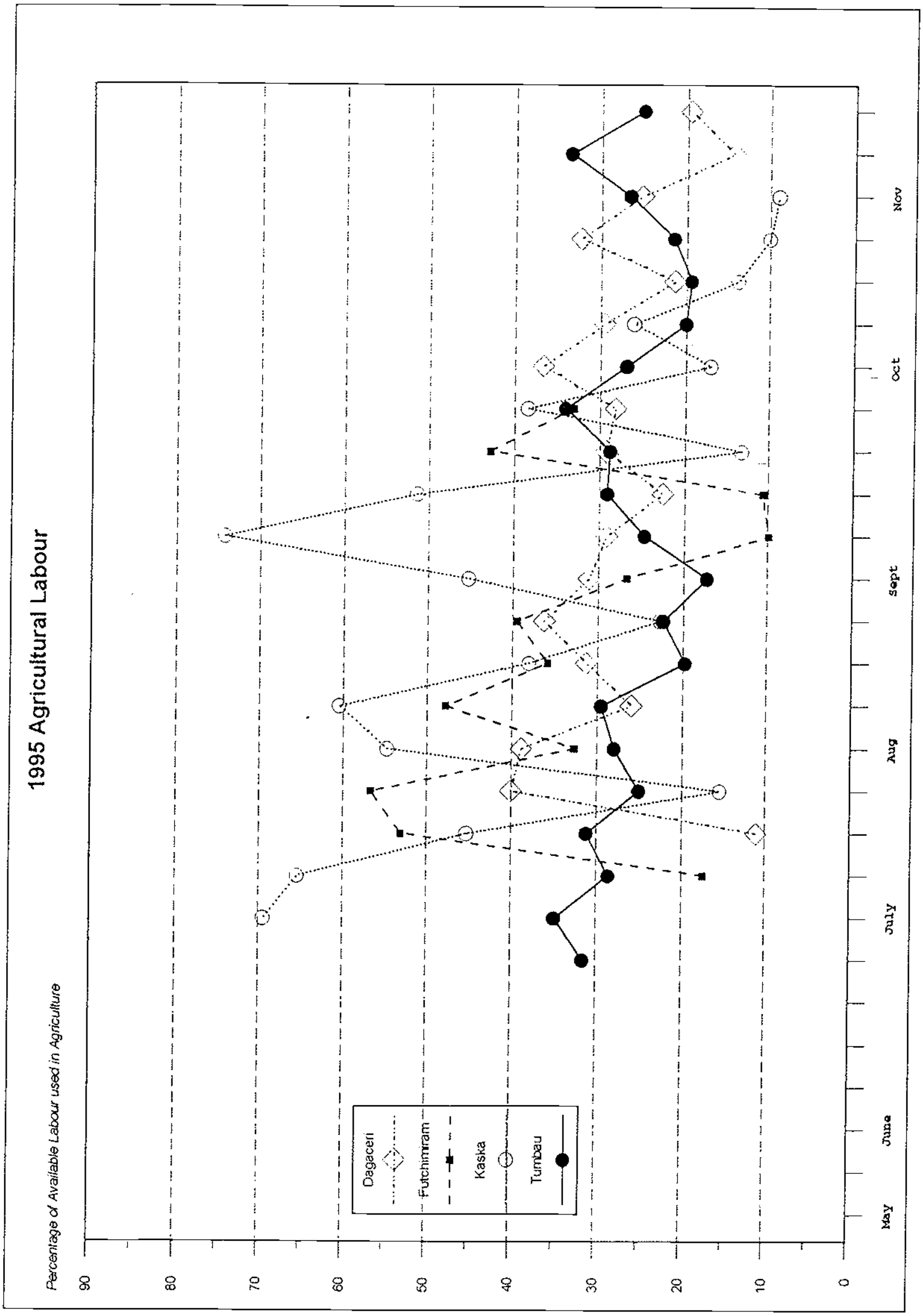


FIGURE 5.3.2(l)
Futchimiram 1996: harvesting categories

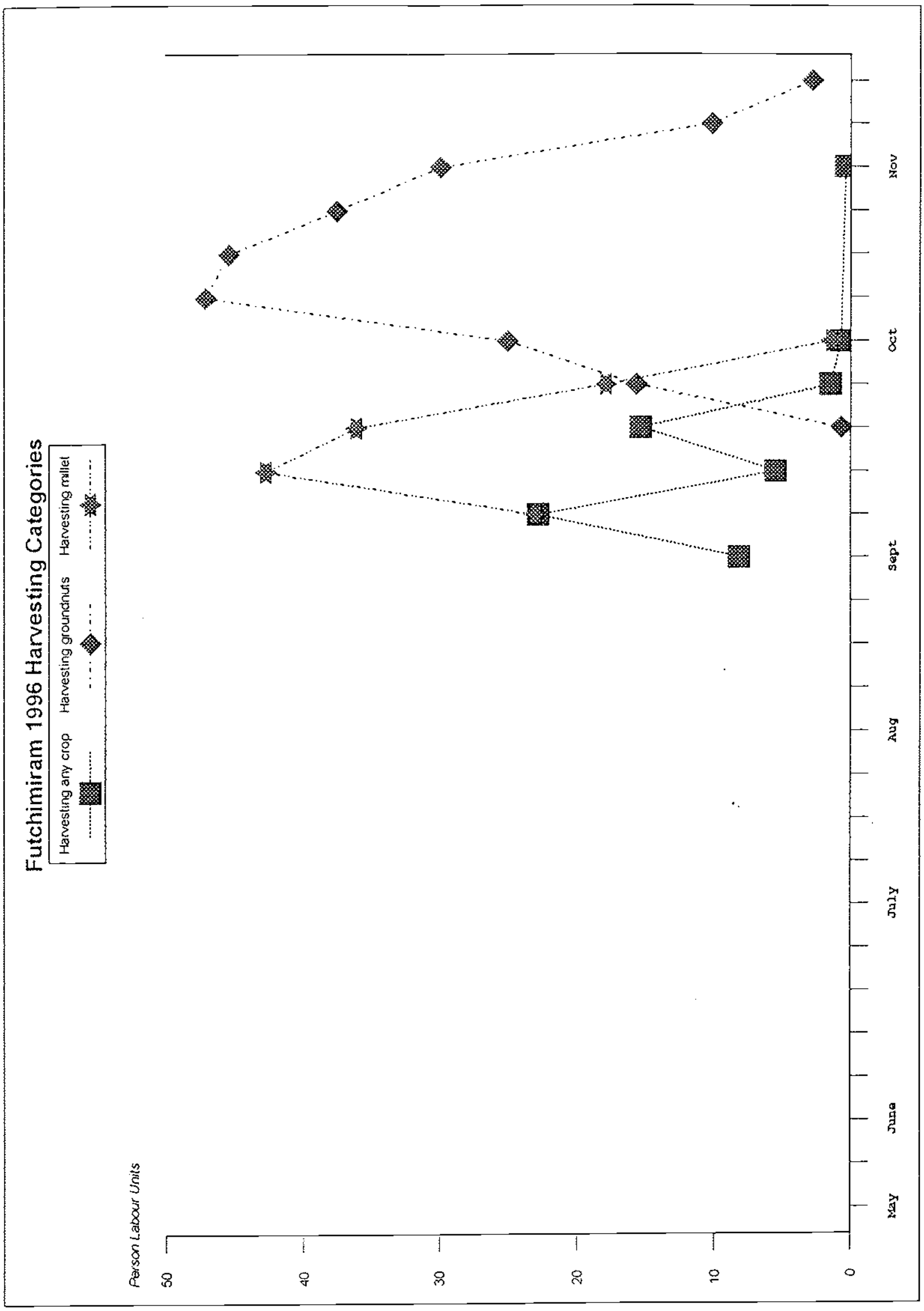


FIGURE 5.3.2(m)

Kaska 1996: harvesting categories

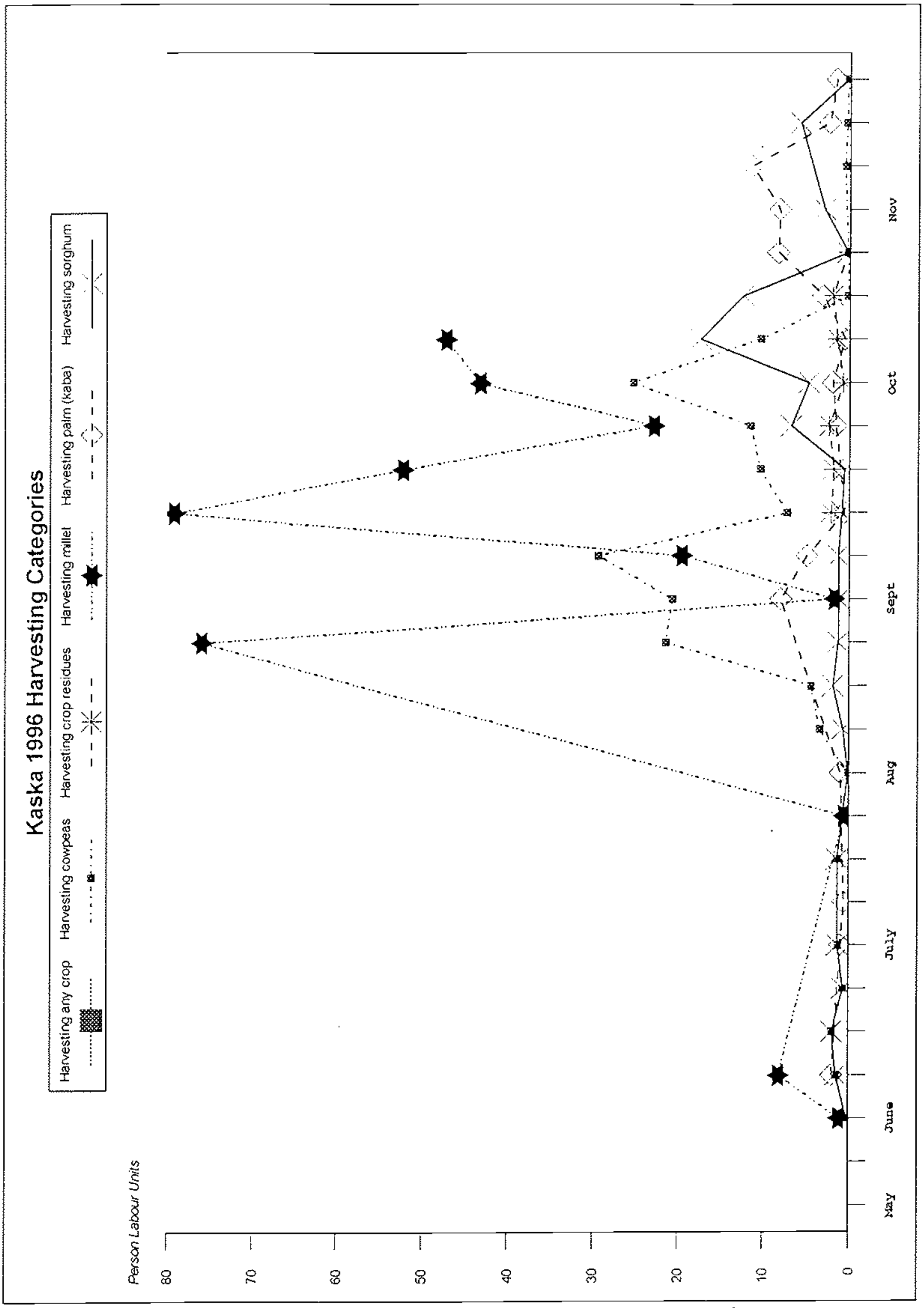


FIGURE 5.3.2(n)

Dagaceri 1996: harvesting categories

Groundnut data should be disregarded.

