

Open Research Online

The Open University's repository of research publications and other research outputs

The Green Revolution and Food Security in Africa: Issues in Research and Technology Development

Other

How to cite:

Woodhouse, Philip (1988). The Green Revolution and Food Security in Africa: Issues in Research and Technology Development. DPP Working Paper 10; Development Policy and Practice Research Group, Faculty of Technology, The Open University.

For guidance on citations see [FAQs](#).

© [not recorded]



<https://creativecommons.org/licenses/by-nc-nd/4.0/>

Version: Version of Record

Link(s) to article on publisher's website:
<http://dx.doi.org/doi:10.22004/ag.econ.295263>

Copyright and Moral Rights for the articles on this site are retained by the individual authors and/or other copyright owners. For more information on Open Research Online's data [policy](#) on reuse of materials please consult the policies page.

oro.open.ac.uk



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Tou

DPP W.P. no. 10

GIANNINI FOUNDATION OF
AGRICULTURAL ECONOMICS
LIBRARY

WITTED KAWIN
AUG 31 1989



dpp

DEVELOPMENT
POLICY AND
PRACTICE

THE OPEN UNIVERSITY.



TOU

DPP W.P. no. 10

GIANNINI FOUNDATION OF
AGRICULTURAL ECONOMICS
LIBRARY

WITTEDRAWN
AUG 31 1989



dpp

DEVELOPMENT
POLICY AND
PRACTICE

THE OPEN UNIVERSITY.

THE GREEN REVOLUTION AND
FOOD SECURITY IN AFRICA:
ISSUES IN RESEARCH AND
TECHNOLOGY DEVELOPMENT

by

Philip Woodhouse

DPP Working Paper No.10

Development Policy and Practice Research Group

Faculty of Technology

The Open University

January 1988

THE GREEN REVOLUTION AND
FOOD SECURITY IN AFRICA:
ISSUES IN RESEARCH AND
TECHNOLOGY DEVELOPMENT

by

Philip Woodhouse

DPP Working Paper No.10

CONTENTS

	Page
1. INTRODUCTION	1
2. THE DIAGNOSIS OF LOW FARM PRODUCTIVITY IN AFRICA	2
3. FARMING SYSTEMS RESEARCH AND FARM TECHNOLOGY DEVELOPMENT	6
4. TECHNOLOGICAL CHANGE TO INCREASE FARM OUTPUT: THE ROLE OF WATER CONTROL	10
5. PAST IRRIGATION PERFORMANCE IN AFRICA	17
6. CURRENT POLICIES AND DEVELOPMENTS IN IRRIGATED FARMING IN AFRICA	25
7. ISSUES IN THE DEVELOPMENT OF IRRIGATION FOR INCREASED FOOD PRODUCTION	29
8. FUTURE DIRECTIONS FOR RESEARCH	35

Philip Woodhouse is a research fellow with the Development Policy and Practice Research Group. He has previously worked on problems of soil productivity and on farming systems research in Mozambique.

Acknowledgments

Many thanks to DPP colleagues, and in particular to Maureen Mackintosh, Ben Crow, and Dave Wield for helpful discussion of earlier drafts of this paper.

1. INTRODUCTION

This paper has been written following a period of eight years in which the author was engaged in agricultural research in Africa. Its purpose is to review current research and development trends in farm technology, and to identify the directions which future research should pursue in order to promote food security in Africa.

Although the paper seeks to make explicit the socio-economic dimension in technological change, it has been written from the perspective of an agricultural scientist and is restricted to a survey of those issues considered to directly affect the technology of crop production. This approach has been consciously adopted for two reasons. Firstly, because a technological 'green revolution' is widely sought as the long-term solution to current African food deficits. Secondly, because, although many socio-economic studies have shown in detail why past attempts to promote technological innovation in African agriculture have had negative outcomes, control over future initiatives remains largely in the hands of agricultural scientists, who decide the 'feasibility' of options for technological change. It is this process of feasibility assessment that this paper attempts to address.

In the paper, a brief survey of recent research and development trends in African agriculture is followed by a more detailed discussion of the question of improved water control, which the paper argues must play a central role in increasing agricultural productivity in many parts of Africa. Finally, the paper identifies

weaknesses in present research and development approaches, and outlines research priorities to overcome these weaknesses.

