The Relevance of Nigerian Farmers' Responses to Dryland Farming Systems in India and Southern Africa

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1. Executive Summary

Poor rural people in small households in semi-arid ecosystems are a sub-set of the world's poor, and their peculiar difficulties set them apart from others; thus while poverty is found everywhere, its symptoms in semi-arid lands (and the opportunities for overcoming it) diverge - and are diverse.

This report summarises the main findings of recent research in Nigeria (supported by DFID's Natural Resources Systems Programme Semi Arid Production System (DFID-NRSP-SAPS). This work, covering four projects carried out during five years of field work from 1992 to 1996, developed an integrated, multidisciplinary approach for working with a systems framework at the household level, and a set of methodologies. This approach is called, for convenience, the *Soils, Cultivars and Livelihoods* (S,C&L) approach. It builds on earlier work by anthropologists, agricultural economists, ecologists, geographers, soil scientists and others and is here placed in the wider context of disciplinary and thematic research, and especially in relation to the scientific and technical work in agriculture which has dominated the attempts made by development agencies to enhance incomes in semi-arid systems.

The report draws on discussions with over 70 scientists in India, and brief visits to institutions and farming systems in the field covering the major themes in India's experience of drylands research for development. It related the S,C&L approach to this experience, and to some new development interventions which are being supported by the DFID. It further reviews drylands research and research opportunities in southern Africa (Zimbabwe and Malawi). The differences between these two countries are held to account for important differences in the context of household decision making. Selected research themes drawn from debates in southern Africa are reviewed in relation to the S,C&L approach. The report aims to suggest a way forward in defining a common agenda for research to support poverty alleviation and sustainable NRM amongst small households in SAPS in the three regions, West Africa, southern Africa and India.

This report argues a case for research on smallholders' production systems in rainfed drylands which adopts an integrated approach to NRM and livelihoods. The rural household system has to be recognised as rational, though constrained (Schultz, 1964). The ways in which the constraints (whether of water, land, soil nutrients, biodiversity, labour, skills, capital, or livelihood options) are managed, and the ways whereby household members attempt to manage changes which originate from outside, are adaptive. Development interventions must therefore be based on some understanding of the nature of these constraints and adaptations.

Eleven components of change with significant impacts at household level have been identified, failing into three groups:

- **Social changes**

1. Demographic transitions;
2. Education and migration;
3. AIDS;
4. Breakdown of family units and/or roles;
5. Hiring labour;

- **Environmental changes**

6. Climate change;
7. Land scarcity;
8. The soil fertility crisis (or transition);

- **Changes in natural resource management**

9. Woodland clearance (or conversion)
10. Crop-livestock integration;
11. Biodiversity;
12. Privatisation of natural resources.

We have described an integrated methodology for researching systems, which has been adapted to the special circumstances of SAPS. Our emphasis is on constraint *management* (rather than on breaking constraints by developing new technologies), and on *linkages* between components of the system (rather than quantifying the components themselves). This methodology relates closely to DFID's sustainable rural livelihoods agenda, and builds on the strengths of Farming Systems Research. With a wide agenda and a open-ended potential, it trades the security of a targeted agenda for the challenge of harnessing research in support of livelihoods.

Annex C.

Methods Used in the Nigerian Research

A range of methodologies was used to handle different kinds of data. In this annexe, we describe these with organisational details where relevant.

1. Rainfall

Regional rainfall data for synoptic stations (Kano, Maiduguri, Potiskum, Nguru). Automatic tipping bucket rain gauges were installed in each of the four villages

2. Population density

At the local government (formerly district) level, census data is available for 1952, 1963, and 1991 (total males and females only). A population enumeration was carried out in the Dagaceri study area, covering about 50% of the area mapped for land cover change. 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.

3. Land use and vegetation change

Detailed mapping of land cover was done using standard vertical air photography contracted originally for topographical mapping (Turner 1997). Recent photography (1981 or 1990) was obtained in Kano or Garin Alkali. 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. 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 km2 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.

4. 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 using Microsoft Access was constructed containing demographic data on all persons in collaborating households and maintained from year to year.

5. 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.

6. Farming system characterisation

Inventories were made of cultivar types, livestock breeds, technologies, soil types, and household income strategies , 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.

7. 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 pre-designed scheme would have been misleading or incomplete as the range of farm and non-farm activities exposed in the data was very wide). Task codes were structured heirarchically so that the data can be analysed at different levels of generality (from farm versus non-farm to, for example, food selling (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/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.

8. Soils survey

Two rounds of field soil sampling were carried out in all four villages: 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. 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.

9. Nutrient cycling

In addition to the soil sampling, more detailed work was carried out in Tumbau and Dagaceri (Harris 1996, 1998 , in press). Following interviews with farmers, a sub-sample of farmers practising contrasting soil fertility management practices was selected with which to carry out a detailed study of nutrient cycling within their landholdings. Nutrient inputs such as animal manure, compound waste and inorganic fertiliser were weighed and sub-samples taken for chemical analysis. All harvested material (whether crops, residues, weeds, or grazed material) were measured, and further samples analysed to determine their chemical content (NPK, and Ca and Mg in Tumbau in 1993). Harmattan dust deposition was measured using wet dust traps; nitrogen fixation was measured by the N-difference method. Quadrats were used to measure the amount of vegetation removed from grazed fields, and the amount of manure left in fields by grazing animals. Summation of nutrients gained and lost on a field by field, and then farmholding basis (including fallow and rangeland in Dagaceri), provided a nutrient balance of the farmer’s landholdings. Monitoring of farmers’ practices, regular interviews, and relation of the nutrient cycling data to access to recourses, market values of inputs and outputs, and labour inputs, provided insights into the dynamics of soil fertility management, and how farmers’ strategies related to household resources.

10. Cultivars data

An inventory of multipurpose plants and cultivars were made in all villages, 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 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*..

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.

11. Livelihoods data

Inventories of livelihood options (including farming and livestock) were undertaken. 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. 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.

2. Background

2.1 Poverty Alleviation as a Focus of Research

Poverty alleviation has always been an aim of development assistance, but it has recently been brought more sharply into focus in the UK's development policy (DFID, 1997).

Many lessons have been learnt (both negative and positive) from three or more decades of research and development assistance in poor countries. For the research community, there is now a fresh emphasis on delivering outputs which have verifiable impacts on policy, target institutions or disadvantaged social groups. It is apparent that neither macro-economic improvements in poor countries, nor productivity enhancing technologies in agriculture, necessarily deliver better living conditions to the poor and marginalised. Something more is required. In the policy vacuum which has followed this discovery, new, more tightly managed research is needed, both at the fundamental and applied levels.

Research agendas must prioritise, and researchers are now expected by some funding bodies to take the fight against poverty beyond the publication of scientific findings and into the arena of dissemination and uptake. For scientists in the 'North', this calls for closer relationships with in-country partners, both in the design and in the execution of research, more follow-up activities, and other institutional arrangements. It also calls for research designs which (through various forms of community participation or collaboration) take better account of the real-life situations of the proposed beneficiaries, the poor households themselves.

A socially and geographically disaggregated approach to understanding and alleviating poverty is necessary. There are four possible levels of resolution:

Communities, whether districts, administrative areas, villages, wards, social, ethnic, gender or occupational classes. Though not necessarily functioning as units, such divisions express commonalities of interest and provide possible analytical or programmatic frameworks.

Institutions, whether indigenous, exogenous or hybrid, which organise social and economic activity around such matters as access to natural resources, participation in markets, management of common property, labour sharing, and migratory employment.

Households. Too often assumed to be self-defining and uncontroversial focii of decision making in rural communities, households based on co-residence, food sharing, labour management, and kinship nevertheless remain fundamental organisational units in many (though not all) low income systems.

Individuals, whose activities are governed by decisions and norms which, though operating within a context of community, institution and household, may with justification (in a changing world) be analysed in terms of some degree of autonomy.

It is a premiss of this paper that poverty alleviation targets, expressed in various programmatic frameworks, cannot safely assume that enough is already known about the distribution and processes of poverty, given the situational diversity of poor countries. In parallel with development assistance programmes, and (where possible) in association with them, researchers face a sharpened intellectual challenge, which is:

- more than finding technical solutions to productivity bottlenecks or conservation crises

- more than prescribing economic incentives to promote profitability
- more than developing new forms of management to enhance resource use
- more than upgrading service provision (health, education)

but confronts the perplexing diversity and systemic interelations of the livelihood system as a whole, and how its constraints and opportunities are being (and can be) managed to secure improved incomes and welfare.

2.2 Sustainable Natural Resource Management is a Requirement for Alleviating Poverty.

Degrading the renewable natural resources threatens livelihoods (both rural and urban).

> 'DFID's Renewable Natural Resources Knowledge Strategy (RNRKS) aims to contribute to poverty alleviation in target countries by generating research outputs which sustainably enhance the production and productivity of RNR systems' (DFID, 1999).