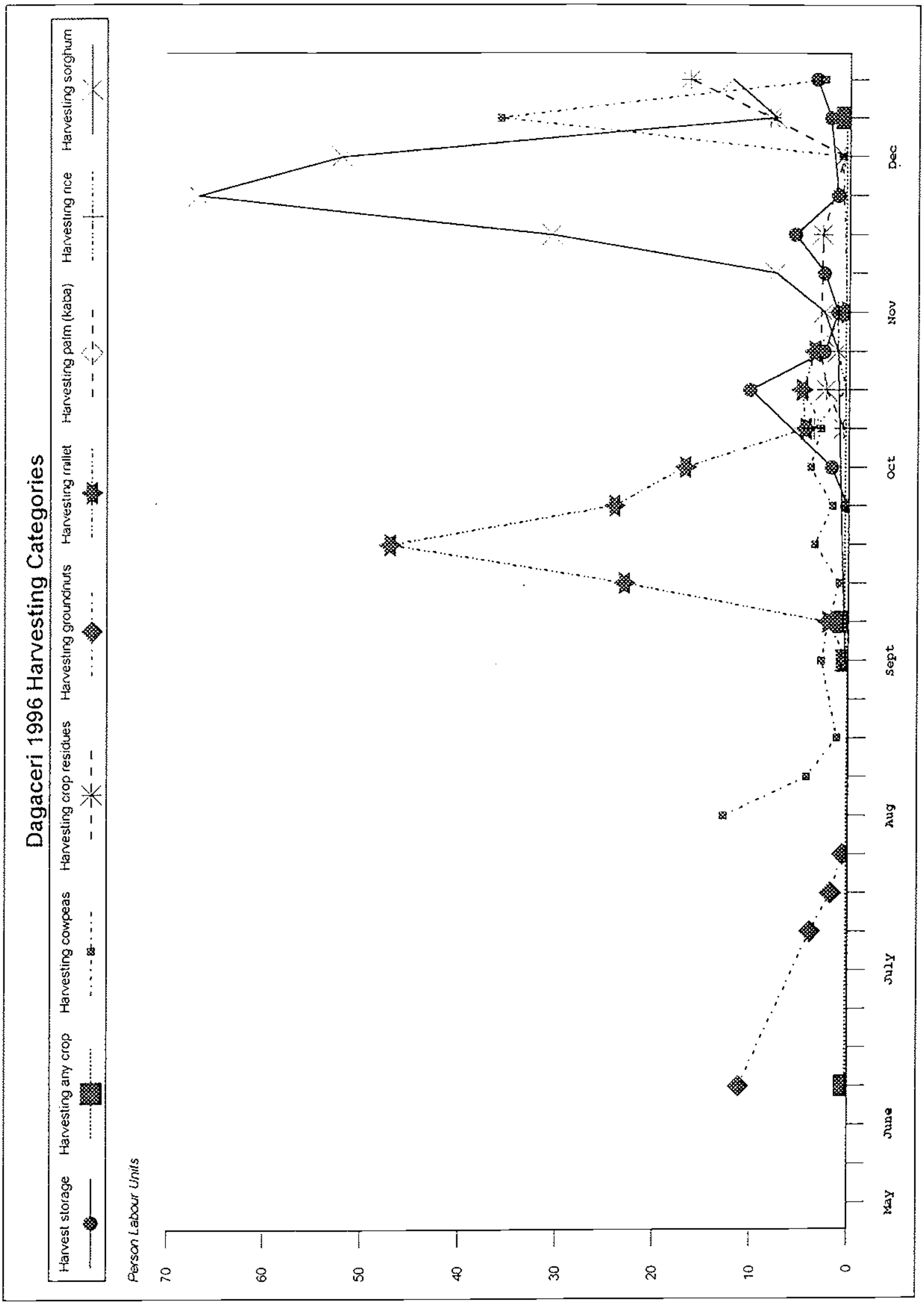


FIGURE 5.3.2(o)
Tumbau 1996: harvesting categories

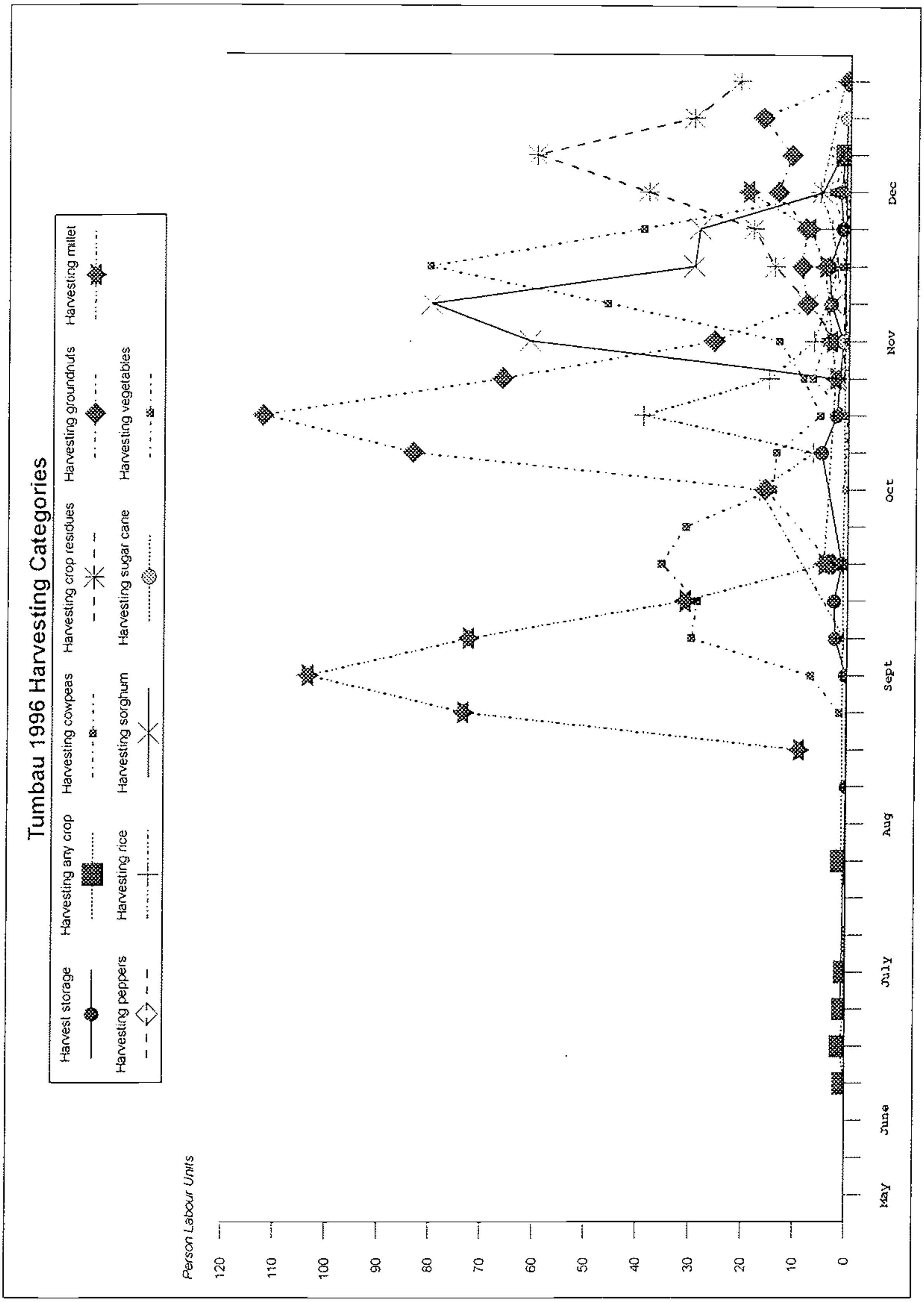


FIGURE 5.3.2(p)
Tumbau 1995: harvesting categories

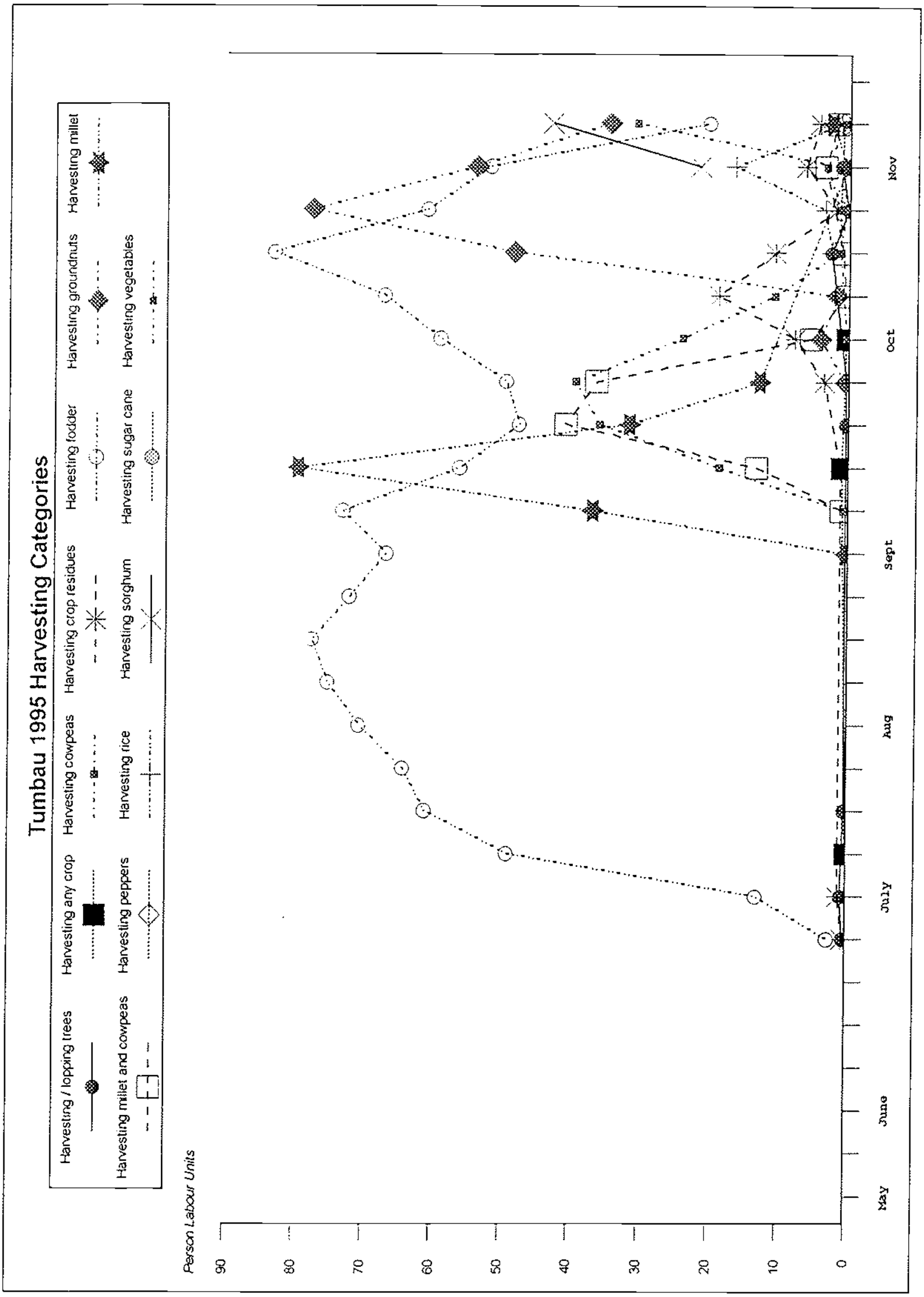


FIGURE 5.3.3(a)

Tumbau 1996: labour use by category

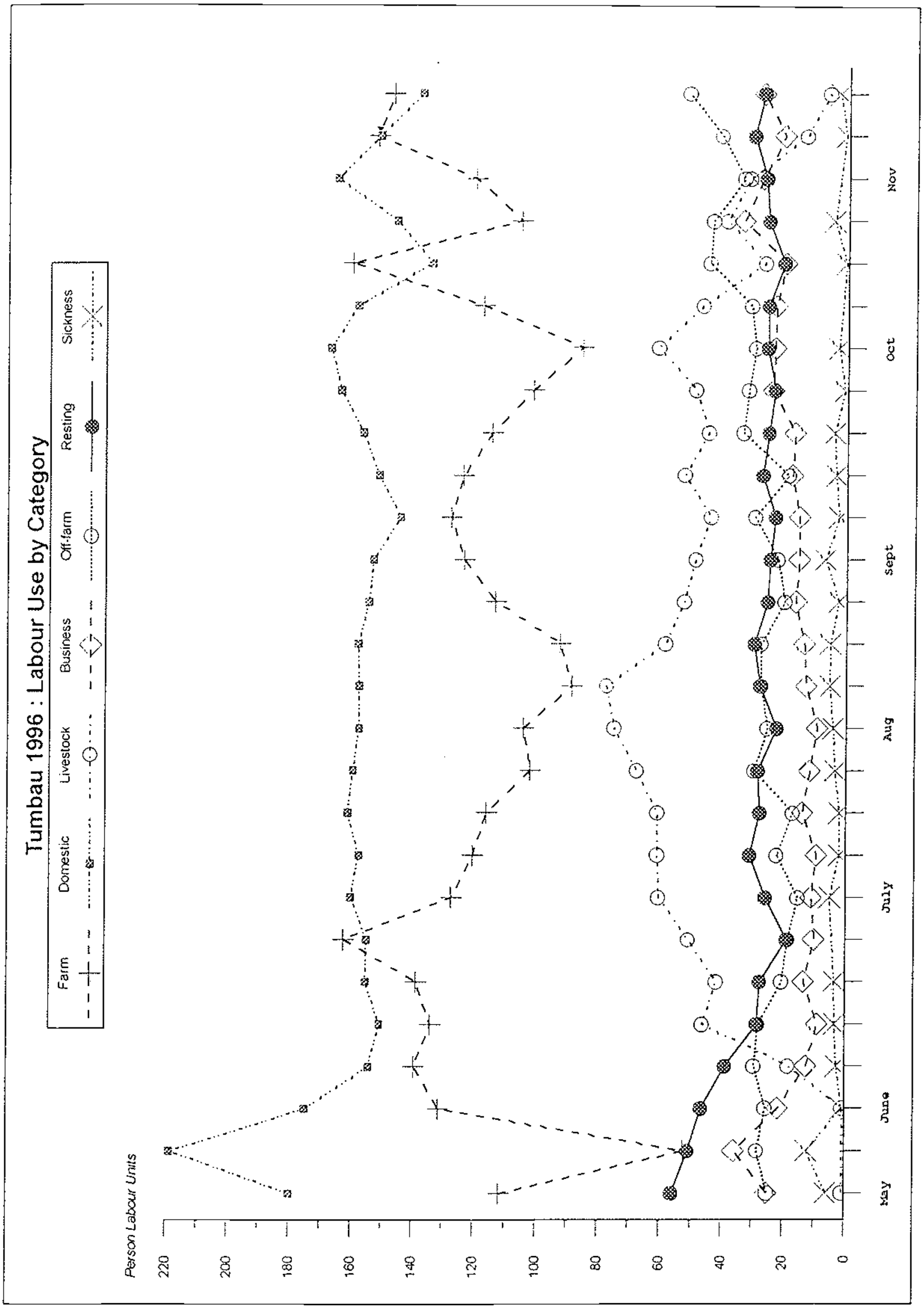


FIGURE 5.3.3(b)
Dagaceri 1996: labour use by category

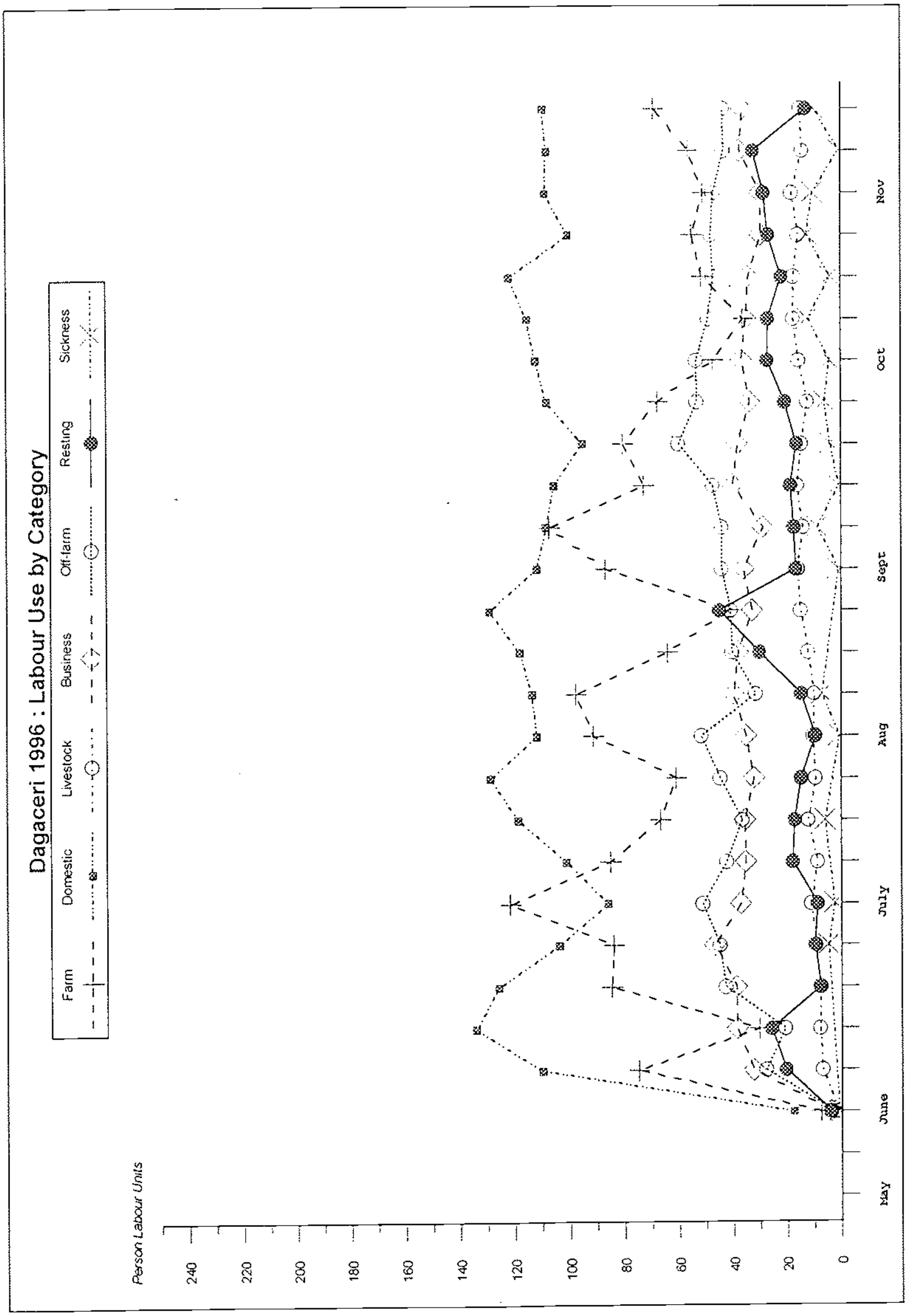


FIGURE 5.3.3(c)
Kaska, 1996: labour use by category

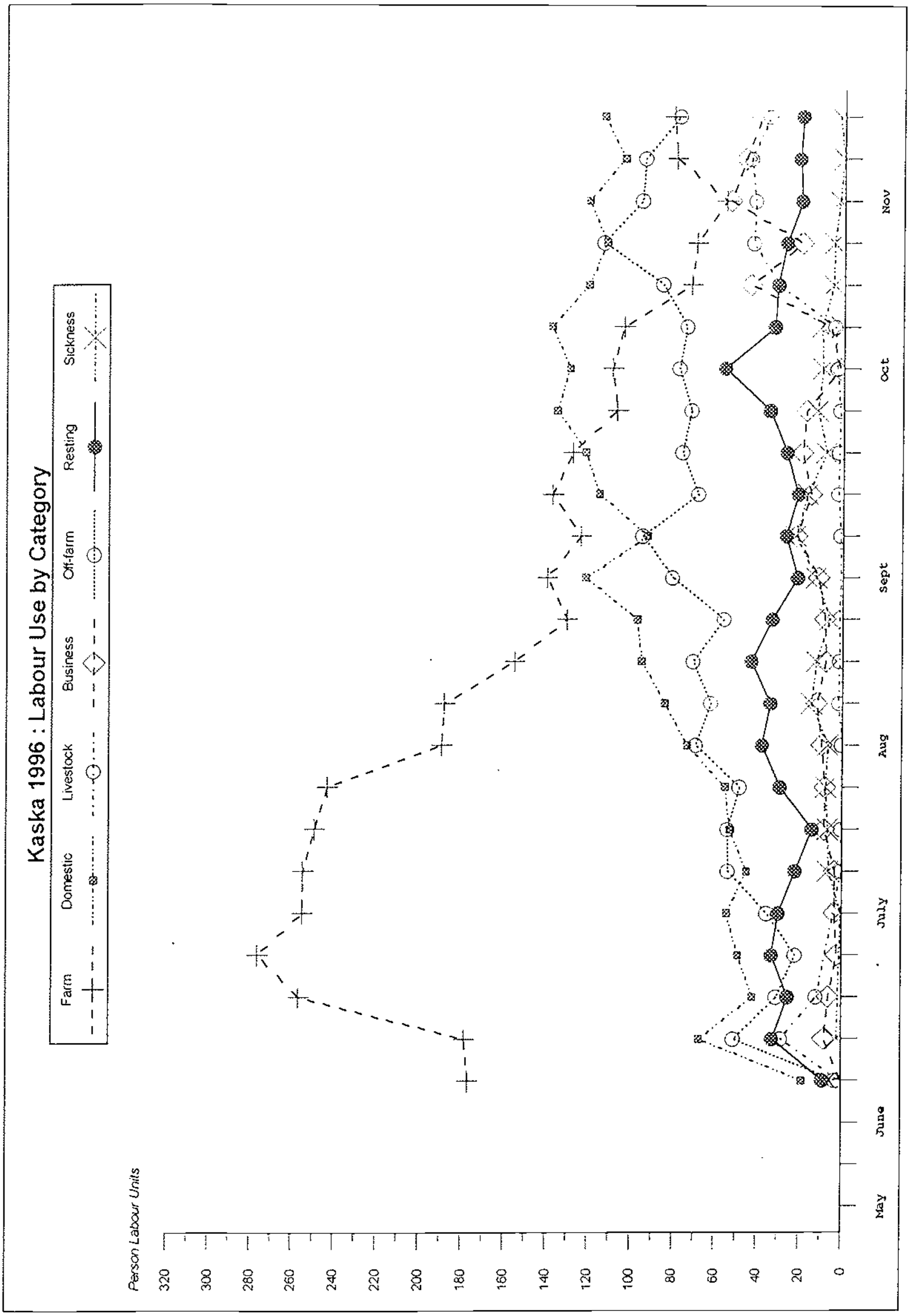


FIGURE 5.3.3(d)
Futchimiram 1996: labour use by category

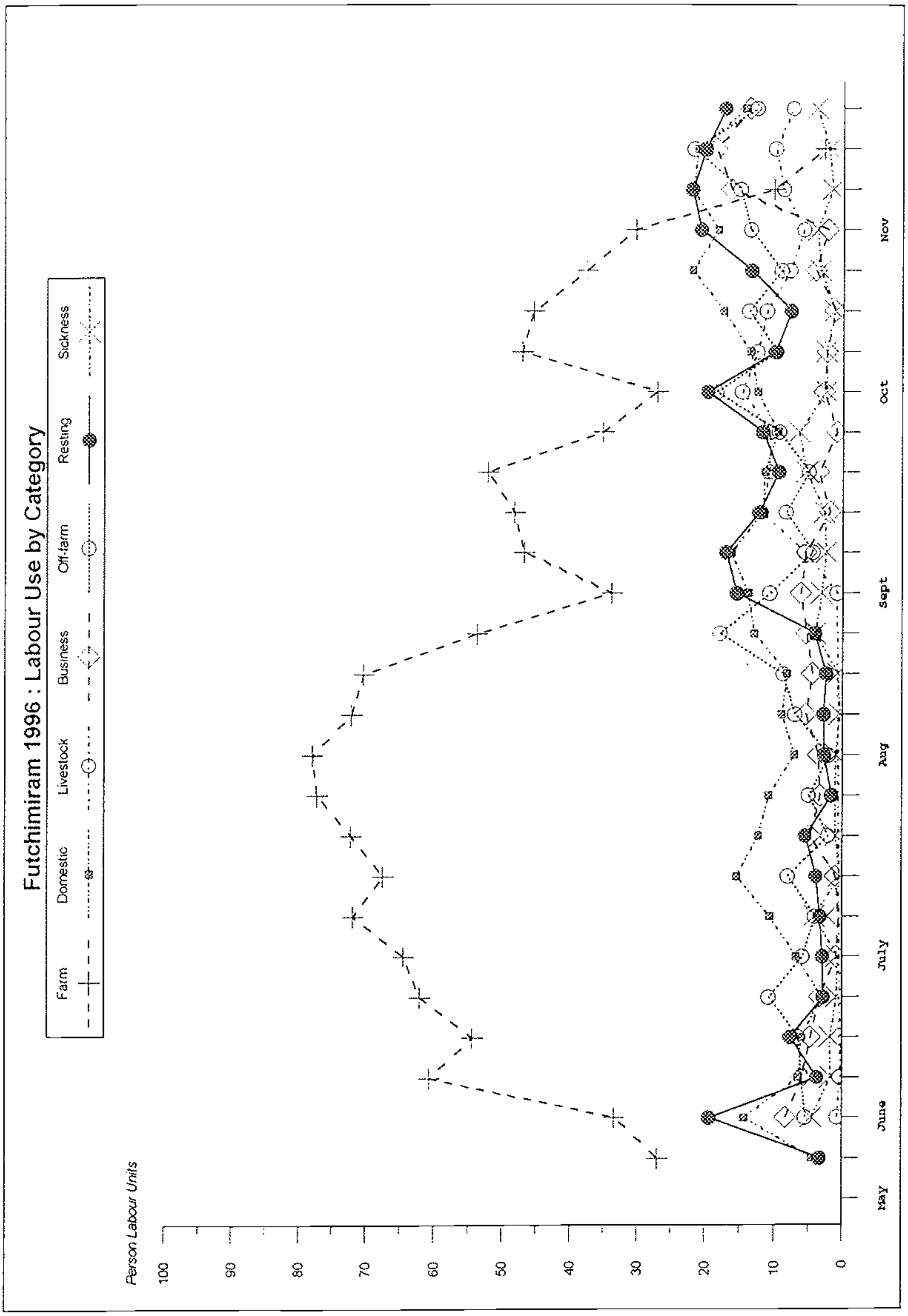


FIGURE 5.3.3(e)