2. THE DIAGNOSIS OF LOW FARM PRODUCTIVITY IN AFRICA

The most commonly encouraged diagnosis of the problem of chronic African food deficits is that, although sparsely populated compared to other continents, Africa has fast-growing population which has outstripped the traditional production of food by small-scale African farmers. As a consequence, food output per head of population is declining in many African countries south of the Sahara (IBRD, 1981; USDA, 1982). In this diagnosis African agriculture is frequently referred to as 'stagnant', with low productivity, evidenced by statistics showing low average crop yields per hectare in Africa compared to Asia or Latin America, attributed to low levels of agrochemicals and machinery use (see, for example, FAO, 1981).

The failure of African farmers to invest in more productive technology has been ascribed to pricing and marketing policies which embody an 'urban bias' unfavourable to farmers: high urban wages, low retail food prices, and an overvalued currency which makes food imports cheap and reduces the incentives to produce agricultural crops for export. This diagnosis, which forms the basis of some aspects of the economic adjustment programmes currently being implemented by African governments, assumes that altered pricing and marketing policies will encourage farmers to invest more in agricultural production. However, while it is implicit in this assumption that more investment will involve a change in farm technology in order to achieve higher output (Christiansen and

Witucki, 1982), there is much debate as to what that technological change should be. At the heart of this debate is the widespread acknowledgement that previous attempts to 'transfer' technology to African farmers have largely failed to improve food output.

It is this failure which underlines the image of stagnation so frequently applied to African agriculture and which tends to obscure the many changes that have occurred in African farming patterns over the past century. But the factors that had the greatest impact during that period were the introduction of new crops and the development of new markets (Hill, 1986; Richards, 1986). Thus, for example, the expansion of production of perennial crops like cocoa, coffee, tea and oil palm in the humid areas and annual crops like tobacco, cotton and groundnut in drier areas had profound effects on small-scale African farming systems, including those producing staple food crops. However, until the late 1950's the technology employed in growing these crops was based mainly on indigenous farming skills. Subsequently, the use of imported pesticides and fertilizer has become relatively common among small-scale farmers growing crops for overseas markets. It is in the production of staple food crops that efforts to introduce non-indigenous technology have largely failed. Notable in this failure were the attempted introduction of large scale tractor cultivation for cereal production in West Africa during the 1950's and 1960's, and the introduction from Asia of 'green revolution' technical 'packages' (high-yielding crop varieties grown with fertilizer and irrigation) for millet, sorghum and rice during the 1970's (USDA, 1982).

This failed promotion of technological change brings into question agricultural scientists' perceptions of the constraints to agricultural productivity under African conditions which the proposed technology was intended to remove or reduce. In practice these perceptions have tended to reflect the discipline background of researchers, with biological disciplines emphasising declining soil productivity as a consequence of land shortage, while economists and social scientists have stressed labour shortage as the principal constraint.

According to the former view, the problem is that traditional African farming methods require land to lie fallow for 3-5 years for every year of cultivation in order to maintain productivity. Increasing population has increased the area cultivated and hence reduced the area available for fallow, so that fallow periods are shorter and soil productivity less. The resultant decline in crop yields requires a greater area to be cultivated in order to achieve the same output, exacerbating the reduction in fallow and precipitating a spiral of land degradation which results in irrevocable ecological damage. This, in essence, is the analysis of African farming put forward by agencies such as FAO (FAO, 1986), and provides the justification for much of the agricultural research carried out in Africa, which is directed at increasing per hectare crop yields (e.g. Okigbo, 1984). However, there is reason to question the usefulness of this analysis as a basis on which to design and evaluate technological innovations for African agriculture.

Firstly, although land degradation is widespread in Africa, it is not always caused by an increase in population, but also by changes in

farming patterns in response to agricultural policy or market changes. The expansion of groundnut cultivation in the Sahel during the 1960's is a well-documented instance of such a process (Franke and Chasin, 1981). Secondly, the empirical evidence concerning the reduction of fallow periods and the effects of shorter fallows on yields is very weak. As noted in the report which provided the technical criteria for FAO's study of population-supporting capacity of tropical agriculture, very few experiments have in fact been carried out to determine critical cultivation/fallow ratios (Young and Wright, 1980). Recent survey work in Northern Nigeria has indicated, moreover, that similar cultivation/fallow ratios may be found in areas with very different population densities, due to different farming systems employed (Abalu *et al.*, 1987). This indicates that cultivation/fallow ratios are, by themselves, probably a poor guide to the intensity of land use.