Sustainable rural livelihoods are therefore the centrepiece of DFID's poverty-alleviation strategy (Carney, 1998). For those who live in rural areas, sustainable management of natural resources (NRM) will be, in future, a condition for enhancing their incomes from primary production. However, the rural poor will become (through markets) more and more active participants in the urban sector, and (through migration or short-term mobility), in the economies of regions outside their own. Thus, the management of those natural resources to which they enjoy private or communal rights of access becomes intertwined with their management of their livelihood options away from their farms, their herds, flocks or trees. The challenge, however, is not only economic and technical. New pressures are transforming social relations within and between communities, including, for example:

- access to, and division of, labour;
- systems of resource tenure;
- leadership structures;
- inter-generational commitments and
    - relations within the household.

In order to penetrate the complexity of such fluid, dynamic and multi-sectoral livelihood systems, integrated multidisciplinary research methodologies are needed. This need is the starting point of the present study.

2.3 New Knowledge of NRM Requires a Systems Approach

> 'A systems approach to research means identifying and addressing researchable issues in their developmental context, by undertaking analysis of all the technical, economic, social and institutional inter-relationships that are involved in a given situation' (DFID, 1999)

This is not a new discovery. In some disciplines (notably anthropology and geography) there are old traditions of holistic analysis of rural communities, and in agricultural economics, farming systems research (FSR) has been in vogue for at least three decades (Collinson, 1972; Norman et al., 1982). The current popularity of participatory methods in agricultural research reflects the same consensus (Farrington and Martin, 1988; Okali et al., 1994). Among major donors, the World Bank has pursued a research initiative on population-poverty-environment

linkages or 'nexuses'. Applied to Africa, this approach generated widespread interest (Cleaver and Schreiber, 1994), but so long as the analysis is restricted to the macro-scale, it may not necessarily illuminate the decisions made by actual households or individuals.

An important truth is that even the most complex linkages are exhibited at the household level, and are the subject of daily manipulation by small-scale resource managers. New knowledge may, therefore, be appropriately generated at this level. The justification for new knowledge - as a part of a poverty alleviation strategy - arises from poor households' own needs to strengthen, improve, and diversify their available options, to protect their cumulative investments, and thereby to enhance their living standards and security in an uncertain environment. This uncertainty arises from environmental, political and economic variability. Appropriate policies and interventions can support smallholders' strategies and help them achieve these things.

While learning from antecedents in multi-disciplinary systems research, the present brief study, and the field research in Nigeria which preceded it, aim to go beyond normal FSR practice in three ways:

- The focus is on sustainable resource management, including natural resources, rather than on new or improved technologies. Improved understanding of how households *manage* their resources (or a scarcity of them) is expected to identify researchable constraints, predict the systemic impact of innovations, and identify barriers to sustainability. Technologies are evaluated primarily in terms of their impact on system sustainability.

- The approach to the farming system is explicitly broadened by *situating* it in the livelihood system as a whole, the way farming families see it. This goes beyond seeking to identify externalities to farming, to grapple with the livelihood system as a whole.

- A dynamic perspective is highlighted by targeting households' adaptation to change and uncertainty. Household systems are necessarily adaptive - it is a condition of their survival - and it is this adaptive process we seek to influence when we speak of 'poverty alleviating' interventions.

2.4 The Nigerian Sahel, India, and Southern Africa

The priorities identified in the preceding section argue for a *management* focus distinct from the traditional development focii of *economic profitability* and *technical improvement*. The objective of resource management by households is to maximise the benefits obtained from factors which are permanently or seasonally constrained - rainfall (in semi-arid systems), soil nutrients, biodiversity, off-farm livelihood options, markets, labour, land, capital, and knowledge/skills. Rather than setting values on these constraints and analysing them in a neo-classical economic framework, we have approached the problem as a matrix of *allocative* (or *negotiated*) decisions which reflect the multiple goals of households and individuals and their varying management capabilities. In this way we attempt to reflect the smallholders' own priorities and point the way to policies which can strengthen or enhance (rather than replace) indigenous resources.

Uncertainty is a fact of life in many poor rural societies, and is not easily susceptible to traditional economic and technical research. In arid and semi-arid regions, the primary (but by no means the only) source of uncertainty is variability in the rainfall. The present study is targeted on semi-arid farming communities in the Sahel, India, and Southern Africa.

A linked series of studies was funded by the ESRC (Global Environmental Change Programme), NRI (Agronomy Programme), and NRSP (Semi-Arid Production Systems) from 1992 to 1998. These four projects focused on the semi-arid zone of northern Nigeria. They have been reported by Harris (1996; 1998; 1999), Adams and Mortimore (1997), Mortimore and Adams (1999a,b), and Mortimore et al., 1999.

The projects were based on field research in four villages situated on an environmental and socio-economic profile of:

- diminishing rural population density, from very high (> 200/km^2) to very low (<20/km^2);
- diminishing average annual rainfall (from moist semi-arid (>500 mm) to dry (<350mm);
- increasing remoteness from large urban markets.

The villages lie in Kano, Jigawa and Yobe States of Nigeria (Figure 1). Methods are summarised in Box 1.

Figure 1. Study villages in Nigeria.

Box 1: Summary of methods, Nigeria studies

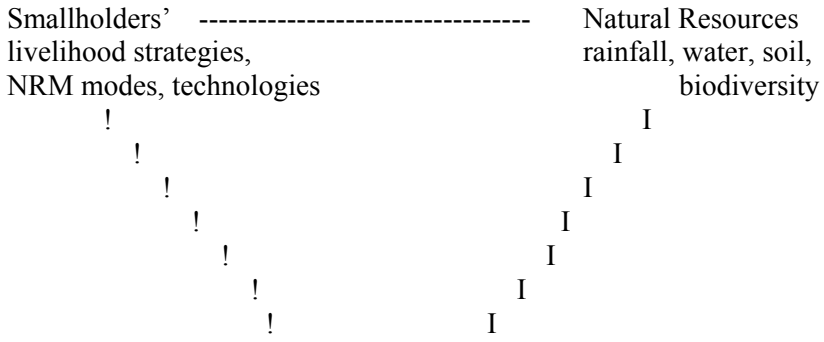
Field studies were carried out by a team of researchers at Bayero University, Kano, supervised and co-ordinated by senior researchers based at Cambridge and Bayero Universities. There were 12-13 collaborating households in three of the villages, and 8 in the fourth. An integrated programme of
work on rainfall, labour allocation, and the management of soil fertility, biodiversity and livelihood options was carried out over four successive farming years (May - December, 1993-1996).

Analytical studies of nutrient cycling were carried out in two villages (Harris, 1996, 1998, 1999). These villages were (a) high population density, moist semi-arid (investigated in 1993 and 1994) and (b) transitional population density, dry semi-arid (investigated in 1996). Village (a) operates a very high intensity system with annual cultivation, heavy manuring, and no fallowing. Village (b) operates a lower intensity system which includes some land under annual cultivation, much more under grass/shrub
fallow cycles, and rangeland, protected from cultivation, on up to a half of the total area. On-farm sampling (three holdings in village (a) and six holdings in village (b)) of the soils, crops and other vegetation, inputs and exports resulted in the quantification of nutrient balances and the identification of nutrient cycles in the farming systems.

For further details of the methodology, see **Annex C**.

The logic of the NRSP 'target countries' is that research questions, designs, methods, and outputs applied in one country may provide a basis for an exchange of experience between countries, and point a way to wider applicability of findings. There is, of course, enormous variability between and within countries. Hence this study attempts to place the Nigerian findings in the context of Indian and Southern African experience, with all the risks of superficiality and hasty generalisation that that implies. These risks we consider to be justifiable, in view of the failure of agricultural research to deliver productivity increases according to expectations in semi-arid smallholder systems. Though the achievements of research in certain areas have been considerable, a general 'green revolution' has not occurred. Instead, people are finding their own solutions to livelihood sustainability in small-scale, incremental adaptations, income diversification and migration. If the difficulties of transforming farming systems have been under-estimated, a strong case can be made for improving knowledge of how semi-arid livelihood systems work, in particular with regard to the management of natural resources (Figure 2), and how they can be strengthened.

Figure 2. Knowledge Dilemmas in Semi-arid Systems of NRM



The weak linkages between knowledge generation and smallholders result from either (a) ignorance of the nature of smallholders' livelihood strategies and constraints or (b) the use of wrong management paradigms in designing and/or promoting new technologies, etc. (for example, output maximisation versus risk minimisation in opportunistic grazing or multi-cropping; GR packages dependent on inputs or other costly resources). New knowledge, it may be argued, has not generated enough system-compatible outputs which can have a visible poverty-alleviating impact in SAS.

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3. Project Purpose

The purpose of this project was to assess the relevance of an analytical framework for understanding interactions between household management of labour, crop diversity and soil fertility to environmental change and uncertainty, developed in previous projects funded by ODA/DFID RNRRS SAPS in the Nigerian Sahel to analogous dryland environments in Zimbabwe and India. It sought to assess differences in the adaptive challenge facing farmers in the three regions, identify potential for a common research agenda, and consider the utility of the approach, and the capability of turning potential into action.