Tumbau 1995: incidence of labour incapacity and rainfall

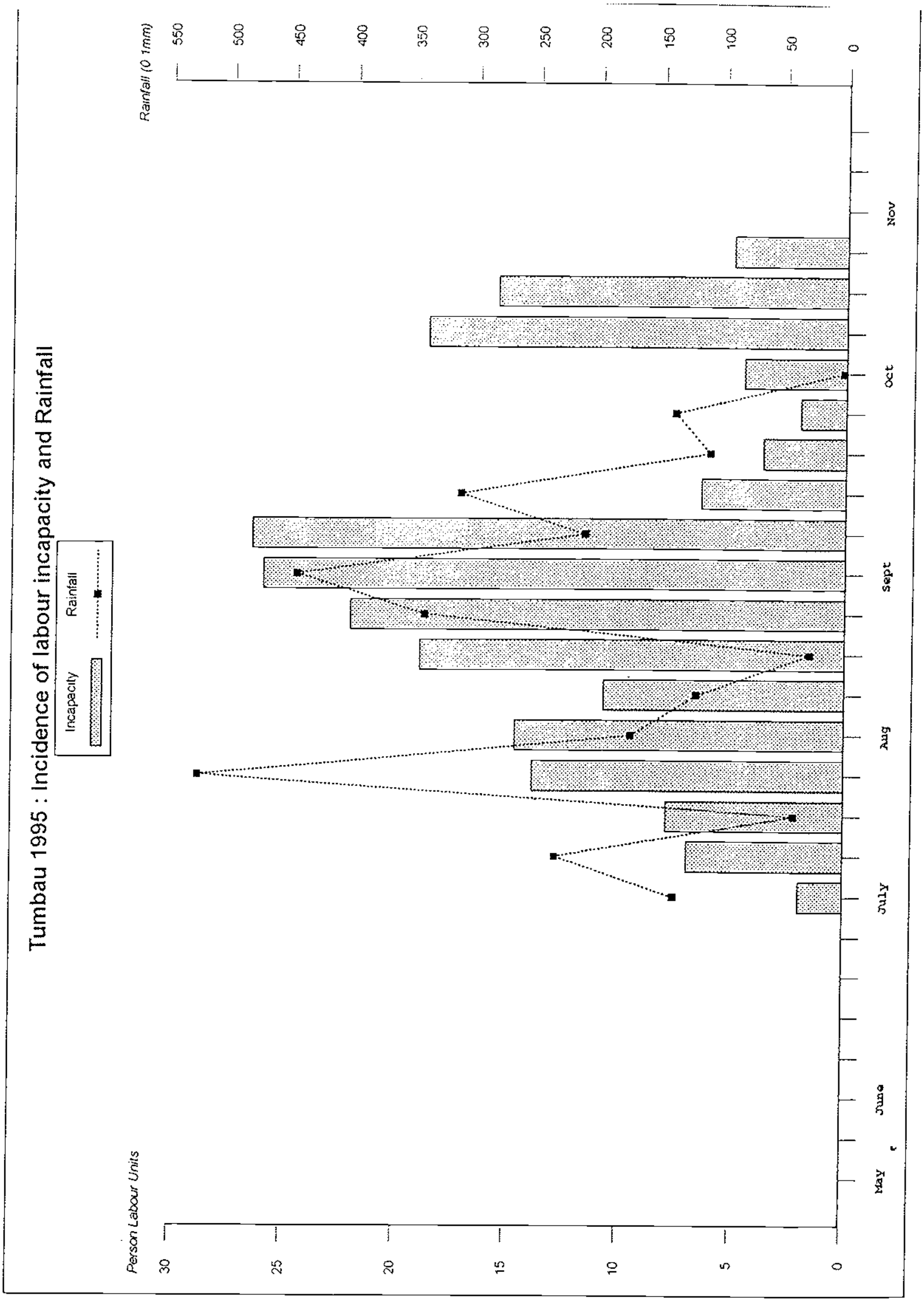


FIGURE 5.3.3(f)

Tumbau 1995: labour use by category

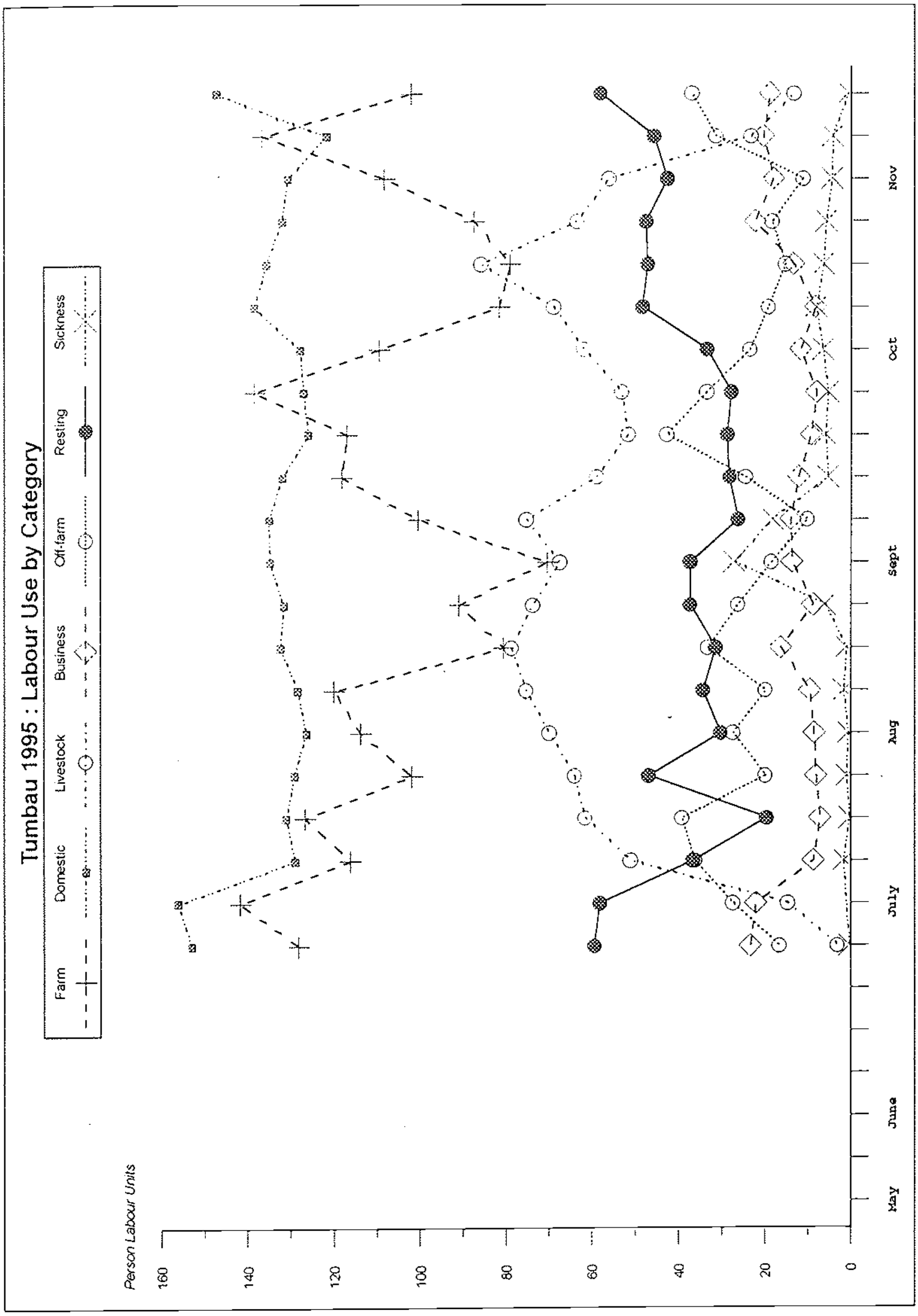


FIGURE 5.3.4(a)

Percentage of available female labour used in specific agricultural tasks, 1996

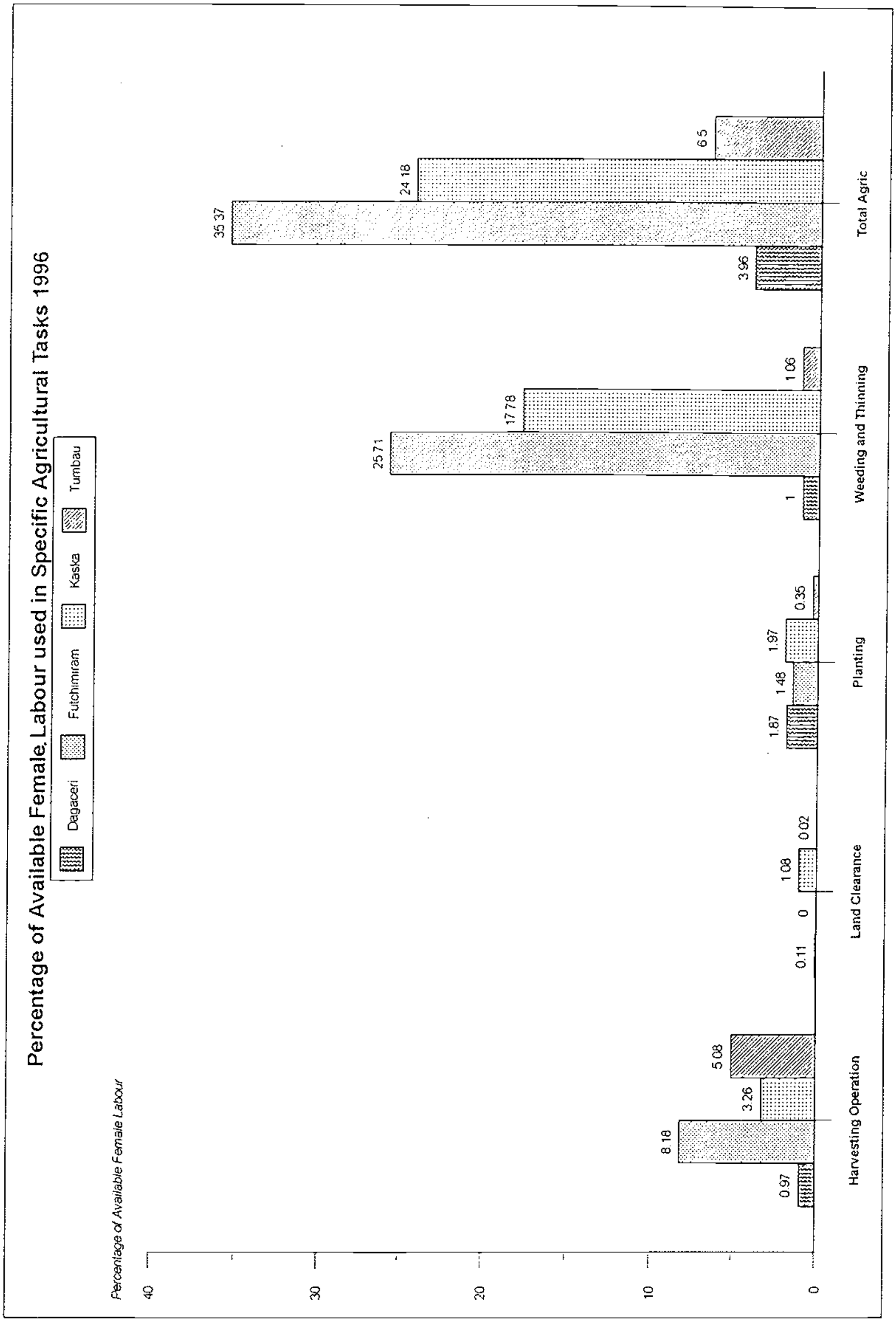


FIGURE 5.3.4(b)

1995 male agricultural labour:percentage of available male labour used in agriculture

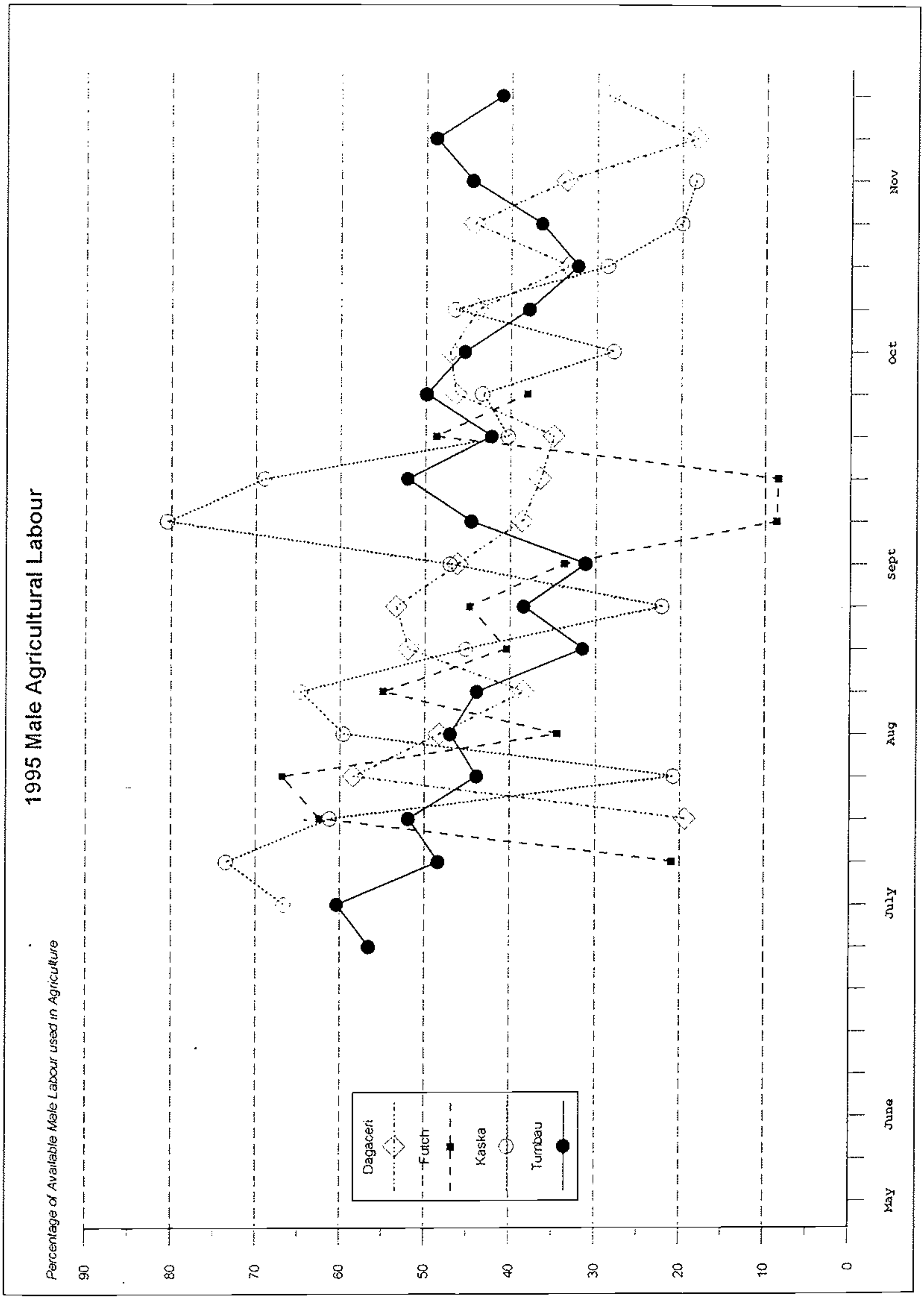


FIGURE 5.3.4(c)
Percentage of available female labour used in agriculture,1996

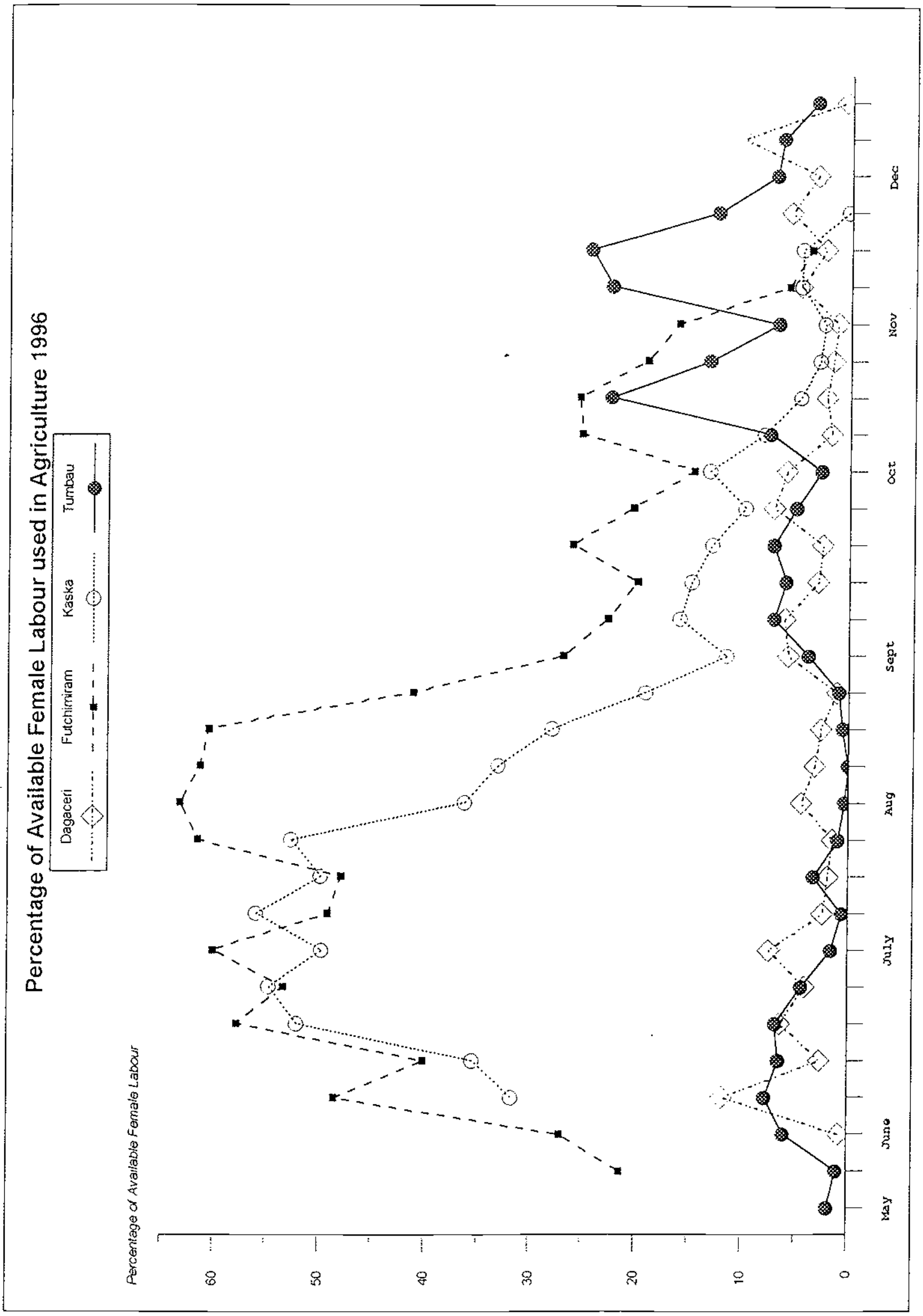


FIGURE 5.3.5(a)