Finally, seasonal agricultural labour shortages are commonly reported in areas of Africa with high population densities (e.g. Nweke, 1980; Callear, 1984). Detailed studies of African farming have repeatedly demonstrated that labour demand in rainfed agriculture is highly seasonal, and that those engaged in farming invariably have other sources of income which may involve seasonal migration either to urban areas or to other rural areas (Norman, 1967, 1972; Norman *et al.*, 1976; Longhurst, 1984; Haswell 1963; Spencer and Byerlee, 1977; Low, 1986). Furthermore, seasonal work in agriculture must compete for labour with non-seasonal jobs in mining, industrial and urban areas. Migration to earn wages in these areas, whether temporary or permanent, constitutes a withdrawal of labour from agriculture and may result in a reduction in the area of land cultivated,

particularly where this involves clearing bush fallow (Haswell, 1963; Tommy, 1984). On the other hand, in some cases income from non-farm work may be used to finance farming (van der Laan, 1984; Low, 1986).

These considerations indicate that continent-wide or country-wide generalizations based upon 'population pressure' concepts are unlikely to be useful as a basis for assessing the needs for technological change in African farming. While land shortage is in some areas important, any adoption of new farm technology will be strongly influenced by the pattern of earnings in rural areas: through its effect on the structure of the farm labour force, and through the fact that increasing agricultural output is not normally the only option for those engaged in farming to increase their income. There is recent evidence that past emphasis upon land productivity and yield-increasing technology in agricultural research is becoming more widely superseded by the view that increased labour productivity is the key criterion for technological change to increase African food production (Binswanger, 1986; Low, 1986; IFPRI, 1987).

3. FARMING SYSTEMS AND FARM TECHNOLOGY DEVELOPMENT

Recognition that failure to improve African farm productivity was due in part to inadequate understanding of constraints in existing African farming has led over the last decade to a re-evaluation of agricultural research methodology. Two manifestations of this are the development of farming systems research (FSR) in the research mainstream embodied in the Consultative Group on International Agricultural Research (CGIAR), and the parallel increase in awareness

of indigenous African agricultural management techniques exemplified in the writing of Richards (1985, 1986). Both these developments seek to foster research that is more closely guided by farmers' resources and priorities, and that allows a greater degree of participation by the farmers themselves.

Farming systems research now forms part of the programmes of all the International Agricultural Research Centres (IARCs) funded through the CGIAR (1). Methodologies vary, but that which has been most widely disseminated, particularly in southern and eastern Africa, was developed by the economics programme at Centro Internacional de Mejoramiento del Mais y Trigo (CIMMYT) in Mexico, and was based on concepts developed at a number of central American research establishments (2) as a response to the finding that 'improved' technology packages were often rejected or only partially adopted by small-scale farmers.

CIMMYT has been promoting FSR in Africa for about 10 years (Collinson, 1981) and its methodology emphasises interdisciplinarity of approach, both in terms of the broad range of information which it uses and in terms of the discipline skills required in research teams (Byerlee et al, 1980, 1982). A second emphasis which distinguishes this method of FSR from much previous agricultural research is that of working on farmers' fields, both for the purpose of identifying productivity constraints and for the evaluation of alternative technologies. Two further key aspects of CIMMYT's method are the subdivision of farmers into target groups ('recommendation domains') within which each farmer's resources for, and responses to, technological innovation are thought to be similar, and a rapid

turnover of information (about three months for a cycle of survey and analysis). This latter is considered important to allow the FSR programme to have an early impact upon related research and extension policy, and there can be little doubt that this promise of quick results strengthened the appeal of FSR to funding agencies and assisted its spread. However, there is evidence to suggest that in the practical application of FSR, a number of unresolved difficulties weaken its impact on technology development for food crop production.

Some of these difficulties are institutional. The interdisciplinarity of FSR has been found to create tensions within established research institutions (Collinson, 1981; Okigbo, 1984), and between researchers with different disciplinary methodologies and perceptions (Rhoades et al, 1986). Clearly, one way that these tensions may be resolved is for the interdisciplinarity of FSR programmes to be reduced. Indeed, Norman and Baker (1986) comment that FSR programmes are often in practice engaged in determining not 'constraints to production' but 'constraints to adoption' of a rather narrow range of technological alternatives determined by the discipline background of the researchers or the research mandate (e.g. crop type) of the institution running the programme. A similar point is made by Chambers and Jiggins (1986).