This project had the following six specific objectives:

(1) To define the challenge which faces smallholder households in semi-arid ecosystems. Poor rural people in SAPS are a sub-set of the world's poor, and their peculiar difficulties set them apart from others; thus while poverty is found everywhere, its symptoms in semi-arid lands (and the opportunities for overcoming it) need to be accurately specified (section 5.1). Moreover, the configurations of this challenge are constantly changing (see Section 5.2)

(2) To summarise some findings from recent research in Nigeria (supported by the NRSP-SAPS Programme of the DFID), which developed an integrated and multidisciplinary approach, which we term the *Soils, Cultivars and Livelihoods* (S,C&L) approach (section 5.3), and to relate this approach to the situation in India and southern Africa (Section 5.3.8).

(3) To place this approach, which builds on earlier work by anthropologists, agricultural economists, ecologists, geographers, soil scientists and others, in the wider context of disciplinary and thematic research, and especially in relation to the scientific and technical work in agriculture which has dominated the attempts made by development agencies to enhance incomes in these systems (section 5.4)

(4) To review some major themes in India's rich Arid Zone research, and some new development interventions in India which are being supported by the DFID (Annex A).

(5) To review relevant research and needs in Southern Africa (Zimbabwe - a 'core country' - and Malawi) (Annex B)

(6) To suggest a possible way forward in defining a common agenda for research to support poverty alleviation and sustainable NRM amongst small households in SAPS. A subsidiary aim includes linking research, and particularly medium-term *fundamental* research (such as that undertaken with the S,C&L approach), with the activities of development programmes whose needs are for short-term *applied* research (section 5.4.5).

4. Research Activities

4.1 Outline

Research activity included the following elements:

1. A research visit to dryland zones of Western India, to focus on soil fertility research (Frances Harris), June 1998.
2. A research visit to dryland zones of Western India, to focus on the interactions of soils, cultivars and livelihoods (Mike Mortimore, September 1998)
3. A research visit to Zimbabwe and Malawi to focus on the interactions of soils, cultivars and livelihoods (Mike Mortimore and Bill Adams, December 1998).

4.2 Activities

Each visit incorporated the following elements:

(a) a presentation of the SCL approach for critical review in the light of in-country experience (in Zimbabwe through a formal workshop; in India as a formal presentation to researchers at CRIDA,, and also through sequential meetings with researchers at different institutions, and in Malawi through a series of sequential meetings with researchers in different institutions);
(b) field visits to field locations where research projects were in progress and discussion with research personnel and farmers;
(c) determination of the scope for developing common research agendas;
(d) visits to key persons in research, governmental and non-governmental organisations working with semi-arid farming systems, to obtain research materials and visit field sites of research or development projects

4.3 Programme

The following visits were completed:

India

- Discussions with more than 70 people at the following research centres:
  Central Arid Zone Research Institute, Jodhpur, Rajastan
  University of Agricultural Sciences, Dharwad, Karnataka
  University of Agricultural Sciences, Bangalore (GKVK and Hebbal campuses), including the All India co-ordinated research project for dryland areas and the operational research project on watershed management)
  Departments of Geography and Environmental Studies, Jawaharal Nehru University, Delhi
  Bijapur Agricultural Research Station,
  Gulbarga Agricultural Research Station
  ICRISAT, Patancheru, Andra Pradesh
  Central Research Institute for Dryland Agriculture, Hyderabad, Andra Pradesh
  Institute of Social and Economic Change, Bangalore
  Indian Council of Agricultural Research, Delhi
  Rural Development Office, Department for International Development, and British Council offices in Delhi.

- Visits to two DFID projects (KRIBCO and KAWAD) and NRSP project (peri-urban interface, Hubli Dharwad.
- Field visits to six cropping systems under active management.

Zimbabwe
Visits were made to the following:
- Institute of Environmental Studies University of Zimbabwe,
- Farming Systems Research Unit, Department of Research and Specialist Services (DR&SS),
- Ministry of Agriculture,
- Agritex,
- CARE International,
- DFID,
- Selected districts of southern Zimbabwe;

Malawi
Visits were made to the following:
- DFID;
- farming systems in Zomba area;
- farming systems in Shire Valley and SW lakeshore areas.

The proposal stated the assumption for the achievement of the project goal (which is beyond the scope of this study) as the existence of an enabling policy and economic environment. The proposed study depended on meaningful interaction with Zimbabwean and Indian research communities within the short time-frame. Researchers and project staff proved generous with their time, but logistical constraints limited the range of field settings that could be studied.

5. Outputs

5.1 The challenge facing small holders in SAPS

Smallholders who live in the tropical drylands are unable to escape from the impact of two fundamental properties of their ecosystems: they are dry, and their rainfall is unreliable. The heart of the African drylands is the semi-arid zone, which receives from 250 to 1,000 mm of rainfall each year, and has a growing period of 75-179 days.

1) Aridity: Drylands normally have little or no rain for five months or more. Ecosystems are adapted to drought stress, the production of biomass is sharply concentrated into the wet seasons, and there are long quiescent periods when annual plants die and perennials produce little growth. Domestic animals undergo weight loss and (in drier years) starvation. They may have to be watered from wells, consuming much labour. Rainfed farming is episodic, with periods of intense and exhausting work separated by periods of relative inactivity. The monthly distribution of rainfall may be profoundly influenced by latitude (as in West Africa) or by altitude and rain shadowing effects (as in southern India).

The exceptions are the wetlands, which offer dry season grazing, flood-recession farming, or irrigation opportunities. The value of these wetlands is a function of their scarcity (generally less than ten percent of the rainfed areas).

Low agro-ecological potentials lie at the heart of the degradational (or *desertification*) hypotheses that have dominated attempts to plan, control or improve natural resource management (NRM). From earlier scenarios of desert advance, driven by deforestation, overcultivation or overgrazing, scientific opinion has shifted towards soil degradation, or nutrient mining, as the dominant process responsible for an alleged decline in productive potentials. Under this hypothesis, smallholders are taking more from the soil than they are replacing and nutrient balances are negative. In some semi-arid areas (notably in West Africa), aridity is actually intensifying under a declining trend in rainfall over the past 30 years.

2) Variability: Rainfall is not only sharply seasonal but it is also variable: both between years, and during seasons. For both animals (wild or domestic) and humans, variability introduces an element of risk into almost all life-supporting activity. The impact of variability increases with aridity. The greater part of the rainfall occurs in short episodes of high intensity. Variability can be expressed in probabilities. Unfortunately, while such a statement enables an assessment of risk and returns in agriculture, it provides no basis for predicting the time or intensity of drought events. The incorporation of rainfall variability into development policy or projects is extremely difficult.

3) Natural Diversity: Drylands are ecologically diverse. In India, eight major agro-ecological regions are recognised, three of them arid, and five semi-arid. In the semi-arid zone of Africa alone, rainfall, vegetation and soils were combined to identify over 80 distinct environmental units (Mortimore, 1991). The semiarid and subhumid zones are associated predominantly with savannas, the density and size of trees diminishing with increasing aridity. In the arid zone steppes, the dominant species of the grasslands are quite variable. Owing to burning, clearance for cultivation, and grazing, the natural communities have been transformed into mosaics, consisting of farmland, fallow, rangeland, residual woodland and

eroded or degraded land. Topographical wetlands interrupt these patterns. Local communities and households have adapted in intricate ways to the micro-diversity of their environments.

4) Variable population densities: There is a very weak relationship between agro-ecological potential and population density in the drylands. While high rural densities are rare in the arid zone, surprisingly high densities are sometimes found in the semiarid, both in India and in parts of Africa. In the drylands, a range from >300 to <5 persons/km^2 has implications both for theory and for development policy. It confounds any attempt to establish a generalised relationship between density (therefore, people) and degradation.

The observed variation in rural population densities demands a diversity of responses in the form of NRM systems, from the one extreme where labour scarcity is a major driving factor, to the opposite, where land scarcity has provoked various forms of agricultural intensification (Boserup, 1965; Tiffen et al., 1994).

5. 2 Strategic Adaptation: sources of change

Poverty alleviation in the tropical drylands is more than an individual struggle against an inhospitable and variable environment. People must also adapt to a powerful dynamic of social and environmental change and of transformation in the relations between societies and their natural resources. Households - whether well or ill-educated, having grand or poor resource endowments, capable or incapable management, female or male heads - must confront many of these changes on a day-by-day, year-on-year, or longer time scale. Eleven of these changes may be identified (though superficially) as follows.

5.2.1 Social changes

(1) ***Demographic transitions***. In recent decades, rates of natural increase in the population have been <2% pa in India and >3% pa in sub-Saharan Africa. At the household level, higher rates create high dependency ratios, though they promise labour for the future. Fission and the creation of new households, with the necessary subdivision of landholdings, set up long term (inter-generational) resource allocation and management challenges, which affect short term behaviour, notwithstanding the popular dogma (rarely supported by empirical data) that poor people discount the future. Sub-Saharan African populations are now beginning to follow the Indian sub-Continent into a transition to lower levels of fertility (Gould, 1996, Caldwell, 1997). As family labour becomes more scarce, the relationships found between labour and land, which are critical in smallholder systems the world over (Netting, 1993), also change.