Kaska, 1995: agricultural labour in small, medium and large households

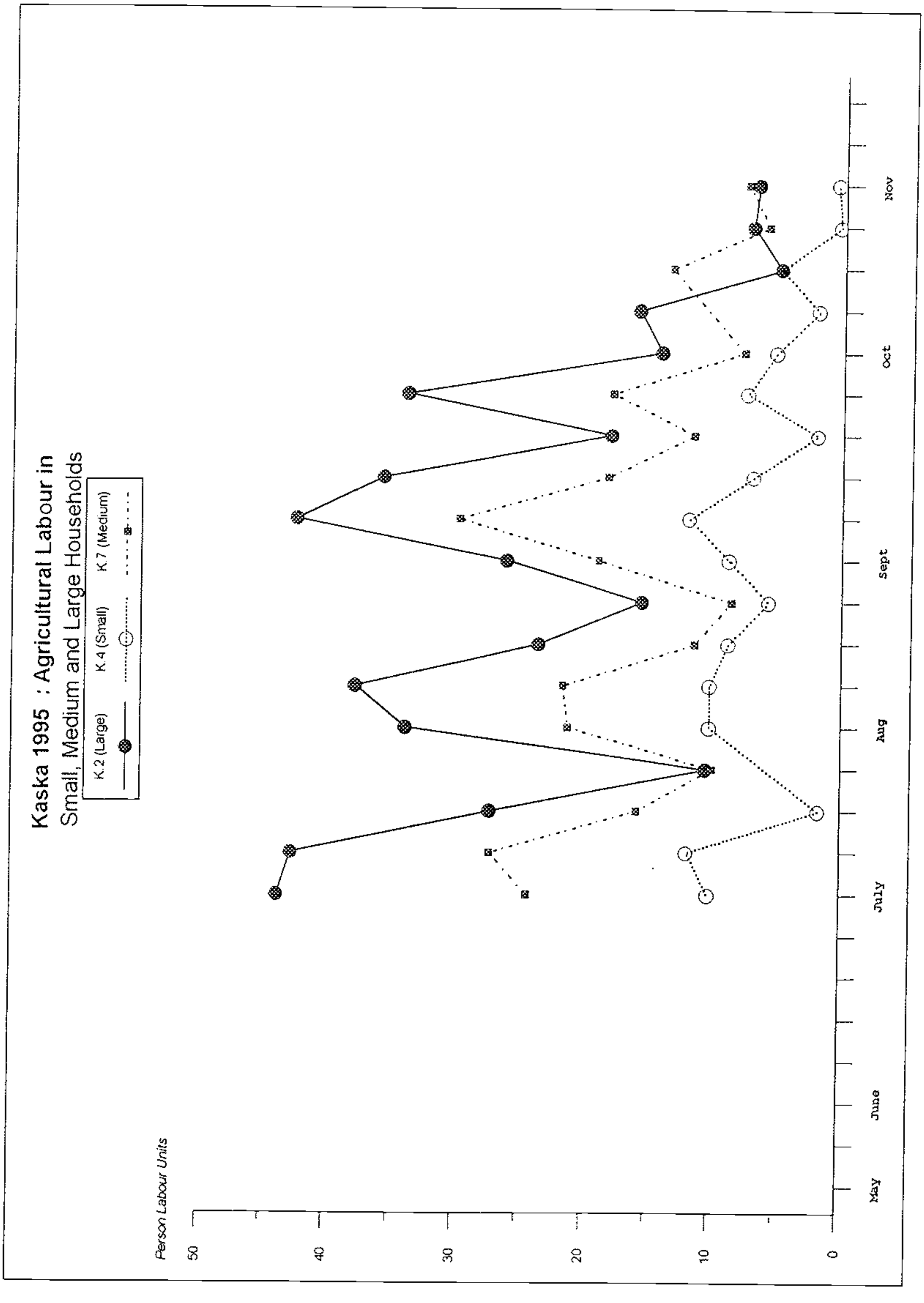
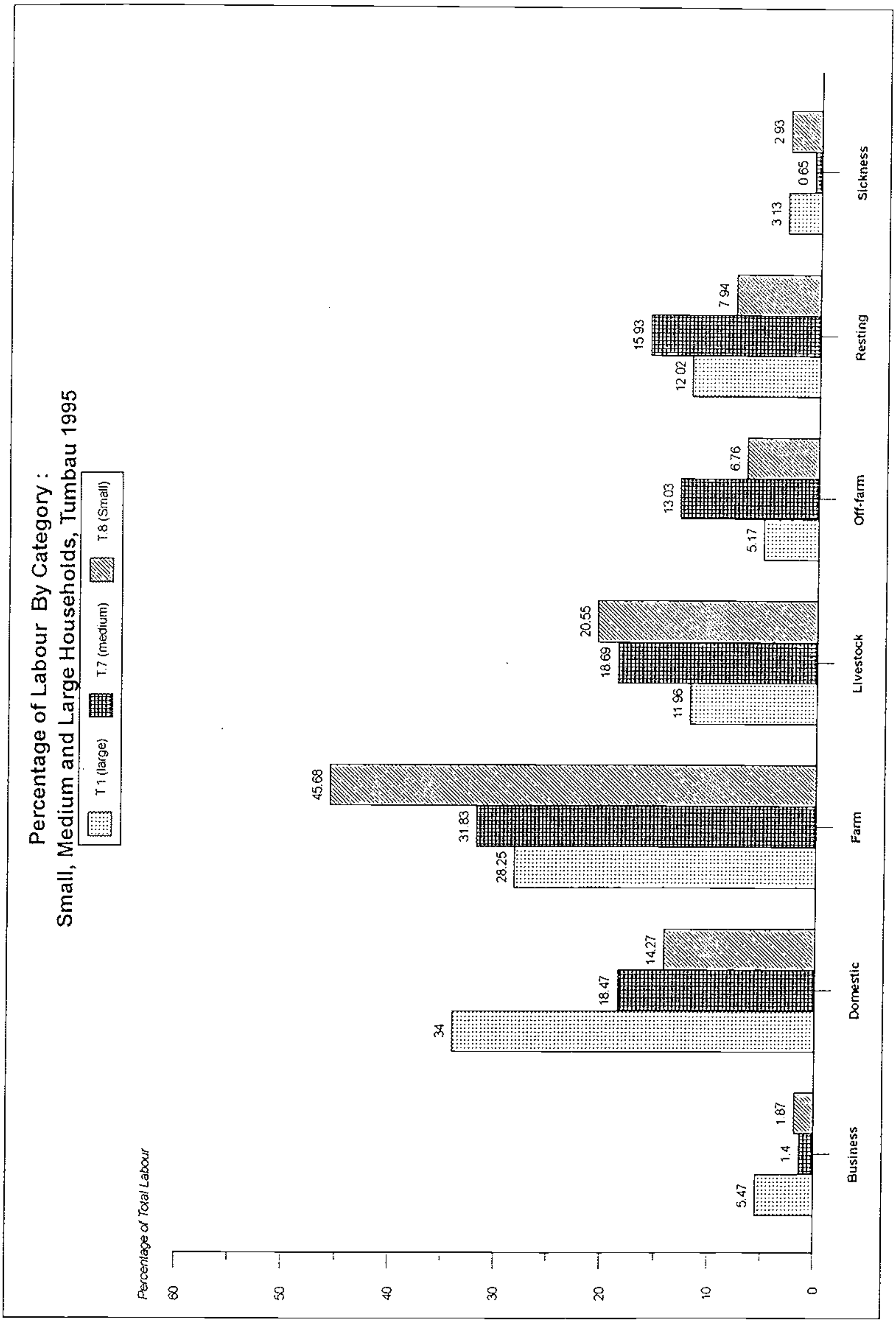


FIGURE 5.3.5(b)

Percentage of labour by category: small, medium and large households, Tumbau, 1995



5.4 Soil and Biomass Management

In this Section, we report on investigations of soil fertility and its management under each of the four farming systems, and on a preliminary conceptualisation of the implications of land use change for biomass management. The objective is to quantity some of the parameters in the land degradation debate. The two major controls affecting soil fertility, our hypothesis states, are ecology and management. The effects of the first will be estimated by comparing sites; and the effects of the second by using comparisons between management regimes (between various arable modes and uncultivated control sites) to infer changes through time - a spatial analogue of temporal change.

The argument proceeds in the following stages: (a) a classification of the major soil types in topographical context, using indigenous perceptions in each village; (b) a classification of management regimes, which with soil types are the basis of the soil sampling design; (c) the results of the soil analyses; (d) an account of soil fertility management by farmers; (e) their management of livestock and fodder; and (f) an introduction to estimating the biomass implications of land use change.

5.4.1 Soil Types

The following descriptions draw on inventories, sampling and profile pits carried out in Phase I (Essiet, 1994), a detailed study of fertility and its management in Tumbau (Yusuf, 1994), and additional sampling and analyses carried out in Phase II.

Tumbau.
Investigations were confined to upland soils which comprise approximately 90% of the 11 x 11 km block containing the rainfed Tumbau farmlands. The remainder is lowland whose ecology and management is dominated by surface or subsurface water availability throughout the year. Stream courses grade downwards towards the Kano River, whose extensive flood plain is about 20 m below the upland, whose surface is generally flat or very gently sloping. Under intensive rainfall, not only the lowland soils but also pockets of upland may be covered by standing water for short periods.

Sandy ferruginous soils (Latosols) are laterised on exposed slopes and more extensively below the surface. The weathered regolith of the Basement Complex is covered by drift and the soils are mature, well drained and acidic with high percentages of sand and low in organic matter, usually less than 0.5% (Yusuf, 1997). According to Bennett et al. (1978), the soils of the Kano Close-Settled Zone are generally deeper than 100 cm, well drained, lacking a coarse material layer, and with iron segregation mottles occupying less than 20% of any horizon. The topsoil and subsoil colour are variable (possibly owing to intensive cultivation), but the dominant B horizon colour is yellowish red.

Farmers recognise two upland soil types on the basis of colour:
- *rairayi* or white (actually light yellowish to yellowish brown), which is lighter and retains less moisture, and
- *jangargari* or red (actually reddish yellow and strong brown), which is heavier, retains more moisture, and gives better residual effects from fertilizer.

There is no significant difference in fertility (Essiet, 1994; Yusuf, 1994), nor in management. Consequently, these soils are not distinguished in the fertility analyses which follow.

Dagaceri
The parent material is deep sandy stabilised dunes with interdune depressions aligned from ENE to WSW. The relative relief is of the order of 10 m. The dune soils weather to a reddish colour on some crests, and elsewhere are white. There are no wetland areas, though flooding may persist for a day or two after heavy rain in the interdunes (which have no integrated drainage), and a few seasonal ponds are associated with areas of black or grey soils.

Farmers recognise three main soil types (Mohammed, 1996):

- *kati-kime*, red (actually yellowish red), with incomplete mineralisation of potassium feldspar, weak angular blocky structures, sandy texture, micropores and generally porous;
- *keza-keza*, white (actually strong brown below the surface), with weak blocky structure, surface capping, micropores and sandy texture;
- *tulo-tulo*, black (actually dark brown below the surface), hard and compact with massive and crumb structures, sandy clay texture, mottles present, both macro- and micropores.

Profile pits revealed only a limited differentiation of horizons in all three types. Farmers plant all crops in all soils, though with smaller spacing in *tulo-tulo*. Many only farm on *keza-keza*, which accounts for perhaps 70% of the surface.

Kaska

The relative relief in Kaska is greater than in the other areas, with about 20 m separating the upland (stabilised or moving dunes) from the bottomlands of the steep-sided, closed circular or eliptical depressions which often contain saline ponds. Intermediate in terms of relief are sandy floored lowlands, thought to be infilled depressions. This area had an active dunefield until relatively recently and still has not developed a woodland vegetation, except in the depressions where dense woodland takes advantage of shallow groundwater. Flooding occurs in the deep depressions after heavy rain.

Farmers follow these topographical elements in their classification of the soils:

- *tudu*, upland, yellow or white dune sands lacking any profile, very freely draining, but sometimes differentiated by colour within a short vertical or horizontal distance, disturbed by frequent remobilisation in the recent past, and supporting only annual grasses;
- *faya*, intermediate lowland, white sands, freely draining, but not subject to remobilisation, supporting grasses, shrubs and scattered trees;
- *kwari*, deep depression alkaline soils with silt and clay present in significant quantities, hard surface capping, rainwater running off into the ponds, supporting (except where capped) dense woodland, with groundwater 1-3 m below the surface.

Sharp differences in management reflect the same categories. Until the 1980s, almost all farming was confined to the *faya* and some *kwari* soils, the latter being used for irrigated farming during the dry season where groundwater is less than 2 m deep. The *kwari* soils are recognised as the most fertile, where impeded drainage, salinity, alkalinity or surface capping are not problematic. The *tudu* soils were left for grazing. With reduced rainfall, the dried out *kwari* soils are hard to cultivate for rainfed farming. This activity has since been extended from the *faya* to an increasing area of *tudu* soils. Most farmers have a portfolio including all three soil types, the *faya* still providing the basis for rainfed farming, and the *kwari* being restricted to dry season cultivation.

Futchimiram

Only one soil type is recognised in Futchimiram, which has a gently undulating surface (relative relief <6 m) covered by open woodland and annual grasses and herbs, with a few very episodic shallow pools. The soils are sandy and porous throughout the profile, low in organic matter, total nitrogen, available phosphorus and total exchangeable bases (Chiroma, 1996). The parent material is deep Chad Formation deposits of alternating coarse and fine sands.

5.4.2 Management regimes

Fertility management regimes vary according to soil type and location. While they give no indication of inputs or outputs, these descriptive classes do reflect important differences in practice which have a bearing on sustainability. Table 5.4.2 displays the regimes identified with the locations and soil types where they occur, and where they were sampled. The top 20 cm of the profile was sampled, and each entry in the table represents four composite samples (unless otherwise stated).

TABLE 5.4.2
Management regimes sampled in the four villages

Regime	Tumbau		Dagaceri			Kaska		Futchimiram
	all soils	*red*	*white*	*black*	*tudu*	*faya*	*kwari*	*uniform soil*
1 Uncultivated	UC	UC	UC	UC	UC	UC	UC	UC
2 Long fallow >5 yrs	-	LF	LF	LF	-	-	LF	LF
3 Short fallow <3 yrs	SF[1]	-	-	-	-	SF	-	-
4 Short cultivation 2-5 yrs	-	-	-	-	SC[3]	-	-	SC
5 Long cultivated >19 yrs	-	LC	LC	LC	-	LC[2]	LC[2]	LC
6 LC+rotational manuring	RM	-	RM	-	-	RM[3]	-	-
7 LC+annual manuring	AM	-	-	-	-	-	-	-
8 LC+inorganic fertilizers	IF	-	-	-	-	-	-	-
9 LC+manure+IF	MIF	-	-	-	-	-	-	-
10 Continuous cassava	CC	-	-	-	-	-	-	-
11 Irrigated farming	-	-	-	-	-	-	IR	-
12 Moving dunes	-	-	-	-	MD	-	-	-

Notes:

1) Intermittent fallow
2) >29 years
3) Up to 6 years

Additional sampling was undertaken in Tumbau to compare soil fertility (a) under legumes, grains, and rotations, and (b) under hand cultivation and ox-ploughing (not reported here).

The variables analysed were: sand, silt and clay fractions; available water holding capacity; soil water pH; electrical conductivity; organic carbon; total nitrogen; and available phosphorus. In Tumbau, the samples were also analysed for: bulk density; calcium; magnesium; potassium; sodium; and cation exchangeable capacity (not reported here).

5.4.3 Analytical Results

In Tables 5.4.3(a)-(i), which follow, the soil parameters are presented one by one in order to permit comparisons of both inter-village (i.e., ecological) and inter-regime (i.e., management) effects. The statistical size of the samples is small, but the results are indicative. Larger samples would, in many cases, be impracticable. [Instructive comparisons of these soils data may be made with those in Harris and Bache (1995) for three farms in Tumbau; Bennett et al. (1978) and Mortimore, Essiet and Patrick (1990) for the Kano Close-Settled Zone; and in due course, Harris (NRI project in progress) for farms in Dagaceri.]

Soil texture and water holding capacity

TABLE 5.4.3(a)
Soils analytical results: percent sand

Regime	Tumbau	Dagaceri				Kaska		Futchimiram
	all soils	*red*	*white*	*black*	*tudu*	*faya*	*kwari*	*uniform soil*
1 Uncultivated	80.6	91.5	87.2	83.5	86.5	86.0	64.0	88.3
2 Long fallow >5 yrs	-	89.5	87.4	84.5[1]	-	-	78.0	87.7
3 Short fallow <3 yrs	83.0	-	-	-	-	88.3	-	-
4 Short cultivation 2-5 yrs	-	-	-	-	86.3	-	-	87.3
5 Long cultivated >19 yrs	-	83.7	89.7	80.1	-	87.8	87.8	92.1
6 LC+rotational manuring	83.4	-	90.1	-	-	88.3	-	-
7 LC+annual manuring	83.3	-	-	-	-	-	-	-
8 LC+inorganic fertilizers	87.5	-	-	-	-	-	-	-
9 LC+manure+IF	83.1	-	-	-	-	-	-	-
10 Continuous cassava	84.6	-	-	-	-	-	-	-
11 Irrigated farming	-	-	-	-	-	-	70.0	-
12 Moving dunes	-	-	-	-	90.2[2]	-	-	-

Notes:
1) 2 samples only
2) 3 samples

TABLE 5.4.3(b)
Soils analytical results: percent silt

Regime	Tumbau	Dagaceri				Kaska		Futchimiram
	all soils	*red*	*white*	*black*	*tudu*	*faya*	*kwari*	*uniform soil*
1 Uncultivated	15.5	2.3	4.3	6.5	5.0	3.2	12.7	2.2
2 Long fallow >5 yrs	-	2.3	5.6	6.0[1]	-	-	7.5	2.0
3 Short fallow <3 yrs	15.0	-	-	-	-	2.2	-	-
4 Short cultivation 2-5 yrs	-	-	-	-	3.0	-	-	2.5
5 Long cultivated >19 yrs	-	5.6	4.5	12.5	-	3.0	3.0	6.5
6 LC+rotational manuring	15.2	-	4.2	-	-	2.8	-	-
7 LC+annual manuring	14.7	-	-	-	-	-	-	-
8 LC+inorganic fertilizers	11.3	-	-	-	-	-	-	-
9 LC+manure+IF	14.5	-	-	-	-	-	-	-
10 Continuous cassava	14.0	-	-	-	-	-	-	-
11 Irrigated farming	-	-	-	-	-	-	10.2	-
12 Moving dunes	-	-	-	-	2.0[2]	-	-	-

Notes:
1) 2 samples
2) 3 samples

TABLE 5.4.3(c)
Soils analytical results: percentage clay

Regime	Tumbau *all soils*	*red*	Dagaceri *white*	*black*	*tudu*	Kaska *faya*	*kwari*	Futchimiram *uniform soil*
1 Uncultivated	3.6	6.2	8.5	9.5	8.7	10.7	23.2	10.4
2 Long fallow >5 yrs	-	7.7	7.0	9.5[1]	-	-	14.5	10.5
3 Short fallow <3 yrs	2.0	-	-	-	-	9.5	-	-
4 Short cultivation 2-5 yrs	-	-	-	-	10.7	-	-	6.2
5 Long cultivated >19 yrs	-	10.7	5.7	8.0	-	9.5	9.2	5.4
6 LC+rotational manuring	1.7	-	5.7	-	-	9.0	-	-
7 LC+annual manuring	2.0	-	-	-	-	-	-	-
8 LC+inorganic fertilizers	1.2	-	-	-	-	-	-	-
9 LC+manure+IF	2.3	-	-	-	-	-	-	-
10 Continuous cassava	1.4	-	-	-	-	-	-	-
11 Irrigated farming	-	-	-	-	-	-	19.7	-
12 Moving dunes	-	-	-	-	7.8[2]	-	-	-

Notes:
1) 2 samples
2) 3 samples

Comparison of percent sand (Table 5.4.3(a)) and clay (Table 5.4.3(c)) in the control sites (Management 1) at the four locations shows a surprising trend - an increase in the clay fraction in upland soils from Tumbau to Futchimiram, with the single exception of the deep depression soils (*kwari*) at Kaska.