A further unresolved difficulty in the implementation of FSR is that it 'is asked to do more in a national setting than in the research centre' (Norman and Baker, 1986). More specifically, it may be expected to take into consideration questions of rural welfare, rather than agricultural productivity alone. While there is a danger that broadening the scope of FSR beyond agricultural activity might

produce the same lack of focus that defeated the earlier 'integrated rural development projects', it is clear that the FSR concept of the 'farm-household' as an economic decision-making unit capable of allocation to one of several independent 'recommendation domains' is severely distorting in many African contexts. In particular it risks ignoring intra- and interhousehold economic relationships which may strongly influence the adoption of changes in farm technology. Work on gender issues in Africa has highlighted the need to question the unity of decision-making within the 'farm-household' and to take into account intra-household conflicts of interest over the adoption of technological change (e.g. Moock, 1986; Carney, 1988). It is not clear, however, how such an awareness will manifest itself in FSR methodology. Certainly, in the 'new farm-household economics' (Low, 1986), which is intended to provide FSR with a broader economic analytical framework to predict the technology adoption behaviour of African households with off-farm wage income as well as farming activities, it is assumed that the economic activity of individual household members is so as to optimise the income of the household as a unit. However, research elsewhere has shown that this is not what happens (Jones, 1986).

An assumption implicit in the division of farmers into 'recommendation domains' is that technological change undertaken by farmers in one 'domain' will not affect farmers in other 'domains'. However, the experience of the 'green revolution' in Asia was demonstrably the reverse (Pearse, 1980). Moreover, as will be argued below, although land shortage may not play the same role in Africa as in Asia, there are aspects of the development of controlled water resources for crop production, which indicate that interhousehold or

interfarmer relationships will be key factors determining the pattern of technological change in Africa.

4. TECHNOLOGICAL CHANGE TO INCREASE FARM OUTPUT; THE ROLE OF WATER CONTROL.

It has been stated above that the pronounced seasonality of rainfall in much of Africa has a profound effect on the pattern of labour use in rainfed farming. For any given crop, labour use is concentrated in 'peak' periods of relatively short duration: typically 30-50% of total annual labour is expended in a 2-3 month period. As noted above, this pattern of labour absorption in agriculture creates needs and opportunities for non-farm income. Studies in northern Nigeria (Norman, 1967, 1972; Norman et al, 1976) and Zimbabwe (Shumba, 1985) indicated that non-farm income represented 20-30% of total income of those cultivating the land. In addition to this effect of the short duration of the season for agricultural employment of labour, rainfall uncertainty during the growing season plays a major role in technology development. In Africa south of the Sahara only about 42% of the area has a climate classified as 'moist sub-humid' or 'humid', in which drought risk is moderate or low (FAO, 1986, annex II). The remaining 58% has a high drought risk (3), which introduces a high degree of risk into investment in rainfed farming.

The need to minimise risk and to spread labour use during the available growing period are recognised as factors shaping indigenous African farming patterns such as intercropping, sequential planting, and the distribution of crops between plots with different soils and topographical positions (catena farming) (Richards, 1986). Recently,

it has also come to be recognised by irrigation engineers that such farming patterns often incorporate methods of controlling the water regime of crops so as to extend the growing season (Underhill, 1984; Kay et al, 1985). The social organisation and usufruct land tenure system found in much of Africa may be seen as underpinning these farming methods. Thus, the organisation of production by means of land tenure rights has often been cited as a major factor conditioning technologies adoption. Most frequently, it has been argued that usufruct land tenure constitutes an obstacle to the adoption of 'improved' farming practices involving investments such as fertilizer application. It is less frequently observed that for farmers using indigenous management techniques, the 'consolidation' of small dispersed plots into a single, larger plot for each 'family', would almost always reduce the range of soil types and water regimes available to each farmer and hence reduce the scope for the diversified production patterns necessary to minimise peaks of labour use.

When considering strategies to improve farm output, emphasis may therefore be given to:

- reorganisation of production, in order to achieve more efficient use of inputs or land at a given level of investment;
- or
- increased investment of inputs or land in production, while maintaining the organisation or production unchanged.