(2) ***Education and migration***. Better access to primary education is among the positive indicators of human development found in many poor countries during the past few decades. But a conflict between school attendance and farming (during the short, intensive season) has been observed. Education tends to be linked with a rising incidence of out-migration, in weekday commuting, in other short-term movements, or in a permanent 'exodus'. Such movements, by raising the costs of farm labour, have sometimes led to the neglect of on-farm infrastructure or farm work. Elsewhere, they have funded farm investments, and as education is seen as a necessary preliminary to employment outside the community, scarce funds may be invested in it (Tiffen et al., 1994).

(3) ***AIDS***. The impact of this terrible new scourge, where HIV-positive adults may exceed 30 percent of their age/sex group, on families' labour supply is disastrous. Deaths are now decimating the active population of young adults (whether farmers or absent income-earners)

in some areas in Southern Africa. Numbers testing positive are reported to be rising rapidly in India, and in West Africa it is feared that poor data may disguise a similar situation. The fearsome truth about AIDS is that its seemingly remorseless ascendancy strikes at the very heart of the adaptive livelihood systems developed in the drylands, by removing family labour (of either sex) entirely. Furthermore it transfers the burdens of production and of child care onto the elderly, or onto other children, plunging households below the threshold of economic viability, even under good rainfall.

(4) ***Breakdown of family units and/or roles***. The emergence of female-headed (or child-headed) households has proceeded furthest in southern Africa, where nearly a hundred years of labour migration came on the heels of the political and ecological instabilities accompanying the imposition of white rule. In some countries (e.g., Kenya), women have found a voice in social leadership; but in many, their workload has increased. In India and West Africa, changes are slower. In dryland systems, where much evidence suggests that the large, integrated, extended family is best placed to manage risk, change may intensify the insecurity of small and poor households, even while enhancing the employment opportunities available to women or others.

(5) ***Hiring labour.*** Smallholders depend on family labour (Netting, 1993). Labour-sharing institutions can adjust the household's labour supply to its need, and include a large measure of reciprocity. But hired labour is tending to replace them. Migrant labour is attracted to areas of market production. In some dryland systems in West Africa, labour hiring has been recognised as a social discriminator (Hill, 1969). This process is linked to technical changes in farming. For example, new technologies can increase the demand for skilled hired labour, or, contrarily, it may be cheaper to hire labour in place of costly labour-saving technologies. Hired labour, because of its cost, cannot provide a solution to labour shortages in the poorest households.

5.2.2 Environmental changes

(6) ***Climate change.*** Scenarios for the tropical drylands, under continued global warming, are still uncertain. However, the Sahel has already undergone rainfall decline, since the 1960s, of a magnitude greater than that predicted in climate change models (Hulme, 1997). Southern Africa and India have not experienced comparable long term change. A decline in average rainfall is encountered by the smallholder in increasingly frequent droughts. Adaptive behaviour is highly specific to the agro-ecosystem in question and its situation in the larger economic system (e.g., Mortimore, 1989).

(7) ***Land scarcity***. Notwithstanding urbanization, rising rural population densities are more common than the converse. These bring other changes in train. As a scarcity of cultivable land develops, average labour inputs per hectare increase. As more households enter the market, the demand for land increases further. More work per hectare means that the common assumption that rising densities *necessarily* mean unemployment, or 'overpopulation', is misleading. Paradoxically, in every system we have encountered, labour shortages are reported at critical points in the farming season. Given the need to respond flexibly to sharply fluctuating rainfall, losses of output may follow from an inability to mobilise enough labour when it is needed.

(8) ***The soil fertility crisis (or transition)***. In many rainfed ecosystems, the opportunity to manage low natural fertility with long fallows disappeared years ago. Scenarios of falling yields, or plant biomass production, and 'soil mining' are logically powerful, though in the forms in which they are expressed, they seem to be at odds with farmers' or livestock breeders' persistence in sustaining their livelihoods. It now seems clear that increased use of

inorganic fertilizers, particularly nitrogen and phosphorus, under deregulated markets, may not be economic, except for high value crops. The alternative, low external input technology involving more efficient on-farm nutrient cycling, implies lower yield increases and higher inputs of labour. Can such a transition be accomplished autonomously by smallholders (Harris, 1997;1998)?

5.2.3 Changes in natural resource management

(9) ***Woodland clearance (or conversion)***. In drylands, where commercial logging operations are relatively infrequent, the two principal processes effecting change in woodland are the extension of the cultivated area and woodcutting for fuel and construction, though increasing aridity also plays a part in West Africa. Alarmist scenarios of 'deforestation' (which have been issued, and challenged, for at least 60 years in West Africa), where replaced by more careful assessments, have yielded to a positive evaluation of farmers' potential as conservators (Cline-Cole, et al., 1990). Unprotected woodlands, on the other hand, are vulnerable to commercial destruction for urban markets, and forest reserves are hard to protect except on uncultivable land.

(10) ***Crop-livestock integration.*** Most, if not all dryland farming households aspire to own livestock, and livestock numbers and densities are prone to rise. Interactions between crop production and livestock management have implications for nutrient cycling, farm energy, income generation, diet and wealth accumulation. A staged hypothesis of integration, correlating with rising population density, land scarcity and intensification (McIntire *et al.,* 1992; Mortimore and Turner, 1993), cannot always accommodate the diversity found (IDS, 1998). However, the centre of the relationship is always the organisation of family labour, for that spent in tending livestock cannot be spent in farming. The benefits of keeping livestock include both saving labour (animal traction) and spending it (fertilizing). A micro-network of trade-offs is resolved at the level of the individual household or (if animals are tended collectively) that of the community.

(11) ***Biodiversity conservation.*** Dismissal of indigenous cultivated plants, or animals breeds, on grounds of low productivity or profitability is now somewhat rare. However the aim of formal breeding is still the replacement of unimproved types by exotics, hybrids or crosses. Where markets are strong, there is usually a strong positive response to such improvements; where the aim is to transform subsistence production, progress has been more ambivalent. NGOs are promoting, with farmers, the conservation of local cultivars and wild plants in India (e.g., Green, 1998) and Africa. In the face of international competition for the ownership of natural or cultivated seed patents, the potential value of local farmers as conservators of local biodiversity - in living germplasm banks - is recognised. However, such conservation forms a part of the system, and cannot continue without it. The preservation of potentially useful plants - especially cultivars - while consistent with labour-intensive, low external input, multicrop farming on small holdings, does not lend itself to the interests of the large scale or specialist market producer.

(12) ***Privatisation of natural resources.*** Diminishing areas of rangeland and woodland, accompanied by the private appropriation of cultivation rights, are reported almost everywhere. Common land offers market value, not only to farmers, but to the cutters, collectors or processors of many natural products which enter market chains driven by urban demand - fuelwood being only the best known of these. Graziers cannot defend customary rights for their herds. Nomadic peoples find increasing difficulties in supporting themselves. Access to crop residues, fallows, and farm trees by grazing animals is questioned or denied. Title is registered in the names of individuals to previously shared (or disputed) resources.

Enclosures are erected around private territory. More examples could be cited. The dilemma is that while often providing the necessary security for investment, these processes also form a part of the poverty scenario in systems under transformation.

Outsiders have been more concerned, however, with the degradation of soils, vegetation, or even water resources in common property resources (CPRs), which is usually blamed on ineffective local level management. The undermining of local institutions by centralised policing of forests and game reserves, which often extended to the cutting of privately owned trees on farmland, is now admitted, and agencies are developing new or adapted institutions to reintroduce local communities to the ownership and sustainable management of CPRs. However, sustainable productivity means the exclusion of some uses or users - usually the poorest members of the community. Resource tenure (in the broadest sense) is, therefore, at the centre of the changes which are occurring.

5.3 Strategic Adaptation: how Nigerian Sahelians adapt

Households' decisions about their livelihood strategies and natural resource management centre on the allocation of scarce resources. Such decisions are small in scale, frequent in occurrence, and sequential in pattern: that is, decisions taken on one day form a part of the next day's decision-making matrix. Decisions are responsive not only to the resource endowments of the household (of labour, livestock, arable land, etc.), but to exogenous events in the natural and economic environment (especially rainfall) over which smallholders have no control. Each year must be negotiated, with as much *flexibility* as possible, and the 'accounting' - of food stocks, income, capital - forms the starting point for the next year. From year to year, and in the longer term, such decisions, seen in aggregate, represent a progressive *adaptation* of the livelihood system as constraints or opportunities change.

The Nigerian research on which this model is based (Mortimore and Adams, 1999) suggests that there are six interactive areas of strategic adaptation, as follows.

5.3.1 Negotiating the rain.

Average data are a poor guide to the conditions farmers face in managing biomass production on small farms in the Sahel. For example, in the year 1996, and the village of Tumbau the weekly distribution of rainfall was characteristically erratic from the end of May until mid-October, with a long dry spell in July, and a false finish in September (Box 2). There is a sharp limit to the amount of labour available, which is defined by the number of people in the family, their age and sex, and the resources available for bringing in extra labour from outside.