Inspection of the vertical columns in the tables shows that cultivation - and particularly intensive cultivation - tends to reduce clay and increase sand compared with control sites; but Dagaceri *red* and Kaska *tudu* provide exceptions to this rule.

There is little doubt that centuries of intensive cultivation have lowered the clay fraction in Tumbau soils; where the control site itself is subject to intensive use (wood cutting and grass harvesting), which affect its organic matter in the long run, to a greater extent than in the other sites.

However, what Tumbau soils have lost in clay, they have made up in higher silt fractions (Table 5.4.3(b)), with few exceptions, than in all the other soils - irrespective of management.

Evidently clay and silt complement one another with regard to available water holding capacity (Table 5.4.3(d)), where there is no general trend either along the ecological gradient or down the range of management regimes.

TABLE 5.4.3(d)
Soils analytical results: available water holding capacity

Regime	Tumbau *all soils*	Dagaceri *red*	Dagaceri *white*	Dagaceri *black*	Kaska *tudu*	Kaska *faya*	Kaska *kwari*	Futchimiram *uniform soil*
1 Uncultivated	16.7	12.5	18.7	23.8	13.0	15.2	16.7	16.6
2 Long fallow >5 yrs	-	15.0	11.2	10.0[1]	-	-	16.2	16.7
3 Short fallow <3 yrs	14.2	-	-	-	-	14.5	-	-
4 Short cultivation 2-5 yrs	-	-	-	-	13.0	-	-	14.7
5 Long cultivated >19 yrs	-	21.2	13.7	15.0	-	15.0	16.0	13.7
6 LC+rotational manuring	17.1	-	12.5	-	-	15.7	-	-
7 LC+annual manuring	16.7	-	-	-	-	-	-	-
8 LC+inorganic fertilizers	14.0	-	-	-	-	-	-	-
9 LC+manure+IF	15.0	-	-	-	-	-	-	-
10 Continuous cassava	16.4	-	-	-	-	-	-	-
11 Irrigated farming	-	-	-	-	-	-	19.0	-
12 Moving dunes	-	-	-	-	12.0[2]	-	-	-

Notes:
1) 2 samples
2) 3 samples

Soil pH

TABLE 5.4.3(e)
Soils analytical results: pH soil water

Regime	Tumbau *all soils*	Dagaceri *red*	Dagaceri *white*	Dagaceri *black*	Kaska *tudu*	Kaska *faya*	Kaska *kwari*	Futchimiram *uniform soil*
1 Uncultivated	5.7	5.6	6.4	5.7	7.2	6.5	7.5	6.4
2 Long fallow >5 yrs	-	5.7	6.4	5.9[1]	-	-	7.3	5.6
3 Short fallow <3 yrs	5.4	-	-	-	-	6.3	-	-
4 Short cultivation 2-5 yrs	-	-	-	-	6.9	-	-	5.7
5 Long cultivated >19 yrs	-	5.8	6.0	5.8	-	6.7	7.0	5.9
6 LC+rotational manuring	5.7	-	6.0	-	-	6.7	-	-
7 LC+annual manuring	6.3	-	-	-	-	-	-	-
8 LC+inorganic fertilizers	6.0	-	-	-	-	-	-	-
9 LC+manure+IF	6.0	-	-	-	-	-	-	-
10 Continuous cassava	6.0	-	-	-	-	-	-	-
11 Irrigated farming	-	-	-	-	-	-	7.3	-
12 Moving dunes	-	-	-	-	6.3[2]	-	-	-

Notes:
1) 2 samples
2) 3 samples

The extensive *white* soils of Dagaceri, *tudu* soils of Kaska, and soils of Futchimiram, all derived from stablised dune parent materials, lie midway in terms of acidity between, on the one hand, the more neutral soils of Tumbau and Dagaceri *black*, and on the other, the more acid *kwari* soils found in the deep depressions of Kaska. In Tumbau, the effect of cultivation is a small increase in soil acidity, but in Futchimiram, a small decrease. In the other sites, the differences are too small or erratic to support conclusions.

TABLE 5.4.3(f)
Soils analytical results: electrical conductivity (mmhos/cm)

Regime	Tumbau	Dagaceri				Kaska		Futchimiram
	all soils	*red*	*white*	*black*	*tudu*	*faya*	*kwari*	*uniform soil*
1 Uncultivated	0.04	0.01	0.01	0.01	0.01	0.01	0.02	0.01
2 Long fallow >5 yrs	-	0.01	0.01	0.01[1]	-	-	0.03	0.02
3 Short fallow <3 yrs	0.03	-	-	-	-	0.01	-	-
4 Short cultivation 2-5 yrs	-	-	-	-	0.01	-	-	0.01
5 Long cultivated >19 yrs	-	0.01	0.01	0.01	-	0.01	0.02	0.01
6 LC+rotational manuring	0.12	-	0.01	-	-	0.02	-	-
7 LC+annual manuring	0.07	-	-	-	-	-	-	-
8 LC+inorganic fertilizers	0.04	-	-	-	-	-	-	-
9 LC+manure+IF	0.08	-	-	-	-	-	-	-
10 Continuous cassava	0.08	-	-	-	-	-	-	-
11 Irrigated farming	-	-	-	-	-	-	0.53	-
12 Moving dunes	-	-	-	-	0.01[2]	-	-	-

Notes:
1) 2 samples
2) 3 samples

Tumbau soils, irrespective of management, have higher levels of electrical conductivity than those of the other sites (except for irrigated *kwari* soils in Kaska).

TABLE 5.4.3(g)
Soils analytical results: organic carbon (percent)

Regime	Tumbau	Dagaceri				Kaska		Futchimiram
	all soils	*red*	*white*	*black*	*tudu*	*faya*	*kwari*	*uniform soil*
1 Uncultivated	0.56	0.17	0.26	0.47	0.19	0.20	0.23	0.15
2 Long fallow >5 yrs	-	0.21	0.16	0.21[1]	-	-	0.85	0.13
3 Short fallow <3 yrs	0.27	-	-	-	-	0.14	-	-
4 Short cultivation 2-5 yrs	-	-	-	-	0.08	-	-	0.13
5 Long cultivated >19 yrs	-	0.14	0.14	0.32	-	0.22	0.11	0.11
6 LC+rotational manuring	0.69	-	0.27	-	-	0.17	-	-
7 LC+annual manuring	0.42	-	-	-	-	-	-	-
8 LC+inorganic fertilizers	0.26	-	-	-	-	-	-	-
9 LC+manure+IF	0.47	-	-	-	-	-	-	-
10 Continuous cassava	0.65	-	-	-	-	-	-	-
11 Irrigated farming	-	-	-	-	-	-	0.32	-
12 Moving dunes	-	-	-	-	0.06[2]	-	-	-

Notes:
1) 2 samples
2) 3 samples

A comparison of organic carbon in the soils of the control sites (Management 1) demonstrates an ecological gradient from Tumbau to Futchimiram very clearly, whether the three soils of Dagaceri and of Kaska are each averaged, or the key soils, Dagaceri *white* and Kaska *faya*, are considered alone to represent those sites. This essential indicator of Sahelian productive potential thus conforms with expectation based on average rainfall.

Examination of the effects of management on each soil type is also instructive. In Tumbau, manuring on long cultivated land (Management 6) is capable of maintaining or improving the organic carbon content of uncultivated soil (Management 1), but inorganic fertiliser alone (Management 7) is not. Short fallow (Management 3) is associated with a deterioration. This is because fallows, under this intensive system, are not a strategy for soil recuperation but rather the result of insufficient capital or inputs to bring abandoned land back into use; such land is heavily grazed or cut over, removing rather than restoring nutrients.

In Dagaceri, the striking feature is the apparent ineffectiveness of fallowing (Management 2) in restoring organic carbon content after long cultivation (Management 5), when compared with manuring (Management 6). The *red* soils are different, but start at a lower level. This system, however, makes extensive use of fallows, unlike that of Tumbau, though the ambivalent status of fallows (soil recuperation versus lack of working capital) has also been observed there.

The lowest levels of organic carbon are found in the *tudu* soils of Kaska after cultivation for several years (Management 4), which decline close to those of moving dunes; on the one hand this appears to suggest fragility, but on the other, it is quite possible to grow crops in moving dunes if the rainfall is sufficient to stabilise the surface and supply the plants! In Kaska, too, long cultivation (Management 5) need not degrade *faya* soils.

In Futchimiram, the effect of cultivation on soil organic carbon is straitforwardly negative. But no significant soil amelioration is practised in a system which relies on long recuperative fallows.

Nitrogen

TABLE 5.4.3(h)
Soils analytical results: total nitrogen (percent)

Regime	Tumbau		Dagaceri			Kaska		Futchimiram
	all soils	*red*	*white*	*black*	*tudu*	*faya*	*kwari*	*uniform soil*
1 Uncultivated	0.024	0.039	0.084	0.030	0.049	0.072	0.076	0.025
2 Long fallow >5 yrs	-	0.037	0.052	0.020[1]	-	-	0.061	0.045
3 Short fallow <3 yrs	0.024	-	-	-	-	0.073	-	-
4 Short cultivation 2-5 yrs	-	-	-	-	0.054	-	-	0.086
5 Long cultivated >19 yrs	-	0.020	0.021	0.023	-	0.077	0.073	0.027
6 LC+rotational manuring	0.027	-	0.041	-	-	0.080	-	-
7 LC+annual manuring	0.031	-	-	-	-	-	-	-
8 LC+inorganic fertilizers	0.042	-	-	-	-	-	-	-
9 LC+manure+IF	0.024	-	-	-	-	-	-	-
10 Continuous cassava	0.024	-	-	-	-	-	-	-
11 Irrigated farming	-	-	-	-	-	-	0.087	-
12 Moving dunes	-	-	-	-	0.022[2]	-	-	-

Notes:
1) 2 samples
2) 3 samples

Total nitrogen is lower in the control soils (Management 1) of Tumbau than in any other site except Futchimiram.

The more remarkable observation from this table is the opposite effects of cultivation on nitrogen levels in Tumbau, Kaska, and Futchimiram, on the one hand, and in Dagaceri on the other. In the first group, there is no evidence that cultivation, with or without manuring (Managements 5-7, 9-10), affects nitrogen levels adversely, though inorganic fertilizers (Management 8) - unsurprisingly - double them in Tumbau. In Dagaceri, however, uniform decline occurs in nitrogen levels through long fallow (Management 2) to long cultivation (Management 5), only reversed with manuring (Management 6).

But absolute levels in Tumbau and Futchimiram are very low - comparable to those of moving dunes (Management 12) in Kaska. Does a level of around 0.020% represent a floor below which further deterioration is unlikely to occur? If so, how does the intensive system of Tumbau maintain its economic output at such low levels?

Phosphorus

TABLE 5.4.3(i)
Soils analytical results: available phosphorus (ppm)

Regime	Tumbau *all soils*	Dagaceri *red*	*white*	*black*	*tudu*	Kaska *faya*	*kwari*	Futchimiram *uniform soil*
1 Uncultivated	1.57	16.02	18.19	19.56	16.69	18.83	20.24	18.26
2 Long fallow >5 yrs	-	18.24	15.39	18.08[1]	-	-	19.13	19.05
3 Short fallow <3 yrs	1.34	-	-	-	-	19.54	-	-
4 Short cultivation 2-5 yrs	-	-	-	-	16.89	-	-	17.76
5 Long cultivated >19 yrs	-	17.48	16.56	14.56	-	18.17	17.56	15.69
6 LC+rotational manuring	4.70	-	16.06	-	-	20.61	-	-
7 LC+annual manuring	3.58	-	-	-	-	-	-	-
8 LC+inorganic fertilizers	0.87	-	-	-	-	-	-	-
9 LC+manure+IF	4.26	-	-	-	-	-	-	-
10 Continuous cassava	2.46	-	-	-	-	-	-	-
11 Irrigated farming	-	-	-	-	-	-	21.33	-
12 Moving dunes	-	-	-	-	16.90	-	-	-

Notes:

1) 2 samples
2) 3 samples
3) The first column of figures was obtained using a different method from the remaining columns (Bray I), and so cross-comparisons should not be made with the other columns. Comparisons between rows can be made. Using Bray I, Harris and Bache (1995: Table 2) obtained an average of 27.83 pmm from 12 samples from fields corresponding to Managements 6-9.

With nitrogen, phosphorus scarcity is considered to be a major constraint on agricultural productivity in the Sahel; unlike nitrogen, it cannot be replenished from the atmosphere by leguminous plants. Using Harris and Bache's figure of 27.83 pmm for Tumbau farms (see Note to Table), it is apparent that Tumbau soils under cultivation are substantially richer in phosphorus than those of all other sites, and this can be put down to fertilization under intensive farming. The soils of the control sites (Management 1) are also below this level. It appears, therefore, that successful phosphorus management has something to do with the economic productivity of this system.

From the first column of figures for Tumbau, the pronounced effect of using manure (Managements 6, 7 and 9) is apparent. The low figure for inorganic fertilizers is anomalous, as most types contain P.

Among the remaining soils, Dagaceri *black*, Kaska *kwari* and Futchimiram soils show a negative effect of cultivation on phosphorus levels, but the major upland soils in Dagaceri (*red* and *white*) and Kaska (*tudu* and *faya*) do not.

5.4.4 Farmers' Management of Soil Fertility

Fallows

As mentioned in the previous section, fallow in the Tumbau system has become a residual category resulting from a scarcity of the other factors of production, and only one or two small patches were observed in the study area. In Dagaceri, where fallow fields and fallow patches in cultivated fields are very common, twice as many farmers explain them in terms of labour shortage than in terms of fertility recuperation. As we proceed down our gradient of intensity, however, attitudes change. In Kaska, twice as many farmers regard fallows in terms of fertility recuperation than of labour shortage, and in Futchimiram, all fallowing is for fertility recuperation which is marked by the appearance of plant indicators. Access to hired tractors in Dagaceri tends to reduce the proportion of fallow; in Kaska and Futchimiram such access has not been significant before now.

Almost all land in Tumbau is cultivated every year; in Dagaceri, a ring of fields around the village up to a distance of about 1 km has attained this status; in Kaska, annual cultivation has been maintained on the *faya* soils in the intermediate depressions for as long as 50 years on one farm where manure is available; in Futchimiram there is a distinction between home farms under annual cultivation, where low fertility is a constant complaint, and bush fields under shifting cultivation.

Residue management

Residues may be burnt in the fields during the late dry season. In Tumbau, few are left after fodder and construction material has been removed, and burning is regarded merely as a clearing operation. In Kaska, by contrast, the quantity produced exceeds the transport capacity and much is burnt, both to improve fertility and to clear the farm for planting.

Likewise, Tumbau farmers have no residues to incorporate into the soil in the following season, while Kaska farmers regard incorporation as an impediment to weeding. In Dagaceri, however, some farmers regard it as soil improving, and also approve of residues breaking down by termite action.

Manure making

Only in Tumbau is manure-making a necessary activity for every household, provided it owns animals (see also Harris, 1996). Pen droppings, ash, weeds, straw, shrub foliage and compound sweepings are collected and brought to the compost, which is then redistributed to the fields. Farmers are aware of the residual effects of manure and consider that manuring once every two years is adequate, though if supply is unconstrained, they do it every year. The season for manuring is in the mid- or late dry season, though application to plants is often delayed until they have established themselves. Hiring labour for manuring is known in Tumbau, when the rain approaches.

Manure-making is much less common in Dagaceri, partly because not all households have animals, and partly because of the shortage of transport to much more distant fields. Communal rubbish tips on the edges of the village provide compost which can be removed by anyone (Harris, 1997). The lower priority given to manuring is explained by the availability of fallowing as an alternative. In Kaska and Futchimiram, noone makes manure, though the benefits of 'night parking' of livestock are appreciated.

Thus insufficient animals, labour, or transport, and the availability of the option of fallowing, constrain manure production and use. As the farming system becomes more intensive, the last three of these constraints tend to diminish in force. The first, contrary to some expectations, is also reduced, as livestock populations (in weighted livestock units as well as numbers) increase with human population densities.

Inorganic fertilizers
Experience with these diminishes from Tumbau to Futchimiram. Beneficial yield affects are recognised. At Tumbau, all farmers gave capital shortage as the main constraint on their use; in Dagaceri, most did so; in Kaska, soil moisture was regarded as of equal importance. Everyone knows that to use fertilizers when moisture is deficient is to induce vegetative growth at the expense of the economic crop. Organic manure, as well as being more benign in this respect, is regarded as having a longer-lasting residual effect in Tumbau.

Such is the importance that the distribution of inorganic fertilizers has acquired in the political economy of agriculture in northern Nigeria, that there is no doubt that improved access to it would increase its use. In view of the doubts about both economic and ecological sustainability in farming systems heavily dependent on fertilizers, the reduced access to them since the 1980s may not be a bad thing. However, though scarcity has added value and incentives to making and using organic manure, especially in Tumbau (see Mortimore, Essiet and Patrick, 1990), privileged access to fertilizers by wealthier farmers intensifies economic inequality.

Soil and water conservation
Surface run-off is limited by low slopes and high porosity of soils; however in Tumbau, capping can occur and heavy rain may flow off destructively. Ridging is the main way of controlling runoff, though its purpose is both to *retain* water for crop use and to provide dry sites for seedlings. Weeding after rain increases soil water percolation.