In another year, the rainfall distribution is different; and so, both the timing and the quantities of labour allocated to farming tasks. The challenge faced by farmers, therefore, extends beyond an unpredictable drought crisis (when much farm labour is wasted) to the need for a technical flexibility in negotiating the rain in every year. Development interventions - whether projects or policies - have tended to focus on the economic or technical constraints which are perceived to face smallholder agriculture, in order to increase its average output or value. More attention could, with justification, be given to the intricacies of negotiating a way through the uncertainties of Sahelian rainy seasons.

Box 2: Rainfall and farm labour, Tumbau, Nigeria, 1996

The amount of farm labour allocated to three major farming operations (planting, weeding and harvesting), fluctuated through the season. Planting work peaked very early; weeding was done three times during the season. Harvesting was divided into two peaks, first early millet and cowpeas, and second sorghum, late cowpeas and groundnuts. The all-important weeding suppressed all other labour tasks; and competed directly with harvesting work later in the season.

5.3.2 Managing biodiversity.

Notwithstanding many years of converting woodland to cultivation, even in apparently degraded natural vegetation receiving less than 400 mm of annual rainfall, there is greater natural biodiversity than might be expected. In Dagaceri village, for example, 121 non-domesticated plants were inventoried, along with their multiple uses, in a study which concluded that the principles of indigenous management, as well as practices induced by forestry rules, are geared towards the protection of the vegetation (Mohammed, 1994). Sequential air photography, while showing major transfers from natural vegetation to farmland over a period of three decades (Turner, 1997), shows little structural change in the vegetation occupying fallows and rangelands. Farmland can, in fact, serve as an arboretum for useful trees. Dozens of such species are preserved on northern Nigerian farmlands (Cline-Cole et al., 1990), and the numbers and timber volumes of mature trees are greater, the higher the density of the human population. In times of famine, the routine use of foods (apart from medicine, fodder, and construction materials) derived from natural vegetation is extended dramatically in hungry households (Mortimore, 1989: pp 67-74). Tree planting and protection require consistent management decisions over many years.

Cultivated biodiversity in each of four villages included 3-12 named types of pearl millet, 6-22 of sorghum, and 14-42 of other cultivated plants. The case of millet, the hardiest and most preferred of food crops, is illustrative (Box 3).

Box 3: pearl millet conservation in four villages

Farmers in each place use from 3 to 12 named types of pearl millet. These have been assembled from local inheritances, their own selections from planted material, and imported

types with recognised advantages over indigenous ones in today's adverse climatic conditions. In none of the villages were improved types acquired directly from extension agents, but several of those used could be traced back to types developed on agricultural stations, in Nigeria or in neighbouring Niger, from which they have degenerated to a greater or lesser extent through outcrossing.

The control of degenerative outcrossing (with neighbours' farms, or wild relatives in the bush), is the continuing challenge faced by farmers who select and store their millet seed for planting each year (Mohammed, 1996). Results of a study of the genetic diversity of three named populations, which are used by three farmers in each of two villages, show the effect of farmers' seed management strategies (Busso *et al*., forthcoming). From statistical analyses of the results of DNA sample analyses, different populations grown by a single farmer-breeder assume a greater genetic identity - or less genetic diversity - than the same populations grown by different farmers. The same populations grown in two villages are genetically distinct. Farmers thus manage their own genetic pools, by selecting and storing the best seed from each year's crop.

5.3.3 Integrating animals

In northern Nigeria, livestock densities increase with population densities (Bourn and Wint, 1994; Hendy, 1977). More animals are kept by farmers (whether livestock producers with farms, or farmers who also keep livestock) than by specialised (and usually nomadic) pastoralists. Everyone owns, or aspires to own, livestock. They are a depository for savings, a reserve for contingencies, an appreciating asset (growing, fattening, and reproducing), a source of current income, and a source of energy for farm, well or road.

In addition to all these, they can support intensification on the farm (by cycling nutrients through crop residues and manure). During the last 20 years, there has been a shift from cattle to small ruminants in northern Nigeria, as they are less costly, more hardy, easier to feed and reproduce faster than cattle (de Leeuw *et al.*, 1995). This shift supports increased integration between crop and livestock production, but at the price of a higher labour requirement (Box 4).

Box 4: Labour used in farming and livestock work, Tumbau, 1996

Where farming is extensive, labour allocated to tending animals during the farming season is low, because a few small children can safely take the animals to graze on common pastures during the day, while everyone else works on the farms. But where farming is intensive, as in Tumbau, there are no common pastures, and sharing the supervision of grazing animals is impossible. So the animals
are stall-fed on weeds and hedge-cuttings which are laboriously gathered by each family every day. Their manure is composted and redistributed to the farms (Harris, 1996; Yusuf, 1996). The proportion of the labour force that is tied up with animal care is high relative to farm work.

5.3.4 Cycling nutrients

Where inorganic fertilizers are expensive or little used, nutrient cycling on farms depends on how the integration of crop with livestock production is managed. As the level of integration, as well as the numbers of livestock, depend on population density, so does the efficiency of nutrient cycling via fodder residues and manure. Population density also determines the cultivated fraction, and the labour supply. Nutrient management is also sensitive to rainfall, a prime determinant of yield, and markets. It cannot be considered a technical matter in isolation from these (and other) factors.

Adaptive management of nutrient balances on cultivated land is illustrated in Box 5.

Box 5: cycling nutrients in high and lower intensity systems
(Harris, 1998; 1999)

In a farming system a residential population density of 223/km^2 and a mean farming season rainfall of 571 mm), the key to nutrient cycling is the integration of crop with livestock production. Small ruminants consume residues, including sorghum stalks and haulms of grain legumes, which are high quality fodder. Legumes contribute about 15 kg ha^{-1} of nitrogen to the soil. Some of the nitrogen fixed by these legumes is converted to manure, which is mixed with compound waste and carried back to the fields, where it is applied at an average rate of 4.3 t ha^{-1}. Sold grains (cowpea and groundnuts) help finance small inputs of inorganic fertilizers (average 37 kg ha^{-1}). Cations and micronutrients are added to the system from the Harmattan dust which is deposited on fields in the dry season. Over 85 percent of the surface is cultivated every year, yet as well as supporting livestock the farmers achieve yields, on their multi-cropped farms, of about 280 kg ha^{-1} of grain legumes, 1.1 t ha^{-1} of cereal grain, and 1.8 t ha^{-1} of fodder (measurements in 1993 and 1994). Nutrients (nitrogen, phosphorus, potassium, calcium, and magnesium) were approximately in balance on three farms in Tumbau in 1993; in 1994 (a year with higher rainfall and greater nutrient uptake), nitrogen was in deficit on two of the three farms.

In a farming system with a lower population density of 43/km^2, and a mean farming season rainfall of 360 mm, nutrient stocks are maintained by transfers from rangeland and fallows, through grazing animals which deposit manure on cultivated fields or in pens, where it is mixed with waste and carried out later. Inorganic fertilizer is uneconomic at prevailing prices, and infrequently used. The Harmattan also affects this area. Only 55 percent of the surface is farmed (including both cultivated and short fallow land). Yields are lower than in the first system, and more variable from year to year. On six farms, nutrients (nitrogen, phosphorus and potassium) were approximately in balance *on average* in 1996, but three of them had significant nitrogen deficits.

5.3.5 Working the land harder

Rural population densities increased throughout the Sahel, during the 30 years, 1961-1990, both in urban hinterlands and in more remote areas (Snrech *et al.*, 1994). Such changes were accompanied by transfers of land from woodland or grassland into farmland and fallows. The conversion of natural woodland into farmland, and the transition from shifting cultivation to permanent fields (with a shortening of fallows), is often represented as degradational. Preliminary data, however, suggest that plant biomass production on cropland compares favourably with that of natural rangeland under comparable rainfall conditions (Mortimore et al., 1999). It is the long term adaptive aim of farmers to stabilise yield decline on cultivated soils, and the means available to them in the past have most often been the use of animals to recycle nutrients and of extra labour to fertilise the fields.

Such 'indigenous intensification' (Adams and Mortimore, 1997), largely accomplished (in the longer term) without benefit of inorganic fertilizers, reflects not merely labour availability, but also the productive potential provided by rainfall and soil nutrients. It is not known whether the full potential of indigenous intensification has yet been exhausted, whereas to depend on imported chemical fertilizers may be both risky and costly to farmers.

5.3.6 Diversifying livelihoods

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To achieve the highest farm labour inputs in peak periods requires a 'strategic waste' of potential farm labour at other times. To minimise risk from crop failure, alternative sources of income are both sought and necessary. Riskiness (arising from rainfall variability), even in the most remote places, merely underlines a need for alternative livelihoods (Ibrahim, 1996). Travel for men to distant places is a condition of entry to some of these activities. Livelihood diversification (see Box), which is associated with high levels of mobility between rural communities and urban or commercial farming zones, has been facilitated by high rates of urbanisation in the Sahel and in the West African region. It does not indicate the failure of farming - on the contrary, in many households, its success.

Box 6: A model of diversification in the household economy

The first step in diversifying out from the farm is into livestock ownership. Scarcely an individual in the four villages (above the age of 12) lacks a source, however small, of income from trading, making articles for sale, or providing services; it is part of being a complete

person. We call such activity 'business', the second step. Outside the farm and household, people pursue other activities, many of which provide income but also have social, religious, or political connotations; the third step.

5.3.7 Adaptation, wealth and poverty

The diversity of circumstances found among households in most dryland communities means that poverty has to be defined in a highly specific way. Indeed, it is scarcely possible to find two identical households, if a few of the following parameters of poverty are considered in combination (rather than in isolation): the endowments of labour and land resources; the level of capitalisation of the farm or other productive enterprises; primary production; market income; the level of food sufficiency; livestock holdings; and access to off-farm incomes. Poverty is traditionally identified, and debated, in terms of economic indicators and poverty lines applied to whole populations. Attempts are being made to improve internationally compatible standards of poverty. But at the micro-scale, strategies for managing or overcoming poverty depend on the circumstantial matrix of particular households.

Figure 3: a simple model of wealth and poverty in Sahelian households

The Nigerian case studies suggest that a circle of livelihood management can be represented, as in Figure 3, which identifies six variables which we consider to be the most important in contributing to a household's relative wealth or poverty:

(1) the labour resource with which a household is endowed, and also its future labour resource (anticipated in having children, especially males, growing up in the house);

(2) the stock of farm capital, such as ploughs, manure, or improvements which, with labour, determine productive capacity;

(3) the productive capacity of the cultivated land to which the members of a household have rights of access (not necessarily by ownership);

(4) the grain stocks held by the household after the harvest is over, which determine the security of the household's subsistence in the coming year;

(5) the livestock owned (or, perhaps, managed) by members of the household, which are used as savings, and their fattening or breeding potential, which is interest on those savings;

(6) a commercial portfolio, comprising business, manufacturing, service or distant options enjoyed by members.

If this is a simple model of *local* causes of wealth or poverty, it must be understood to sit embedded in a larger economic system which dictates, from the outside, many of the terms - for example, access to land is affected by tenure legislation, access to markets is affected by prices, commercial activity is affected by controls, and development project interventions

alter the status quo. If it is also a restricted *economic* model, it must be understood to operate within a specific *social* context which affects the ways in which people can respond to opportunities to better themselves. An assumption that there can be an open system, at village level, where individuals are free to pursue their own advantage without social constraint is almost certainly unrealistic, even today.

5.3.8 Applying the Nigerian experience to India and Southern Africa

It is clear from many discussions with scientists in Indian and Southern African research institutions, farmers and other informed people, that the Sahel is not unique in the broad configuration of the challenges which it poses to its smallholders. Given the dilemma of new knowledge which we identified in Section 2.4 and Figure 2, there are solid grounds for an exchange of experience and an inter-continental debate. This claim is justified in more detail in Annexes A and B.

Negotiating the rain. India has three main dryland areas. That of the north-western Himalayas has a high mountain ecology and will not concern us here. The plains of north-western India however have a graduated rainfall regime, culminating in the Thar Desert, which is strongly analagous to that of the Sahel and carries similar levels of risk for farmers and livestock owners. Its soils, however are different; in particular, a lower coarse sand fraction in the upper profile is thought to account for better moisture retention and the remarkable achievements of farmers who can produce a crop of millet with as little as 120 mm of rainfall. However, negotiating the rain depends not only on labour management during the short growing season, but also on the ownership and management of water buffaloes, for animal-drawn ploughing is more extensive than is usually found in Africa. In the dryland areas of central and southern India, notwithstanding an absence of simple rainfall patterns like that of Rajasthan, rainfall variability is cited universally as the primary constraint facing the very diversified farming systems. Smallholders in Southern African drylands also occupy irregularly differentiated agro-ecological zones which call for location-specific strategies and technologies. Research has not yet exhausted the possibilities of learning from these differentiated strategies which farmers use to manage variable rainfall, and certainly cannot be said to have proven solutions on offer.

Managing biodiversity. Biodiversity conservation, ownership and management is a global theme which threatens to obscure the highly specific nature of biodiversity resources in any community of small farmers and livestock producers. In drylands, the particular relevance of conservation is for banking resources to deal with aridity and moisture variability. Good use has already been made of such resources (for example, the breeding of *Cenchrus ciliaris* fodder grasses at CAZRI, Jodhpur). In indigenous systems of biodiversity management, the poor enjoy access to the full range of community knowledge. The insertion of new genetic material into farming systems has been known to discriminate in favour of persons who enjoy privileged access. The social structures in Africa and India are therefore relevant here. Cataloguing community genetic resources is but a beginning - though there are not many such catalogues in any of our three regions. Strongly developed dynamics in cultivar management in all three reflect both swift indigenous adaptations to change (climatic or economic), and the activities of agencies (public or private) in promoting new genetic material. Research has traditionally favoured scientific breeding approaches, and these are still needed. But the dynamics of biodiversity management need to be investigated at the household level unless we are prepared to allow agents of change to operate untramelled.by any social responsibility.

Integrating animals. Crop-livestock integration is recognised throughout drylands as a potential way forward to higher levels of productivity, with specific benefits for poor households. However, the integration pathways achieved in West and Southern Africa, and in

north-west and central-southern India differ significantly and in at least one important farming system, the maize system of southern Malawi, it has failed (a majority of households own no livestock). A comparative framework for research on animal husbandry by small farmers can link the ancient achievements of high livestock densities and well-integrated systems in India with the dynamics of land use change and animal husbandry in the Sahel, and with the Southern African systems some of which may represent distortions of a theoretically 'normal' integration pathway under a growing population density. It may help to explain why attempts to promote greater integration have met with mixed success.

Cycling nutrients. The technologies of nutrient management under conditions of increasing human and/or livestock population density are of immense importance for the sustainability of all dryland farming systems. Both a better understanding of indigenous practices and evaluations of their impact on the nutrient status of soils, bioproductivity under differing rainfall conditions, and crop output, are needed before bottlenecks can be correctly identified and researched. The place of inorganic fertilization in the low external input systems of poor households requires clarification. The household perspective can bring into focus the differentiation amongst smallholdings whose resources, and therefore their technical options, vary; the linkages between technology and the management of scarce resources of labour and land, and the costs and benefits of the struggle to maintain output and farm livelihoods.Again, the contrast between the comparative stability of India's ancient systems and the dynamics which are observed in Africa is challenging and potentially productive for research.

Working the land harder. The fact that many observers of African farming systems with relatively low population densities have cried 'Degradation!' while those with far higher (and long-established) densities in dryland India appear to be playing out such transitions - if at all - on a far longer time-scale, challenges research. Indeed, there are also challenging contrasts within Africa, such as those in northern Nigeria. Contemporary demographic trends in both continents indicate that urbanization cannot be expected to absorb rural population growth; many people remain in rural areas, or retain strong links with them after migrating (often temporarily) to cities. Even if the demographic transition to lower fertility (which is well advanced in India and just beginning in Africa) accelerates, the future is nevertheless one of increasing rural population densities. In so far as people continue to depend on agriculture for a livelihood, ways and means must be found to produce more from smaller farms. Labour-intensification responds rationally to a diminishing land:labour ratio. Where are its limits? More rigorous definitions and methods are needed to support comparative studies of this issue (Mortimore and Adams, 1999: 96-117).

Diversifying livelihoods. The past role of markets in farming systems in the three regions has been both progressive and divergent. The exploitation of specialised market niches by Indian dryland farmers may have something to teach their counterparts in West Africa, where the production of export crops was never integrated fully into subsistence-oriented systems and has now been replaced (in many areas) by diversification into food production for internal markets. In Southern Africa, smallholders still wrestle with the distortions inherited from a colonial dualism which conceded independent African farmers' access to markets only reluctantly. In both of the African regions, subsistence production appears to be more important to households relative to market production, though the position is changing; perhaps this reflects the greater efficiency of basic food markets in India. These impressions notwithstanding, it is clear that agricultural diversification is critically important in household strategies. Further diversification, off-farm and out of the village, is revealed by household studies as a critical area of adaptive management of risk. In this area are the links with the macro- and (increasingly) the global economy. Such links had the greatest force in Southern Africa, where the tentacles of the South African mining industry reached to every village, affecting the opportunity costs of farm labour and thereby distorting many of the relationships

suggested above for the more autonomous West African systems and the much older Indian ones.

It is contended that the issues briefly surveyed above demand investigation at the household level, a dynamic frame of reference, and a whole-system orientation. These imperatives are discussed further in the following section.

5.4 Generating new knowledge

5.4.1 Households are central

A great deal of developmental research is focussed on supporting decisions by planning or policy makers, development agencies, or other central institutions. However, the best of policies or programme interventions depend for their success on responses at the household or individual level. It is truly astonishing how little understanding of such responses has sometimes been considered necessary before initiating far-reaching interventions.