In Dagaceri, the *red* soils are more prone to runoff than the *white*, which are highly porous. In Kaska, the floors of the depressions may cap badly, but as there is nowhere for the water to run to, it does little damage. In all three drier villages, the behaviour of soil water in the profile is considered important. Although the surface of sandy soils quickly dries out, after rain the moist horizon moves slowly down through the profile and can be reached by the growing roots of crops, enabling them to survive dry spells of ten days or more; whereas heavier soils dry hard, and pose a greater risk. Sandy soils are thus regarded, paradoxically, as retaining more moisture.

Legumes
Although cowpeas are intercropped with grains in all villages, no farmers see any concurrent benefit to the performance of the grain, except indirectly through the suppression of weeds.

Groundnuts, where they are grown intercropped, also suppress weeds, but are not seen as otherwise beneficial to the grain (though in Tumbau a view was expressed that the soil needs less manuring where groundnuts are intercropped). However, the value of rotations for fertility improvement is recognised, both in Tumbau, where continuous cropping of grains without rotation 'kills the soil and will lead to low yield', and in Futchimiram, where patches of closely-spaced groundnuts are regularly moved around the farm.

Intercropping increases economic yield per hectare, reduces weeding labour, and can protect cowpea from insect pests.

The advantages of growing trees on farms are generally recognised. They provide browse for small ruminants which fertilize the soil with their droppings (especially noted in Tumbau), fertilize the soil through leaf fall (especially noted in Dagaceri), reduce wind speed (Dagaceri), assist soil moisture retention, and provide shade for delicate seedlings (e.g. tomato, onion). (An inventory of multipurpose trees in Dagaceri is provided in Mohammed, 1994.) The only negative property of trees is as nesting sites or perches for bird pests, especially noted in Kaska and Futchimiram, where pollarding removes the branches before the season starts.

5.4.5 Farmers' Management of Fodder Resources

It follows from the recognition given to manure, and its increasing importance along the intensification gradient, that maximising the livestock population and integrating animal production with crop production are implicit necessities in the medium term. However, the value of livestock as capital assets is likely to be given more prominent recognition by households in their livelihood strategies.

Common access fodder resources have often been blamed for inducing overstocking in Sahelian systems. Certainly, our interviews failed to find any connection between households' decisions (or ambitions) to acquire animals and the availability of feed. The principal limiting factor on the livestock holding of any household is normally considered to be its capital resources for buying animals (not many farming households are serious breeders, though Ful'be farming families breed animals as a priority).

The reality of the capital constraint - rather than that of feed - is borne out by the observed fact that livestock populations grow with the human population. This is not to deny that *at times* the livestock population exceeds feed supply and there is starvation and increased mortality. Drought episodes, however, only intensify efforts to restock. The long term demographics of livestock give a better guide to what is happening than appearances during a crisis. Notwithstanding the serious deficiencies of livestock population data in northern Nigeria, there is no evidence of decline, and much evidence of increase, from decade to decade in every part of the area. The growth of small ruminant populations is particularly obvious even though statistics are worse than those for cattle.

Along our rising population density gradient, an increasing scarcity of common access grazing land is associated with the privatisation, not only of farm land, but of fodder resources. Far from being destroyed through uncontrolled exploitation, as the desertification scenario would have it, the biomass is supporting increasing numbers and densities of livestock. This accords a high profile to the question of how biomass is being managed and how sustainably.

Buying and selling

In the three drier villages, virtually all households will buy more animals if they have enough money. They are owned by individuals including women and children, and regarded as investments. All will sell if there is a pressing need for cash, e.g. for sickness, a marriage or payment of a fine. The peak selling times are before the religious festivals of Id-el-Kabir and Christmas, when the national market is buoyant, and a favourite times for buying is immediately afterwards, when prices are lower. Given the small quantities of capital available, small ruminants are more accessible than cattle, and have the advantages of easier management and faster growth to marketable weight. Animals may sometimes be sold (in Dagaceri at least) in the late dry season, in order to finance farming inputs (there is much contract ploughing in this village). Not many farmers - only one in six in Kaska, though possibly more in Futchimiram - breed animals.

Thus the livestock economy is, for most farming households, an investment and fattening system, dependent on markets for the supply of animals, and on seasonal price movements for profits. Milk may produce a recurrent income. In Tumbau, the recent popularisation of ox-ploughing has been integrated with these basic objectives. Farmers will import young bulls, train them, fatten them, and use them for farm energy for a few years, and then sell the animals in prime condition before starting again. Any plough team owner relies on contract ploughing to supplement his own requirements and help finance the venture. In Dagaceri and Kaska, the use of bulls for drawing carts is as important as for ploughing, as it generates an income throughout the year. The system depends on breeders supplying the market with animals, and the Ful'be are prominent. In Futchimiram, where Badowoi farmers own cattle as well as small ruminants, breeding is more common than among the Manga farmers of Kaska and Dagaceri, and there the market is also critically important (Geidam, the capital of the Local Government Area, has the most famous cattle market in northern Nigeria).

This commercial livestock system (which has only been outlined here) interfaces with fodder resources which fluctuate seasonally and annually with the rainfall, and is to an important extent premissed on the principle of common access. The entry of fodder into the market, which is a consequence of increasing privatisation, is transforming the system. Willingness to purchase feed when common access fodder ceases to be available is a measure of commitment to animals. Interviews suggested that Dagaceri farmers are more willing to sell animals when fodder is scarce, whereas Kaska and Futchimiram farmers said they would buy fodder. But obviously, prices influence such decisions, and it is common enough to sell one animal in order to feed the rest.

Ranking fodders

In terms of value to the animals, groups of informants in the villages ranked the main fodder sources in 1995-96 as follows:

	TUM	DAG	KAS	FUT
Free grazing	5	2	1	1
Groundnut and cowpea residues	3	3	2	3
Grain residues	2	4	5	2
Grass/herbage cut and carried	1	1	3	5
Tree browse	4	5	4	4

The rankings given to free grazing and to cut-and-carry reflect the relative abundance of rangeland and farmland/fallow in the four systems.

Ranking fodder supply on one variable, however, oversimplifies. In Kaska, a ranking of primary (natural grassland), secondary (residues) and tertiary (processed feeds) fodder in terms of quality, quantity and ease of access and continuity of supply gave the following result (Ibrahim, 1997):

	Quality	Quantity	Access	Continuity
Primary fodder	2	1	1	2
Secondary fodder	1	2	2	3
Tertiary fodder	3	3	3	1

Note: The ranking was based on ten expert interviews.

Feed supply

There are (a) seasonal, (b) animal specific, (c) management and (d) market aspects to this question.

During a normal wet season, natural grazings and (on farmland) weeds are more than enough. Access to these sources is a matter of management (below) rather than supply.

Crop residues are the most preferred feed for livestock (in quality, cowpea and groundnut haulms, and in quantity, millet stalks/leaves). Grazing management therefore focuses on these as soon as they are available, usually by common agreement when animals are released into the fields after harvest. Grassland is left until they have been fully used. The privatisation of residues (more or less complete in Tumbau, Dagaceri and Futchimiram) provides the most direct linkage between livestock population and household landholdings in these systems, as there are really no private grazings (access to scattered fallows cannot be controlled).

The animals may return to the common access rangeland, therefore, when it is well past its prime. The well known late dry season scarcity of natural grazings varies in intensity from year to year, and can only be guarded against to a limited extent by storing fodder or cutting browse. It is perceived as the major feeding problem in Dagaceri and in Kaska, where there are both spatial and temporal limits to the supply. In Tumbau, where rangeland has long disappeared, stored fodder or browse are the only alternatives to the market at this time of the year. But in Futchimiram, where large cattle herds are kept throughout the year in open parkland with annual grasses, informants tend to play down seasonal scarcity as a problem.

Sheep and cattle are more vulnerable to fodder scarcity than goats, but are more valuable. The assignment of priorities to species at times of scarcity can therefore an elaborate system of trade-off. Cattle (work bulls in particular) always come first where they are kept; sheep a close second; and donkeys last.

The management issue is that of labour. In Tumbau, much labour (noted in 5.3) is spent on carrying fodder to penned livestock during the rainy season, but in the dry they roam unrestricted and need less attention. In the other villages, management is also a problem during the wet season, but for a different reason: animals have to be kept off cropland; where village herds of small ruminants are supervised collectively, the labour needed is minimised (Dagaceri and Kaska), but where cattle as well are involved and it is done on a family basis, labour needs are more problematic (Futchimiram). Horses are essential to every household in Futchimiram, where women as well as men use them regularly, followed by Kaska, and are least important in Tumbau, where in the absence of grassland, they are costly to keep.

Finally, the entry of the market into fodder supply through, for example, the bundling and sale of grass from private fallows by Manga to Ful'be in Dagaceri, or restrictions on access to crop residues, or browse, is governed by the scarcity of open grazing which in turn depends on the rainfall in any year. Violent fluctuations, not only in prices, but in levels of market participation, therefore characterise the commercialisation of livestock keeping.

5.4.6 Biomass Management under Land Use Change

The land cover data for the four study areas, reported in 5.1.4, provides a basis for estimating the quantitative changes in biomass that have accompanied land use change over the past 47 years. This is important for two reasons:

- the desertification scenario of biomass degradation needs testing against the productivity achievements of increasingly intensive land use systems, which are feeding both people and animals, and
- the equation between biomass used for supporting livestock and that for other economic purposes needs looking at in the light of the role of livestock in supporting, through crop-livestock integration, the intensification of agriculture.

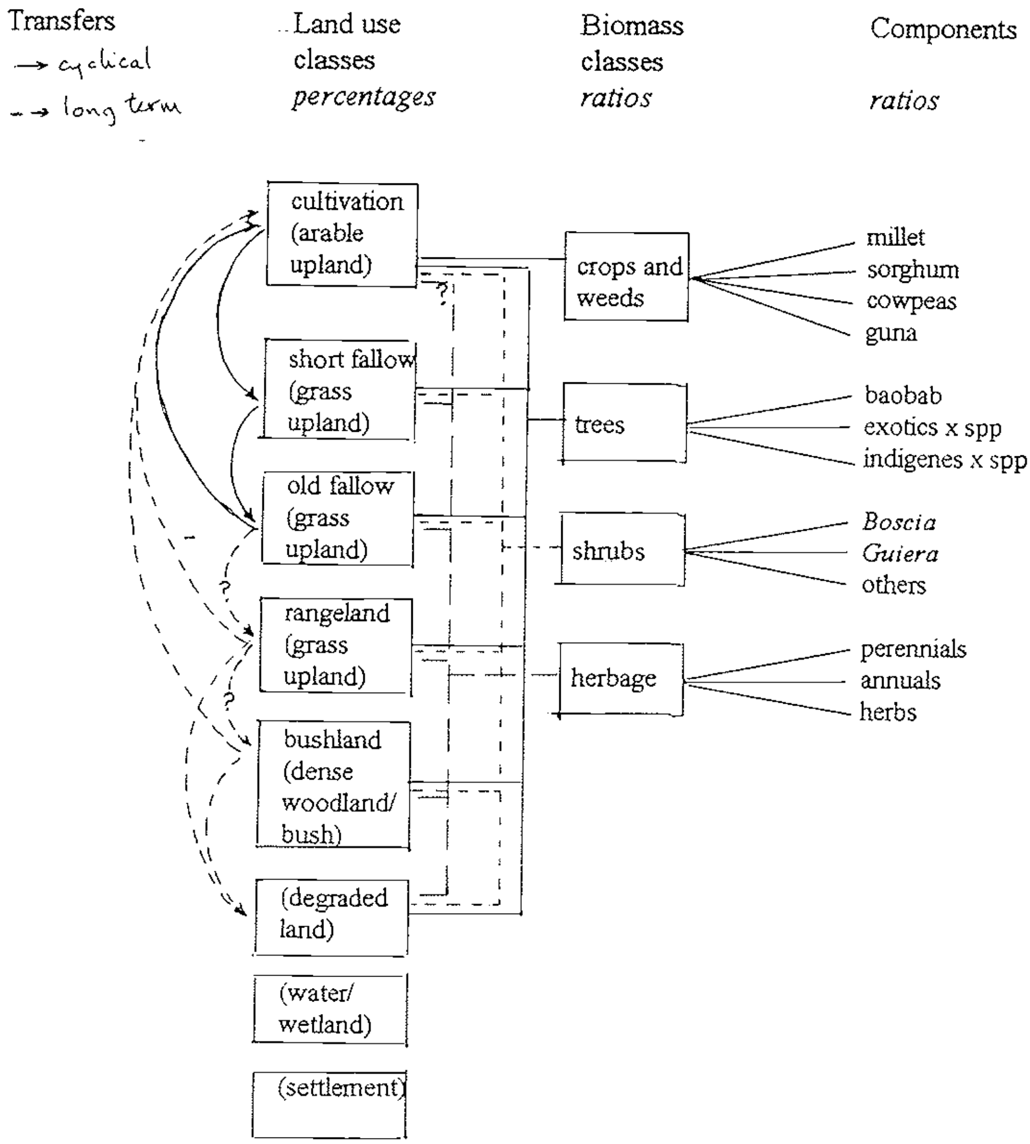
Data collection on biomass, which was scheduled for 1996, was prevented by the premature termination of fieldwork. In collaboration with the NRI project R 6603, a scaled down attempt is in progress to operationalise in Dagaceri the model shown in Figure 5.4.6.

The land cover classes (Section 5.1.4) are the basis of the model, expressed as percentages of the total surface. Each of these classes contains a varying mix (expressed as a ratio) of the four biomass classes, crops/weeds, trees, shrubs, and herbage. These classes require biomass estimates based in turn on their separate components, for which some measurements are available either from fieldwork or by proxy from literature.

Transfers over time from one land cover class to another are shown as curves on the left-hand side of the model. If the biomass components can be quantified, the implications of these transfers can be estimated, and the scenario of management-led degradation can be tested.

FIGURE 5.4.6

A model for estimating the effect of land use change on biomass productivity, Dagaceri.



5.5 Cultivar Diversity and Management

In this Section, we report on (a) inventorying of cultivated plants in the four villages; (b) investigations of genetic diversity in cultivated pearl millets; (c) the seed input-output experiment in Dagaceri; and (d) relevant aspects of seed and cultivar management by the farmers.

5.5.1 Inventorying work.

Farmers recognise types of cultivars at two levels: inter-specific and intra-specific. The first level presents no problems as the distinctions they make coincide with taxonomic categories. However, the second level distinctions made by farmers do not necessarily derive from genetically significant differences, nor are they necessarily applied consistently from place to place or from year to year. The names (which of course, use local languages) are assigned on the basis of observed morphological and phenological characteristics, and known origin (associations with places, persons, or extension organisations). Any collection made in the field may reveal a considerable diversity within a named type, especially where cereal grains are concerned. Deciding equivalences between similar types having different names or differing types having similar names is only possible in an approximate sense, given the diversity in both observed (morphological or phenological) characters and their genetic base. The concept of 'inventory' with which this project started out - relying on indigenous taxonomies and terms - therefore has a rather limited value. It is not clear that the terms 'landrace' 'variety' or 'cultivar' are appropriate. Bunting and Pickersgill (1996) have suggested 'population', but to retain our emphasis on indigenous taxonomic perceptions, we use the general word 'type'.

Inventories were compiled in each village during Phase I of this project and the numbers of cultivars and types recorded are given in Table 5.5.1(a). These inventories were based on group interviews carried out during the harvest season, and discussions were based on specimens brought in by farmers. As the object of the excercise was known to be to achieve the most comprehensive inventory possible in each place, the farmers as well as the interviewers emphasised incremental information rather than analytical discussion of the types already identified. Had the extent of diversity within types been appreciated at the start, a different approach might have been adopted. The inventories were revised up till the end of the project.

The inventory includes information on the following characters for each cultivar and type:

- name(s) in local languages
- growing time to maturity
- source (geographical origin, person or extension agency responsible, etc..)
- popularity rating, and historical trend
- morphological characteristics (colour, size, etc..)
- pest resistance
- fertilizer response
- drought resistance
- food processing characteristics, taste
- fodder value
- market popularity
- soil restrictions

These characters are recorded in terms of farmers' qualitative perceptions.

TABLE 5.5.1(a)
Numbers of cultivar types identified in four villages

Cultivars	TUM	DAG	KAS	FUT
<u>Cereals</u>				
Pearl millet (*Pennisetum glaucum* subsp. *Americanum*, syn. *P. typhoides*)	12	7	6	3
Sorghum (*Sorghum vulgare*)	22	18	13	6
Benniseed (*Sesamum indicum*)	1	2	2	0
Maize (*Zea maiz)*	1	1	1	0
Rice	1	0	0	0
Wheat	(1)	0	1	0
<u>Beans</u>				
Cowpea (*Vigna ungulensis*)	9	6	9	7
Soya	0	0	1	0
<u>Earth nuts</u>				
Groundnut (*Arachis hypogaea*)	5	2	0	4
Bambara groundnut	3	4	1	1
<u>Roots</u>				
Cassava	4	0	3	0
Sweet potato	2	0	1	0
<u>Melons</u>				
'Cow melon' (*guna*)	0	2	4	0
Pumpkin	0	0	1	0
Water melon	0	1	1	0
Melon	0	0	1	0
<u>Peppers</u>	5	0	1	0
<u>Vegetables</u>				
Sorrel	3	2	2	1
Okro	1	2	1	1
Onion	1	0	1	0
Tomato	1	0	2	0
Karkashi	(1)	1	(1)	0
<u>Sugar cane</u>	1	0	1	0
<u>Industrial crops</u>				
Hemp (*rama*)	2	0	0	0
Cotton	0	0	1	0
Total	76	48	55	23

Notes: (1) No local record, but well known in the region
Sources: Chiroma (1997); Ibrahim (1997); Mohammed (1997); Yusuf (1997); field books and integrated project inventories.

A preliminary review of these data indicates that:

- There is a positive correlation between ecology and diversity. Tumbau is the richest and Futchimiram the poorest in terms of the domesticated biodiversity available. However, this is not merely a function of rainfall. Tumbau and Kaska have lowland soils where dry season cultivation, with or without irrigation, is possible. Wheat (*not* rice), several vegetables, some melons and sugar cane depend on such soils in Tumbau. Kaska is able to buck the ecological trend with its lowlands, where maize, wheat, soya, some melons, roots, peppers, some vegetables, sugar and cotton can be grown in small quantities.

- There is a positive correlation between rainfall and the numbers of millet and sorghum types available, but significantly, not with numbers of rainfed cowpea and groundnut types, which are comparable in Tumbau and the drier villages.
- The numbers of cultivars being maintained in these systems is testimony to the advantages of diversity for smallholders with a subsistence priority, and the weak development of market-based specialisation using comparative advantage. However the numbers of types held in the portfolio gives no indication of their relative importance in production either for domestic use or for the market.
- Qualitative indicators of the popularity of types suggest that a small percentage of them provide the greater part of output. For those crops (millet, sorghum, cowpea) having the largest numbers of types available, this raises the question, how and why do farmers maintain seed stocks from year to year for types that are rarely used? The fact that these stocks are maintained argues for a high value placed on domesticated biodiversity as a resource. This supposition is supported by the variable adaptation of types to rainfall and soil moisture conditions, themselves highly variable in space and time.
- An additional dimension to understanding diversity in crop inventories is the position of farming in the household economy. In Futchimiram, livestock including cattle play a larger role in household economies, and unlike Tumbau, where small ruminants may be said to support the cropping system through a high degree of integration, in this system cropping supports livestock by supplying residues at a lower level of integration. The smaller level of diversity in the cropping portfolio of Futchimiram reflects, to an extent that is not easy to assess, a different pattern of economic specialisation.