On the other hand, many researchers disaggregate the household into individuals or groups (women, children, elderly) in order to understand the internal conflict between interests which influences the allocation of resources and the sharing of benefits within it. In support of such disaggregation, it may be claimed that an authoritarian, male-dominated model of the household is no longer appropriate or accurate. While not quarrelling with the use of a disaggregated approach for exploring certain questions, we find that for our objective of linking poverty alleviation with NRM, the household remains the best unit of analysis for four reasons:

- labour resources are defined, in the first instance, in terms of the biological family which is, in most cases, the basis of the household;
- resource access (tenure of cultivated land, rights to use water, cut wood or graze animals) is governed by a set of institutions built upon biological descent and marriage; decisions about NRM, within the limits of the resource portfolios of individuals and families, are taken at this level;
- the division of labour between the sexes as customarily practised relies on complementarity in roles, for example with regard to farming and herding tasks; and
- intergenerational commitments and transfers are extremely important in understanding household decisions about resources.

This does not imply that other scales of analysis (community, district, regional, national or continental) are not useful.

5.4.2 Households are systems

This report therefore makes a case for research on smallholders' production systems in rainfed drylands which adopts an integrated approach to NRM and livelihoods. In the past, many attempts to research and promote new technologies assumed that family farms would resolve the systemic effects themselves: whether labour problems, natural resource conflicts, negative effects on off-farm livelihoods, or technical contradictions. Of course, they will continue to do so. However it is now clear that system constraints have frustrated many technology promotions or development initiatives. It is wasteful for the research community and development institutions to remain ignorant of these interactions.

This rural household system has to be recognised as rational, though constrained (Schultz, 1964). The ways in which the constraints (whether of water, land, soil nutrients, biodiversity, labour, skills, capital, or livelihood options) are managed, and the ways whereby household members attempt to manage changes which originate from outside, are adaptive. Development interventions must therefore be based on some understanding of the nature of these constraints and adaptations. Yet enormous diversity and variability characterise the circumstances of individual households.

We do not intend to conceal the difficulties sometimes encountered in defining economic households, nor the tensions, competition or even conflict that may exist within a household. Rather than an authoritarian model of the household run on the orders of a male head, a model of the household as 'a network of implicit contracts' between its members (Netting, 1993), subject to continuous negotiation, offers an appropriate unit of analysis.

Our labour data were collected for individuals. They are susceptible to analysis in terms of gender, age, occupational or ethnic categories, and some preliminary work has been done. However, we have not probed the decision making process within the household. Our first objective is to understand the household as a 'corporate' manager of its resources. Choice of the household as a unit for analysis is a decision about scale. Scale can affect the conclusions; it is not merely a question of sampling, or of scaling down, or up, as often implied.

Interdisciplinary methodologies must recognise that at this household level, multisectoral decisions and activities are made and carried out by the same people**.** The breadth of competence expected of a household head, and to a lesser extent of other household members, in the management of farming, natural resources, animals, water, technology, subsistence, income diversification and family interests is only apparent on seeking out the linkages and interactions within the system. Single sector interventions cannot readily take account of this. Therefore the policy or intervention response of government, donor or agency, and its supporting research, must be carried out within a multisectoral or systemic context, and not (as too often) professionally specialised to the exclusion of such linkages and interactions.

5.4.3 Household livelihood management focuses on constraints

A focus on the nature of the constraints on livelihoods, and the ways whereby households corporately contrive to manage these constraints, offers a framework for understanding natural resource management. The northern Nigerian studies have highlighted the role of labour management in particular, in patterns of response to unpredictable rainfall during the farming year, to meeting the demands of the multisectoral household economy, and the trade-offs among labour allocative decisions. The other key constraints (over which households can excercise some control) include soil nutrients, biodiversity, and livelihood options. In each, technology, skills, and work play roles.

Such a focus is relevant to poverty alleviation goals. Poverty can be redefined as a resource constraint, but whereas the relaxation of such constraints has proved all but insoluble in semi-arid environments (except in interventions which target large resources on small populations of beneficiaries), the possible optimisation of constraint management raises a set of questions that, we suggest, have not been exhausted yet. The challenge facing research is how to incorporate the immense complexity of household resource management into focussed studies which will yield, in addition to new knowledge about how such systems operate, useful policy or programme recommendations.

5.4.4 Change is endogenous as well as exogenous.

A view of change is needed which is rooted in indigenous knowledge, skills, and dynamism rather than being dependent exclusively on external forcing agents. At risk of oversimplification, it may be said that a colonial contempt for native practice, which led to ignoring or misunderstanding indigenous NRM, followed by a preoccupation among newly independent states with the modernisation of agriculture, created an enduring imbalance in expert interpretations of change. This was further distorted by the degradation debates which followed the African Sahel Drought of the 1970s.

Inventories of knowledge, technologies, and management modes in such key areas as soil, biodiversity and livelihood management provide optional frameworks from which choices are made by households or individuals. Their origin (whether derived from custom, extension, importation or experimentation), their dynamics (diffusion or contraction within the community, extnsion or reduction over time, and interactions with other places), and their control by communities, individuals and households constitute a complex matrix.

The value of such inventories to development agencies seems obvious, but it has often been ignored in programmes initiated by major donors in semi-arid areas. There may be some reluctance to accept that whereas new technologies are generally uniform and simple, indigenous inventories are heterogeneous and complex, and take time to analyse. However in promoting 'improved' technologies, sometimes with a dismal lack of success, it is all too easy to be blind to the subtle adaptive dynamic in the system. In the uncertainty of semi-arid environments, it is more useful for smallholders to have access to a variegated inventory of low cost options than to be precluded (by poverty, labour scarcity, or other constraints) from adopting a high cost promotion, however productive. Technologies that receive acceptance may do so because they extend existing inventories, rather than replacing them.

5.4.5 Research agendas.

The approach we have outlined - the 'S,C&L approach' - differs from conventional social science and technical approaches in certain ways which may be characterised as shown in Table 1. Though simplified, this is compatible with the DFID objective of achieving sustainable rural livelihoods (Carney, 1998).

More specifically, it shifts the focus from questions traditionally raised with regard to some of the more common development interventions (which are by no means unimportant) to a somewhat divergent agenda (Table 2). Many of these 'newer' questions are already familiar and widely accepted. Unstated in the Table is the fundamental question, applicable to all, of the labour requirement at critical times of the year, and the skills required.

Raising farm output as a poverty alleviating strategy has traditionally taken pride of place in research agendas, as the history of colonial agricultural departments and, more recently, of the CGIAR institutions, shows. There have been many dramatic successes, such as (in Africa) Allen cotton, improved groundnuts, and hybrid maize. However, it is by no means certain that such successes will continue, owing to fundamental changes in such factors as the supply of cultivable land, rainfall reliability, soil nutrient supply, world market prices, and the resources of governments afflicted by debt and structural adjustment programmes.

Table 1. The S,C&L Approach Compared with some Traditional Approaches to SAPS Research

	Rural Livelihoods System Approach	**Social science approach**	**Technical constraint approach**
Disciplinarity	Interdisciplinary	Social science discipline	Technical discipline
Unit of analysis	Decisions at household level	Economy of household	Technical decisions by individuals at field/production unit level
Sectoral orientation	Multisectoral approach to farming, livestock production, business, out-of-village occupations	Input costs; returns from production and their distribution	Sectoral output enhancement and sustainability: crops, livestock, forestry
Constraints	Management of labour, resource, technical and livelihood constraints by households	Allocation of resources within and between households	Technical solutions to output/ production constraints
Systemic framework	Operation of WHOLE biological AND economic system	Economic/social system , but not the environmental context	Natural resource management, but not the social/economic context
Principal concern in production system	Productivity AND sustainability	Distribution of wealth, income, power	Productivity

Table 2. Some Research Agendas

Research area	Some traditional questions	Some newer questions
Genetic resources	Germplasm collections divorced from management context Breeding experiments Productive potential, resistance Promotional methods	Inventories of known cultivars in management context Seed management as practised Preferences and uses Social participation and control Participatory interventions
Livestock resources	Improved breeds Productive potential, resistance Production economics	Inventories of local multipurpose breeds Preferences and uses Breeding methods and problems Social participation and control Participatory interventions
Crop production systems	Improved agronomy Optimal cropping patterns Fertilization - usually inorganic Post-harvest improvements	Reasons for local practices Crop mixtures and interactions Fertilization - nutrient cycling Linkages with land & labour use Social determinants of technical change
Feeding systems	Carrying capacity Controlled range management Introduction of fodder crops	Diverse fodder sources Seasonal calendars, herd mobility, grazing rights Labour needs
Crop-livestock integration	Mixed farming packages Rational feed management	Plough introduction, driving forces and benefits Management of livestock for multiple objectives Crop residue management Labour needs vs crops
Soil fertility management	Nutrient balances Fertilization - usually inorganic Nutrient transfers from range to farmland	Nutrient cycling through stock Nutrient cycling within the farm, eg compost
Soil and water conservation	Expert assessment New technologies Testing and monitoring Promotion	Indigenous technologies, if any Conditions for private or community investment Constraints on access to new technologies Benefits of new technologies
Trees and biodiversity	Centralised forestry regulation Protection of CPRs Protection of trees on farms	Indigenous inventories and uses Attitudes to conservation Effects of land use change on trees and biodiversity
Marketing systems	Access to formal product markets Prices, costs and infrastructure	Informal market systems Social access and benefits Market - food sufficiency trade-offs
Off-farm incomes	Outside the farm sector	Inventories of options Migratory participation Social access, costs and benefits Off-farm - farm trade-offs Trends and external determinants

Development approaches based on promoting technologies to increase output as a solution to poverty have fallen on the horns of several dilemmas, for example:

- new technologies, though technically proven under experimental conditions, have sometimes failed to generate the returns necessary to justify investment on semi-arid smallholdings;
- their *insertion* into *systems* has generated unanticipated systemic effects, often to do with labour management;
- they have sometimes addressed the wrong questions, owing to inadequate local participation in the prioritisation and design of projects;
- they fail to address variability, and thereby sidestep the greatest challenge facing semi-arid smallholders.