This work on cultivated plants was supplemented by a special study of multipurpose trees, shrubs and grasses in Dagaceri, carried out in Phase I (Mohammed, 1994).

5.5.2 Genetic Diversity in Pearl Millet

Pearl millet is the staple grain in all four villages, though in Tumbau its position is contested by sorghum whereas in Futchimiram sorghum is grown very little. Work on the genetic mapping of pearl millet is well advanced at the John Innes Institute. Given the known phenotypic diversity of the millets grown by these and other Sahelian farmers (Wilson *et al.*, 1990), investigation of the genetic basis of diversity can be expected to improve understanding of millet domestication and seed management and the possibilities for its improvement.

Three types of millet were selected for study, and Dagaceri village was adopted for the experiment, with supplementary sampling from Kaska (90 km NE of Dagaceri) to test for inter-village effects. The three types were:

- *badenji*, a standard early type originating in the region; seed selected from each year's crop;
- *dan arba'in*, a very early type introduced within the last 20 years; seed selected; and
- *lafsir*, a hairy local wild or hybrid type, not selected, but appearing randomly in the crop.

The sample design stratified collected millet material by village, farmer and farmer's field, and landrace or type as shown in Table 5.5.2.

TABLE 5.5.2
Plant material sample design

Village	Farmer	No. fields	Types/farmer	Method of collection
Dagaceri	Kwaire	3	Badenji, Dan arba'in, Lafsir	Systematic
	Mallum	3	Badenji, Dan arba'in, Lafsir	sampling
	Nakuri	3	Badenji, Dan arba'in, Lafsir	in field[1]
Kaska	Bagari	1	Lafsir	Provided
	Bujinji	1	Dan arba'in	by the
	Bakwato	1	Badenji	farmer

Notes: 1. Samples were collected from one stand in ten, and from one plant (spike) per stand. Three types were collected from each of three fields. Four spikes per type were selected for analysis of six grains from each spike.

The laboratory methods used for the genetic analysis of the sample material at the John Innes Institute are described in **Annex 8**. Principal components analysis was carried out on the data. The first principal component accounted for 10.7% of the variance, and the first two for 15.9%; 45% of 163 principal components accounted for 90% of the variance. The PC 1 ('farmer-landrace interaction') and PC 2 ('farmer') are plotted on two axes in Figure 5.5.2.

The key inferences drawn from the analysis of the data are that

- there are large differences between different farmers' stocks of landraces having the same name; this casts doubt on the genetic identity of named types;
- a group of different landraces grown by one farmer has a greater identity than the same landrace grown by different farmers, even within the same village;
- the differences between populations of the same landrace in nearby fields in the same village can be as great as those between villages 90 km apart;
- the internal variances within the landrace populations grown by different farmers are all of the same order of magnitude, irrespective of origin, selection or characters;
- each farmer appears to manage a genetic pool, notwithstanding the known importance of millet outcrossing both between adjacent fields and between domesticated and wild types.

Annex 8 (Busso *et al.*, forthcoming) provides a detailed account of the methodology and findings. These results have yet to be reviewed in the context of other work on pearl millet diversity, domestication and breeding in the Sahel.

5.5.3 The seed input-output study in Dagaceri

Three factors are known to contribute to the genetic diversity of millet crops under these conditions:

- accidental mixing of seed at source,
- outcrossing with plants in neighbouring fields, and wild or hybrid plants, and
- genetic diversity.

A controlled study was carried out to determine the progeny of seed of known origin on farmers' fields. By eliminating the effects of accidental seed mixing, and assessing the likelihood of outcrossing, it was hoped to evaluate the impact of genetic diversity in terms of the farmers' own taxonomic criteria. Four farmers took part in the experiment and each provided a 10 x 10 m quadrat on one of his farms. Table 5.5.3 summarises the results, which are recorded in greater detail in Mohammed (1996).

TABLE 5.5.3

Results of the seed input-output study (1996)

Farmer:	Kwaire	Mallum	Nakuri	Bakale
1 Crop mixture	M+S+B	M+C	M+S+C+B	M+S+C
2 Millet stands/ha	2,700	3,200	3,600	2,700
3 Planting	wet	wet	dry + wet wet	
4 Grown stems/stand	6.8	7.3	6.0	7.9
5 Grown stems/ha	18,400	23,500	21,600	21,400
6 Grown stems/100 m^2 quadrat	184	235	216	214
7 Millet type planted	Fudewuwa (=Dan arba'in)	Fudewuwa (=Dan arba'in)	Badenji	Idon hawainiya (=Wame)
8 Source of seed	Selected for sowing from granary. Unmixed stock resown for 5 yrs.	Selected for sowing from granary.	Selected by sister from husband's field, at harvest time.	Selected from field at harvest time, favouring yellow colour
9 Seed storage	Granary, unthreshed, untreated.	Granary, unthreshed, untreated	Bowl in house, threshed, bundle, untreated.	Granary, in a unthreshed, untreated.
10 Seed progeny (percentage of grown stems/100 m^2 quadrat):				
Fudewuwa	95.6	89.8 (2.5)	0	10.7 (0.5)
Badenji	0	0	93.0	0
Idon hawainiya	1.1	8.9 (2.1)	0.9	78.5 (2.8)
Lafsir	1.1	0	0.5	2.8
Chilum	1.6	0.8	2.8	0.5
Shura	0.5 (0.5)	0.4 (0.4)	2.8	3.8 (3.8)
11 Distance to neighbour's field, W and crop mixture	3 m: M+S	64 m: M+S+C (Fudewuwa)	2 m: M+S+C (Badenji)	54 m: fallow
12 Distance to neighbour's field, E and crop mixture	37 m: S+B	87 m: grass/ shrubland	32 m: M+S+C (Fudewuwa)	27 m: M+S+C (Badenji)

Explanation of rows

1 M = early millet, S = sorghum, C = cowpea, B = benniseed. **Bold** = main.

2 A stand is a pocket into which a handful of seed is thrown and buried; it may be thinned during weeding operations. Per ha populations projected from quadrat counts.

3 Dry planting is done in anticipation of rain; wet planting after rain. Nakuri replanted as the first failed to germinate.

4,5,6 A 'grown stem' is one from which one or more heads grew to maturity. Per ha populations projected from quadrat counts.

7 *Badenji* is standard early (55 days to ear emergence, 70 days to flowering); *Fudewuwa* is an introduced fast maturing type (40 days to ear emergence and 60 days to flowering); *Idon hawainiya* is intermediate (45-50 days to ear emergence, 65 days to flowering).

10 The numbers in brackets indicate the percentages of twinned or multiple headed stems. *Lafsir* and *Chilum* are types that appear unpredictably and are identified by their long black hairs and red colour, respectively. They are never selected or planted intentionally. *Shura* is the name given to hybrid or wild, almost always multiple-headed, stems. The seed is edible and the heads are harvested by women in some places. *Fudewuwa* and *Idon hawainiya* are subject to occasional twinning, but multiple heads are usually restricted to *Shura*.

11,12 The prevailing wind direction during the growing season is west or south-west, but before and during storms, there are fresh or strong easterly winds.

The experiment was not expected to produce conclusive results. However there are some inferences which suggest lines for further investigation:

- The two quadrats on farms adjacent to grassland (Mallum and Bakale) contained all but one of the twinned or multiple headed stems recorded. Multiple heading is normally associated with *shura* which is understood by farmers to be a degenerative form. Twinning is not selected for because it assures no improvement in grain yield over single, fatter heads. The possibility arises of outcrossing with wild relatives in the grassland, or with volunteers of other types self-seeded in fallow (see *Fudewuwa* on Bakale's farm), but only if the seed used was selected from these fields.
- Proximity to another field of millet is general and this establishes the likelihood of outcrossing from year to year although, of course, it does not affect the crop in the current year. To investigate this further it would be necessary to select seed from the same field and follow it through more than one generation.
- *Badenji* never twins and never appears where it was not planted. Where it was planted (Nakuri), it produced the second highest 'success rate' (93%). *Badenji* is an introduced type
- *Fudewuwa*, which is popular because of its fast maturing, is more prone to twinning and more likely to turn up uninvited than *Badenji*.
- The highest 'success rate' (95.6%) was achieved where seed had been repeatedly selected from progeny of a base stock acquired about five years earlier. It is implied that on the other farms used in the experiment, seed used had a more mixed ancestry.
- *Idon hawainiya* acquires its identity from its characteristic mixture of yellow and grey/green grains, which occurs unpredictably (10.7% of stems on Mallum's quadrat), whereas the other types have uniform grey, green or reddish (Chilum) grains. Bakale selected for yellow seed, and thus was trying to breed a domesticate from a randomly occurring character. His difficulty in achieving this is indicated by his low 'success rate' (78.5%) and the larger number of interlopers on his quadrat.
- It does not appear that time of selection (harvest or sowing) or method of storage had any effect on seed progeny.

Speculative as they are, these inferences provide support for a view of farmers as purposive (and , in view of the ease of outcrossing in millet, highly succesful) managers of genetic resources. They understand the fact, though not the mechanism, of outcrossing ('male' and 'female' plants are thought to interact unobserved during the night).

5.5.4 Farmers' Seed Management

This section summarises qualitative data on millet seed management from farmers in all four villages, which was collected in order to investigate several hypotheses.

Seed reservation
In all villages, farmers normally select and reserve seed every year, and the normal time for doing this is after harvest when the grain is being stored. Unless no seed is available on account of harvest failure, they select from their own fields. Criteria for selection include

- 'female' head, i.e. pointed tip to the head;
- bold, strong, full eye as indicators of seed maturity; and
- large head,

but individuals' tastes also matter. Most farmers do not compare seed performance from farm to farm.

Seed storage
Usually selected seed is stored on the head in bundles, at the top of the granary. No chemical treatment of seed was recorded, but in Tumbau, a quarter of farmers used a herbal treatment, in Kaska, water over which rites have been performed is sprinkled over the seed, and in Futchimiram water is mixed with the seed over which prayers have been offered by the malam (*isakan*). These make the seed insect repellant and ensure a good yield. A question about the efficacy of storage over several months or years produced a wide range of answers.

Choice of type and performance
Drought resistance and drought-escape (early maturity) are both more important than yield considerations in Kaska and Futchimiram; drought resistance and yield are both considered important in Dagaceri (where it was objected that drought cannot be predicted when planting!); but in Tumbau, yield is more important than either. In Tumbau, some farmers mix millet seed deliberately to maintain variety. Selected seeds are expected to do better than unselected, but inter-farm comparisons are confounded by differences in soil fertility or moisture conditions, management (weeding) and (in Futchimiram) possibly crop spacing.

Seed acquisition
Household heads are responsible for selecting and reserving seed, with the participation of other males, and only go outside the house in an emergency (when seed is normally given to a needy neighbour), or when a new variety enters a village, when seed is given and not borrowed. Millet seed may be informally exchanged; it is not the subject of formal contracts. (Cowpea or groundnut seed, not being needed for subsistence, may be treated differently.) If seed has to be bought, farmers go to the nearest market (though in Dagaceri, which is a big village with several traders, some may buy locally). The most common cause of purchasing seed in the drier villages is a failure of early planting or dry planting in a year when supply is scarce.

Millet expertise is recognised in certain persons or houses who specialise in a type. One farmer in the hamlet studied at Futchimiram is regarded as the best millet producer, in quality as well as quantity. In Dagaceri, expertise in *Fudewuwa* is credited to three households and in *Badenji* to more than five. But seed is not a factor in economic differentiation among households.

Outcrossing
Unwanted millet stems are removed from the field at Kaska, but in Tumbau and Dagaceri they are allowed to mature, being hard to identify (Tumbau) or used for consumption, but never stored (Dagaceri). In Dagaceri, it is recognised that types may change. *Badenji* may metamorphose into *Dangargajiya* 'when planted for long', and *Fudewuwa* may change after 3 years into *Badenji*.

Drought resistance: recent changes in millet preferences
Compared with 20 years ago, types which are no longer reserved systematically for planting are:
- Futchimiram: *Moro, Maida* (all farmers questioned)
- Kaska: *Arum Manga* (all farmers questioned)
- Dagaceri: *Zango* (some farmers questioned)
- Tumbau: *Lawur, BaKano Zango, Tamangaji.*(some farmers questioned).

Some informants were rather young in Dagaceri and Tumbau to remember seed reservation practices. The reason given was always that of a long maturing time.

New types that farmers have started planting are (in order of importance in each place):
- Futchimiram: *Buduma* (all farmers)
- Kaska: *Fudewuwa, Badenji* (11 and 1 farmer respectively)
- Dagaceri: *Fudewuwa, Badenji* (some farmers have always planted them)
- Tumbau: *Badenji, Fudewuwa* (half of farmers have not introduced new types)

The reason given in all cases is quick maturity. In Kaska, *Arum Manga* is said to be drought-tolerant.

Millet versus sorghum in drought
The attitudes varied sharply between villages. In Tumbau, millet was said to do better than sorghum under drought, which has no advantage over it if the rains fail. In Dagaceri, however, sorghum is known to be able to mature on residual moisture, though at the same time farmers say that millet is more drought resistant. In Kaska, no difference is perceived as both crops are planted at the same time and have to mature in three months.

Pest and disease resistance
As might be expected, individuals varied in their opinions from village to village. Additional information is contained in the detailed cultivar inventories. More enquiries, however, are essential if the farmers' experience in this area is to be made the basis of integrated pest or disease management. In Futchimiram, disease resistance was said to be important. Outbreaks of pests and diseases are so area- and time-specific, inconsistent, and unpredictable, that it is difficult to systematise experience except at the individual level, and consensus does not easily emerge.

Yield per hectare
Fairly clear majorities emerged from the small samples of informants as to the best yielders:

- *Buduma* in Futchimiram
- *Badenji* in Kaska
- *Fudewuwa* in Dagaceri (also *Badenji*)
- *Fudewuwa* (*Lawur*) in Tumbau (also *Dogon gero*)

However, disentangling the factors yield, drought resistance, early maturity and pest resistance in farmers' preferences is more complex than simple questions allow.

Other factors influencing preferences
The market has little impact on millet varietal preferences as all millet is saleable at the same price. However, seed can be purchased according to preference. Farmers do not think that land scarcity affects choice. Taste and colour are considered, a good-looking head is admired, and ease of handling is important especially where fields are distant (Dagaceri).

Womens' role in seed management
Data are available only for Kaska and Futchimiram. In the latter village, women work their own fields (located and cleared by the husbands) on which they select and reserve seed like their husbands, except that they have access to superior seed, when available, on the mens' fields. They may own groundnuts. They may exchange seed with the men. They share knowledge of seed selection and storage, including of millet, for example the practice of *isakan*. Seed reservation, and storage in the house or granary, is separated from their food processing and cooking responsibilities.

In Kaska, women work on their husbands' fields and do not take part in millet or sorghum seed management, but they manage cowpea or vegetables which are grown on portions of their husbands' fields. They store seed for cowpea and okra mixed with sand. They exchange seed with the men. They keep reserved seed separate from household food stocks.

FIGURE 5.5.2

Divergence of landrace [type] populations grown on different farms in Dagaceri and Kaska.

Each symbol (0 = Lafsir; + = Dan arba'in; x = Badenji) represents the mean of six grains in each of four heads. The samples from each farmer in Dagaceri are surrounded by continuous lines (D1, D2 and D3), and each landrace within these groups is surrounded by a dash-dot line. Each farmer-landrace group in Kaska is surrounded by a dotted line.

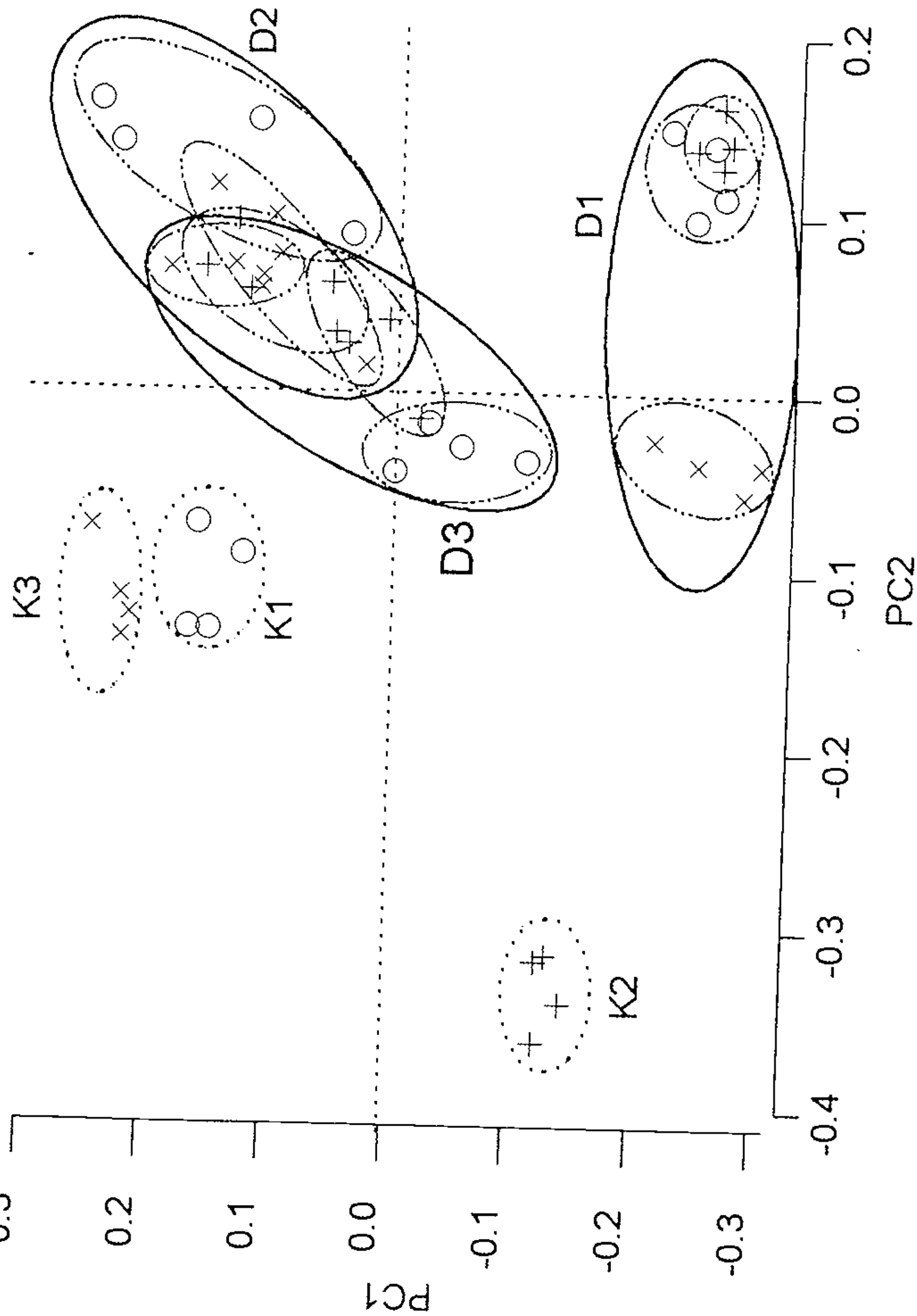


Fig 2

5.6 Policy Implications of Outputs

In this section, some key findings are highlighted with provisional indications of their relevance to policy, development agencies or the DfID's development goals.