The most important qualification to a strategy of raising output to alleviate rural poverty is that its benefits may not be felt by those most in need unless its systemic impact is anticipated. In the same way, technologies for sustainable NRM may not be taken up by the poorest households, whose inability to invest or to innovate is a defining parameter of their poverty. It is therefore necessary to take a broader approach to semi-arid household systems, and to focus, as we have suggested, on the constraints under which they operate *in all sectors*.

6. Contribution of Outputs

6.1 Contribution to DFID Development Goals

This study has sought to contribute to the RNRRS **purpose** of increasing productivity in semi-arid production systems through applying system-wide approaches. It has sought to do this by setting out a methodology used in recent research in Nigeria and exploring its relevance to development-oriented research in semi-arid areas of Southern Africa and India. It is anticipated in this way to contribute to the effective and efficient use of research in support of both (a) development projects or programmes and (b) policy development.

It has been a specific aim of this study to explore social, economic and institutional dimensions of the systems, taking into account the nature of the interactions between the system components (labour, nutrients, biodiversity, livelihood choices). The work relates directly to DFID's commitment to the promotion of 'sustainable livelihoods' (Carney 1998). These are shown in Table 3.

Table 3. DFID Objectives for Sustainable Rural Livelihoods

To promote sustainable livelihoods through:

- more secure access and better management of natural resources
- a more supportive and cohesive social environment
- more secure access to financial resources
- improved access to high-quality education, information, technologies and training and better nutrition and health
- better access to facilitating infrastructure
- a policy and institutional environment which supports multiple livelihoods strategies and promotes equitable access to competitive markets for all.

(Source: Carney 1998, p. 12)

6.2 Promotion Pathways

The institutions at whom the output of this research is targeted consist of those conducting research on farming, livestock, livelihood and natural resource management systems in semi-arid areas in three regions, West Africa, Southern Africa and dryland India. Specifically:

- those in in-country governmental agricultural research institutions
- those in in-country university research institutions
- those in in-country non-governmental organisations
- those in UK and other donor country research and university institutions
- policy-makers in DFID and other first world donors and international agencies
- researchers for DFID, particularly the "Semi-Arid Group" coordinated by NRIL
- those in international NGOs

Promotion of outputs will continue after the end of the project through usual channels of scientific and research communication, and if appropriate through working papers for professionals, agencies, communities.

A need for interaction between researchers and research institutions in different countries and continents follows from the commonalities of semi-arid ecosystems, notwithstanding their known diversity. A need to re-orientate some research towards a systems framework is stated in the RNRRSP's purpose. The arguments set out in this report are intended to be an input to the debate on how to proceed.

Possible follow-up action includes:

(a) revision and presentation of research outputs in a form appropriate for a wider readership;

(b) distribution of the document to researchers and research institutions in Southern Africa, India, the UK and elsewhere (as appropriate) for their critique (Researchers interviewed in India, Zimbabwe and Malawi expressed interest in receiving copies of the report);

(c) at a later date, a representative workshop or conference could be organised to review the objectives, methods, and developmental application of system-wide research in SAPS. This workshop would have to be the subject of a separate funding application, and appropriate staffing.

6.3 Output Products

Seminars

Harris, F. (1998) 'Nutrient Cycling or soil mining in semi-arid West Africa?' Paper to SAPS Catchment Management Project Stakeholder Workshop, Masvingo, Zimbabwe, March 1998.

Harris, F. (1998) 'Nutrient Cycling Studies in Northern Nigeria', seminar to Central Research Institute for Dryland Agriculture, Hyderabad, May 1998.

Adams, W.M. (1998) Presentation on R6051 (Soils, cultivars and livelihoods) and R7093 (Dryland Farming Systems in India and Southern Africa) to Semi-Arid Mini-PAC, October 1998.

Adams, W.M. (1998) 'Drought from the inside: farm work and rainfall in the Nigerian Sahel', invited lecture, Chair's Session, Royal Geographical Society with the Institute of British Geographers Annual Conference, Kingston University, January 1998.

Mortimore, M. (1998) 'Flexibility, adaptability and diversity in dryland livelihood systems', Seminar Institute of Environmental Studies, University of Zimbabwe, December 1998.

Adams, W. (1999) 'Whose drought? rain, crops and farm labour in the Nigerian Sahel', paper to Conference on 'African Environments, Past and Present, St. Anthony's College, Oxford, July 1999.

Mortimore, M. (in press) 'Resoure management for dryland agriculture', in Belshaw, D. and Livingstone, I. (eds.) Volume of proceddings on the fourth SCUSA Inter-University Colloquium on African Studies, University of East Anglia, September 1999.

Reports and Papers

The following list of publications includes selected outputs from the Nigerian studies that preceded R7093 in Nigeria, R6051 (Adams and Mortimore) and R6603 (Harris), where these have been published since the start of R7093 and incorporate insights derived from this project.

A. Published Books, Journal Papers and Book Chapters

Adams, W.M. and Mortimore M.J. (1997) 'Agricultural intensification and flexibility in the Nigerian Sahel', *The Geographical Journal* 163 (2) (July 1997)

Harris, F. 1998 Farm-level assessment of the nutrient balance in northern Nigeria. *Agriculture, Ecosystems and Environment* 71, 201-214

Harris, F.M.A. (1999) 'Nutrient management strategies of small-holder farmers in a short-fallow farming system in north-east Nigeria', *Geographical Journal* 165: 275-85.

Mortimore, M., Singh, B.B., Harris, F. and Blade, S.F. (1998) 'Cowpeas in traditional cropping systems', in B.B. Singh, Mohan Raj, D.R., Dashiell, K.E. and Jackai, L.E.N. (Eds.) *Advances in Cowpea Research* International Institute for Tropical Agriculture and Japan International Research Centre for Agricultural Sciences, Ibadan, Nigeria, pp.99-1113.

Mortimore, M. and Adams, W.M. (1998) 'Farming intensification and its implications for pastoralism in northern Nigeria', pp. 262-273 in I. Hoffman, M von C. Schäfer, J. Steinbach, C. Willeke-Wetstein (Eds.) *Prospects for Pastoralism in West Africa*, Giessener Beiräge zur Entwicklungsforschung, Tropeninstitut Giessen.

Mortimore, M.J. (1998) *Roots in the African Dust: sustaining sub-Saharan Africa's Drylands*, Cambridge University Press, Cambridge

Mortimore. M. and Adams, W.M. (1999) *Working the Sahel: environment and society in northern Nigeria*, (Routledge, London, 226 pp.).

B. Papers in Press

Busso, C., Devos, K., Ross, G., Mortimore, M., Adams, W.M., Alldrick, S., and Gale, M.D. (in press) 'Genetic diversity among landraces of Pearl Millet (*Pennisetum glaucum* (L.) R.Br.) under farmer management in a Sahelian cropping system', forthcoming in *Genetic Resources and Crop Evolution*

Mortimore. M. and Adams, W.M. (in press) 'Farmers adapting to change', forthcoming in *Global Environental Change*.

Mortimore, M., Harris, F.M.A. and Turner, B. (in press) 'Implications of land use change for the production of plant biomass in densely populated Sahelo-Sudanian shrub-grasslands in north-east Nigeria', *Global Ecology and Biogeography Letters* in press

Harris, F. (in prep.) 'The nutrient balance approach to studying farming systems' (journal paper in preparation)

Mortimore, M. (in prep.) 'Households, livelihood systems and the management of change in semi arid production systems' (journal paper in preparation).

Mortimore, M. (in press) 'Overcoming variability and productivity constraints in Sahelian agriculture', Chapter 13 in Benjaminsen, T.A. and Lund, C. (eds.) *Politics, property and production in the West African Sahel: approaches to natural resource management*.

C. Other Published Papers

Adams, W.M. and Mortimore M.J. (1997) 'Environmental security in the Nigerian Sahel', *Development Research Insights* 21 March 1997: 2

Chiroma, A.C., Ibrahim, A.M., Mohammed, S., Yusuf, M, Mortimore, M., Adams, W., and Falola, J.A. (1997) *Farming Systems in the Nigerian Sahel*, Haramata (IIED Drylands Network).

Harris, F. (1998) *The relevance of research on nutrient cycling in small-holder farming in Nigeria to small-holder farming in the semi-arid tropics of India*, CORD, University of Durham (unpub. report).

Salisu, M. *et al.* (1997) *The hidden harvest: the role of wild foods in agricultural systems. Local-level assessment of the economic importance of wild resources in the Hadejia-Nguru Wetlands, Nigeria*. London: IIED.

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