5.6.1 Adaptive Management of Labour

Farming and livelihood systems
(1) Four farming systems have been characterised on a strictly compatible basis, permitting major variables (rainfall, natural resource portfolios, population density, labour and land supply, access to markets) to be linked to decisions made at the household level which impact on natural resource management.

(2) Inventories of technologies and management modes provide an improved understanding of the management resources available locally.

(3) The construction of enabling policies to support the mobilisation of indigenous resources, and of programme interventions in dryland environments, the Nigerian Sahel in particular, can be more firmly based on empirical analysis and less reliant on ill-researched degradation scenarios.

(4) The system characterisations have shown the diversity which exists and which needs to be taken into account by development agencies. The goals of poverty alleviation and mitigating environmental degradation will best be achieved through enabling such communities to mobilise more technical, management and capital resources to realise solutions to their specific problems.

Rainfall and labour management
(5) The variability of the rainfall - between villages in each year, between years in each village, and between short periods (we have used seven-day periods) within each season - has been demonstrated, not in statistical or probability terms, but in terms of how it affects farming practice. Flexibility of response, and the limits of such flexibility, have been demonstrated under a variety of conditions. Development interventions must achieve the same level of flexibility.

(6) Labour management is the key to successful utilisation of rainfall resources, both in terms of timeliness of operations and of quantitative mobilisation.

(7) There is a major differentiation to be made between short season systems requiring sharply peaked labour regimes and longer season systems where the sequencing of multiple operations is more important. A key to crop output is managing the transition from weeding to harvesting activity.

(8) The higher the percentage of available family labour that is used, the less flexibility is available to households that cannot gain access to non-family labour, and to the system as a whole.

(9) There is a link between labour use, rainfall and biomass production, but it is not a straitforward one. Higher rainfall generates more weeding work; however lower rainfall intensifies competition between crops and weeds. Harvesting work is dependent on biomass production. The 'labour bottleneck', in other words, is rainfall- as well as operation-dependent.

(10) The complex interaction that has been shown between rainfall and labour management is a major determinant of agricultural output, and development interventions (for example those promoted by rural development programmes) should be designed to address this interaction, rather than merely productivity constraints, if they are to be inserted sensitively into the system.

Farm and non-farm labour

(11) Flexibility in labour management is also necessary to exploit the opportunity costs of farm versus non-farm labour, even during the growing season when non-farm activity (contrary to myth) continues at a significant level.

(12) Specific interactive patterns are shown to affect farm versus livestock work, depending on the degree of crop-livestock integration achieved in the system in question.

(13) Farm versus domestic work interactions concern, in particular, womens' participation in farm work, and cultural practice . The large amounts of labour time put into domestic work, and the competition that is implicit between farm and domestic work, underline the need to identify development objectives in this area.

(14) Business and off-farm activity use sharply varying amounts of labour, both between villages and between times. Income diversification, and access to markets, dominate these uses of labour. Development interventions, and policies designed (for example) to strengthen the informal sector, need to be based on analyses of this diversity, especially in the Sahel where diversification represents a key resource for dealing with rainfall variability.

(15) Resting and time lost to sickness (in particular as they affect the energy resources available for agriculture) have been quantified although our data do not allow analysis of medical conditions. Given the critical role of labour in the production systems, the high percentage use of available labour at certain times, and the arduous nature of farm work in high temperature and humidity conditions which bears on all irrespective of age or sex, *non-work* has both economic and nutritional significance.

(16) These data indicate that agricultural production should take its place alongside households' non-farm labour commitments in agendas for rural and community development programmes, and suggest that a broader developmental framework, if adopted by governments, will benefit a wider social spectrum than addressing only questions of agricultural productivity.

Division of labour

(17) Women make their contributions to agricultural output both through participating in operations on mens' fields and by working in their own fields; the relative importance of these varies.

(18) Womens' contribution to farm work varies between villages (predictably, as cultural practice is not constant). It is greatest where rainfall variability is highest and the length of the growing season shortest. However where it is greatest, women have more land allocated to them than elsewhere. Where they have more land, they have more autonomy in decisions concerning its use.

(19) The quantitative significance of womens' contribution to farming also varies between years.

(20) Development interventions intended to benefit women farmers require the cultural, ecological and quantitative specificity provided by these data. They cannot be based on slogans.

Household differentiation

(21) Small households are more stressed than larger ones as they have less flexible scope for the use of their labour, which reaches a higher percentage of what is available and fluctuates more sharply.

(22) In some villages, small households use a larger percentage of available labour in farm work (as opposed to non-farm work) than larger households.

(23) Given the importance of labour management, households with a smaller endowment are relatively disadvantaged, with negative consequences for output and incomes. Their greater poverty makes it harder for them to overcome labour constraints by gaining access to non-family labour.

(24) Inter-household differentiation tends to be viewed mainly in terms of relative output and income, but the operational constraints which are exposed in these data add an important dimension.

(25) Poverty alleviation objectives should take account of both the weakness of small households' resource endowments and their operational difficulties. Defining poor households as small households is an over-simplification. But, as demographics are linked with social differentiation in the community, more policy research is warranted on ethical and practical issues.

Labour use per hectare

(26) The intensity of agriculture has been measured in terms of labour:land ratios for these four systems, and a positive correlation exposed between population density and intensity. The relationship has also been measured in terms of total labour use per hectare per major farming operation. A third indicator used is peak intensity of labour use per hectare in critical farm operations.

(27) Variability is found, not only between villages in any one year on the intensity gradient, but also between years in the same village. Such annual fluctuations in intensity of labour use correct a conception of rigidities and suggest subtle adaptive behaviour on the part of farmers.

(28) The complexity of the intensification process requires recognition by development agencies, and in particular (a) the specific characteristics of systems (rainfall, soils, cultivar inventories, etc); (b) the way in which fallowing is operated; (c) the changing ratio of intensively to less intensively used land; (d) access to arable land.

(29) Short of interfering in land tenure, development agencies cannot influence the intensity of land use, as it depends on labour management decisions by individual households. What they can do is to help extend the range of technologies available to farmers working with a land constraint. The responses to land scarcity identified in this study show the importance of diversity of choice under intensification conditions.

5.6.2 Soil and Biomass Management

(30) The soil types and management regimes found in each of four different systems have been characterised and classified. The impact of these management regimes on soil fertility has been assessed, on the basis of reconnaissance field sampling and analysis.

(31) The demonstrable need for soil recuperation after cultivation cycles in the more extensive systems, and the relative sustainability of fertility indicators in the intensive system, underline the critical importance of soil fertility management as a priority for both research and extension.

(32) Farmers' soil fertility management practices include fallows, residues, manures, fertilizers, soil and water conservation, and legumes. Given the questionable viability of inorganic fertilizers, organic manure assumes a central place in any strategy for enhancing productivity.

(33) Thereby the feeding and management of livestock assumes a central place. Research on crop-livestock integration in specific farming systems needs to target nutrient cycling efficiency improvements rather than identify capacity ceilings.

5.6.3 Cultivar Diversity and Management

(34) The diversity of cultivars and multipurpose plants has been inventoried. Cultivar diversity is positively correlated with average rainfall. Yet diversity increases in importance with diminishing rainfall.

(35) As exemplified in pearl millet, farmers (collectively) are purposive managers of genetic resources, selecting against outcrossing to maintain desired types, choosing desired characters, acquiring,

reserving and storing seed, or changing preferences to meet new conditions, on a rational basis of experiment and observation.

(36) Analysis of genetic diversity shows unexpectedly that differences between farmers are more significant than differences between named types of pearl millet. This indicates that (some) farmers operate as partially isolated breeders with a high level of inter-year continuity. The implications of this for the promotion of 'improved' crop varieties need to be worked out for extension programmes.

(37) The genetic diversity found within named types of millet, both between and within villages, and evidence that suggests that one type may sometimes evolve into another, indicate that fluidity is characteristic of this cultivar (and probably others that outcross) in these environments. Managing this fluidity to support food sufficiency for the household is a technical objective completely ignored by traditional approaches to crop breeding and extension.

(38) Many named types of millet are not selected for, and may occur as a result of outcrossing with wild or hybrid relatives, genetic diversity, or (possibly) harvesting at different stages of the growth cycle. Named types that are selected may be either local or introduced, and more or less genetically variable. How an 'improved' type diffuses and interacts in such a system requires urgent attention.

(39) The traditional basis of germplasm collections, the assumption that a named 'landrace' or population is a taxonomically discrete, historically continuous and geographically located entity, needs challenging as the dynamic and adaptive management of genetic resources by farmers becomes better understood.

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6. Contribution of Outputs

6.1 Contribution to DfID Development Goals

This project has sought to contribute to the the **purpose** of the Department for International Development's Renewable Natural Resources Research Strategy to 'enhance productive capacity on an environmentally and economically sustainable basis'. It has specific relevance to RNRRS **goals** of the poverty alleviaton and the mitigation of environmental problems. This project addresses this purpose and goals directly, within the Semi-Arid Production System. Semi-arid systems are constrained by low biological productivity under natural, rainfed conditions, and are capable of degradation unless carefully managed.

This project's findings advance understanding of farming systems in the Nigerian Sahel under different conditions of:

- rainfall, ecology, and natural resources
- population density and intensity of agriculture, and
- access to markets and opportunities for income diversification.

They identify constraints affecting the decisions of households about natural resource management. Outputs relevant to policy or to development recommendations have been set out in Section 5.6.

6.2 Promotion Pathways

This study has aimed to advance understanding of semi-arid farming and livelihood management rather than develop technical recommendations. Promotion of these findings will continue take place after the end of the project through usual channels of scientific and research communication.

A series of forms of promotional and outreach work was outlined in the Research Proposal (**Annex 9**). These have been achieved as follows:

1. Quarterly and annual progress reports to NRI (completed on schedule or in preparation)
2. Working papers for professionals, agencies, communities (five completed and distributed in Nigeria and the UK; these are listed below)
3. Journal papers for researchers (one paper published; one paper and a book in press; several research notes published; further papers planned or in preparation; these are listed below)
4. Final Technical Report for the NRI (in preparation)
5. Reports for specific agencies for policy makers (under discussion)
6. A book for the research community (contract with Routledge; manuscript will be completed by October 1997)
7. A workshop in Nigeria (in 1995 the project part funded and presented papers to the Third Land Resources Workshop in March at Kano, which was attended by government and agency representatives, academic researchers and development; the keynote address and two further papers were presented to the International Arid Zone Conference at the University of Maiduguri in July, 1994.
8. A workshop in Nigeria in 1997 (a proposal for such a workshop was made to NRI in March 1997; no budgetary provision was made in the project proposal for an in-country workshop.).

In addition to these outputs, it was suggested in the proposal that an application might be made for funds to hold an international workshop in West Africa or the UK during the life of the project. The problems associated with the expulsion of the Senior Research Associate from Nigeria in November 1996, and the delay to the completion of the technical work, have meant that this proposal has not been made, although its purpose has to some extent been subsumed under the proposed meeting in Nigeria in 1997 (discussed in 6.3 below).

6.3 List of Publications

A. Published or in press

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B. Internal Documents

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Yusuf, M. (1996) *The Farming System of Tumbau, Kano State, Nigeria.* Soils, Cultivars and Livelihoods in Northeast Nigeria Working Paper Series No. 1, 3 (eds. M.J. Mortimore, J.A. Falola).

C. Paper Presentations

Seminar or paper presentations on the project have been presented at the following institutions or workshops during the life of the project:

- Conference on the Arid Zone of Nigeria, University of Maiduguri (July 1994)
- SEREIN Sahel Workshop Copenhagen (January 1995)
- Nigerian National Workshop on Land Resources, Kano (March 1995)

Second World Cowpea Research Conference, Accra, Ghana (September 1995)
ESRC CSERGE Workshop on Coping Strategies in Africa (January 1996)
Department of Geography, University of Sheffield (March 1996)
SEREIN Workshop for Scandinavian Sahel Researchers (June 1996)
CERES courses for Dutch African Researchers (September 1996, February 1997)
Institute of British Geographers with the Royal Geographical Society, London (November 1996)
Department of Social Studies, University of Central Lancashire (January 1997)
Institute of Development Studies, University of Sussex (February 1997)
Workshop on the future of pastoiralism in West Africa, Uniersity of Geissen (Germany) (June 1997)
University of Aarhus Development Studies Workshop (June 1997)

6.4 Plans for Further Dissemination

Two particular groups of institutions are ongoing targets for dissemination to promote the uptake of the insights of this research. The *first* consists of development and extension agencies and development professionals in Nigeria, and the *second* is the international research community, in Nigeria, the UK, Europe and the USA. It is proposed to reach these groups as follows.

6.4.1 Development and Extension Agencies and Professionals in Nigeria

1. The *Final Technical Report* will be reviewed by Dr Falola (Nigerian Counterpart) and an extended abstract will be prepared suitable for a Nigerian professional readership.
2. With the permission of the NRI, copies of this abstract of the FTR will be sent to selected agencies in Nigeria, accompanied by a covering letter by Dr Falola tailored to the specific interests of the institution, and highlighting relevant findings. The optimal timing for this exercise will be in June or July, 1997.
3. Each agency will be invited to attend a **Workshop in Kano** organised at Kano by the Department of Geography, Bayero University and the British Council . Dr Falola will act as Workshop Organiser.The optimal timing will be in September or October, 1997. An application was made to NRI in February 1997 for funding to support this workshop, which (as envisaged in the Research Proposal) is outside the scope of the funded activities of this project).

The proposed Kano workshop is aimed specifically at decision-makers and policy formulators within natural resource management agencies in northern Nigeria. It should be attended by representatives of government departments, research institutions, farmers' organisations, and researchers. A summary of findings will be presented at this Workshop for critique and appropriate action agreed. As the principal researcher is forbidden to visit Nigeria, a more direct involvement on the part of Cambridge University is impracticable.

The proposed workshop would be organised as follows:

1. Attendance will be by invitation, and will include representatives of the agencies, professionals and extension services (see attached list) , plus individuals from the Federal Government system and research organisation, and committed academics. (Possible attendance by someone from the proposed DfID initiative with NGOs and the DfID Natural Resources adviser in Nigeria).
2. All delegates would receive a technical summary of the main findings of the project, distilled from the Final Technical Report. This report would be written in the UK, sent by courier to Kano and despatched with the Workshop invitation by the British Council, accompanied by a letter written by Dr. Falola.
3. The project's Nigerian team (Falola, Ibrahim, Mohammed and Yusuf) would make a joint presentation of main findings and policy implications in the first session.

4. Invited discussants would take up major issues in the second session. These issues would be carefully co-ordinated to avoid duplication or triviality and to secure an independent, considered critique of the project's findings and policy implications.
5. Delegates would be invited to contribute to discussions in the third session.
6. The proceedings will be recorded on video, retained in Kano and sent to Cambridge to ensure maximum impact on the writing of the book and articles that will be in progress.
7. No publication or other post-workshop expenses are visualised.
8. No participation by Cambridge staff is proposed owing to Michael Mortimore's exclusion from Nigeria and the high cost of flying someone to Kano for a one-day workshop.

(Consideration is also being given to the feasibility of inviting community, pastoralists' and farmers' representatives to the meeting, and securing their inputs.)

Invitees from among the following are envisged:

Institute for Agricultural Research, Zaria,
Kano State Agricultural and Rural Development Authority (KNARDA)
ICRISAT Kano
IITA,
Hadejia-Nguru Wetlands Conservation Project
Centre of Arid Zone Studies at the University of Maiduguri
JARDA
Katsina EC Project
Lake Chad Institute
Chad Basin Development Authority
Hadejia-Jamaiare River Basin Development Authority
Sokoto-Rima Basin Development Authority
Shika NAPRI
Federal Ministry of Agriculture and Forest Research
Alhaji Abdu Dawakin Tofa
Alhaji Iliyasu Salihi
Alhaji Abdu Rufai
Head of Department of Geography
Centre of Arid Zone Studies, Maiduguri
NGOs (Felicity Proctor to advise)
NEST
Nigerian Conservation Foundation
Professor J.M. Baba (FUT, Minna)
Dr. J.A. Ariyo (ABU, Zaria)
Professor E.A. Olofin (Bayero University Kano)
Dr. E.U. Essiet (Bayero University Kano)
Mr. L.F. Buba (Bayero University Kano)
Dr. S. Patrick (Bayero University Kano)
Professor E.O., Oladipo (UNDP, Lagos).

6.4.2 International Researchers and Research Institutions.

Links have been established and are being developed with research groups as follows:

In the UK

University College London, Institute of Development Studies (Sussex)
International Institute for Environment and Development
Overseas Development Institure (London)
University of Sheffield, (Department of Geography)
University of Coventry (Centre for African Studies\)
University of Birmingham (Centre for West African Studies)

Outside the UK
CERES and Universities of Utrecht, Amsterdam, Leiden, Agricultural University of Wageningen (Holland,
CIRAD (Montpelier)
University of Bordeaux II (France)
SEREIN (University of Copenhagen)
African Studies Institute (Stockholm)
Graduate School of Geography, Clark University
Centre for African Studies, University of Florida
Institute for Agricultural Research, Samaru, Nigeria
Kano State Agricultural and Rural Development Authority,
ICRISAT, Kano, Nigeria and Niamey, Niger.
IITA Kano, Nigeria
Hadejia-Nguru Wetlands Conservation Project, Nguru, Nigeria
Centre of Arid Zone Studies at the University of Maiduguri, Nigeria
World Bank, Washington, Environment Department and Africa Department

6.4.3 Research Publications

Publications in the research literature are being prepared. These will include a book and several journal articles. It is important to place some of these in Nigerian publications, and the Nigerian members of the research team will be active in this. Importance is placed on injecting the findings into teaching and ongoing research in the Nigerian Universities and research institutes.

A number of publications are in preparation, or are planned, includingthe following:

- *Working the Sahel: labour management in four villages in the Nigerian Sahel*, Routledge, London (in prep aration; book contract agreed).
- 'Genetic Diversity and Landraces of Pearl Millet (*Pennisetum glaucum*) under farmer management' (Busso *et. al.* in prep. for *Ecology*)
- 'Farmer management of seed and crop diversity in northern Nigeria' (for *Outlook on Agriculture*) 'Land cover changes over 40 years under agricultural intensification' (for *Land Use Policy*)
- 'Rainfall and the allocation of farm labour in four villages of the Nigerian Sahel' (*Journal of Development Studies*)
- 'Risk and labour management by smallholders in the Nigerian Sahel' (development journal)