While in practice reorganisation and increased investment are often undertaken together, the balance of emphasis between the two may have

profound consequences on the options available for technological change.

Past attempts to improve output by reorganisation of farming in Africa have invariably involved higher investment which has not proved economically viable for the production of food for local markets. In particular, efforts to develop large scale mechanization of cereal production in the early West African cases mentioned above, as well as in the more recent state-financed schemes in Tanzania, Mozambique, and Ethiopia, have had to be curtailed or operated with subsidies from the state or overseas 'donors'. In these state-run schemes inexperienced management was partly responsible for low productivity, but the difficulty of paying for a high proportion of production costs with scarce foreign currency is illustrated by comparisons of U.S. and Zimbabwe (Commercial Farmers Union) farm costs, which in 1980 showed a 21% cost advantage for U.S. farmers, despite higher per hectare yields in Zimbabwe (Stanning, 1983). Where European settlers use large scale mechanised technology for cereal production, as in Zambia and Zimbabwe, local producer prices tend to be high (Christiansen and Witucki, 1982). Similar difficulty appears to be experienced by corporate commercial interests who, although operating mechanised farming in Africa for overseas markets (sugarcane, tobacco, cotton) are likely to be involved in food production for local markets only where supported by multilateral 'donor funds' to guarantee foreign currency for input purchases (Dineham and Hines, 1983).

The difficulty of financing the reorganisation of food production using large scale tractor technology has the consequence that food

production for African markets remains the preserve of the small-scale farmer. With the exception of the development of smallholder production in irrigation schemes, which is discussed below, policies to improve food output by these farmers in the past decade have been largely directed towards increasing their investment, rather than changing their organization. However, the high risk associated with this investment has resulted in low rates of adoption of many 'improved' technologies. Part of this risk has been due to distribution and marketing uncertainties, but, as noted above, erratic rainfall establishes an environment where any increased investment in agriculture that does not improve water control constitutes an increase of risk. As a result, technology development 'for the small farmer' in Africa has had to incorporate the need for costs lower than those of the 'green revolution' high-yielding variety + fertilizer + pesticide 'packages' produced for irrigated smallholdings in Asia during the late 1960's and early 1970's.

However, the search for more productive low-cost and low-risk technologies for rainfed farming in Africa has had limited success. Thus, although in higher altitude areas of eastern and southern Africa, where rainfall is relatively dependable, hybrid maize varieties developed for European settler farms are commonly grown with fertilizer by smallholders, this is rather exceptional. Furthermore, as observed by Low (1986), use of this higher yielding technology does not necessarily result in an increase in marketed food output, as, in at least some areas, the reason for its adoption appears to be to reduce the labour required to produce food for own consumption. In general, current work on the development of genetically improved crop varieties lays less emphasis on a potential

for high yields with fertilizer use, and more upon tolerance of suboptimal environments. In particular, breeding programmes have sought to develop disease and pest resistance, and characteristics such as earlier maturity, which allows greater flexibility of planting dates and hence wider scope of response to rainfall uncertainty. Recent years have also seen the development of breeding programmes for previously neglected crops grown traditionally in areas with poor rainfall and soils, such as IITA's cowpea programme and ICRISAT's centre for sorghum and millet established in Bulawayo in 1985. Some promising results of this approach are the release by IITA of weevil-resistant sweet potato, mosaic virus-resistant cassava, streak virus resistant maize, and cowpea varieties with tolerance to important insect pests (thrips). Once seed or cuttings of these varieties have been acquired by farmers, they may be multiplied on the farm. Therefore, such genetic material potentially constitutes a technology which widens farmers' options for improved output without increasing their risk-exposure, because the additional investment required in terms of labour or cash is low. Other technologies proposed for small-scale farming in Africa require higher levels of investment, however, as reviewed briefly in the remaining paragraphs of this section.

Fertilizer costs continue to be high and availability uncertain due to a high foreign exchange component in manufacturing and raw materials cost if not imported as finished products, and high distribution costs. The use of locally-derived manure is widespread in Africa, but generally inadequate. Outside the humid forest zone forage is scarce, and work in Botswana (Herbert, 1983) and Zimbabwe (Rodel and Hopley, 1973) suggests that 10-12ha of grazing land may be

necessary to provide the 4t manure required to maintain the productivity of 1ha of arable land, which may imply high labour costs for herding and carting manure. Moreover, as crop response to fertilizer or manure is strongly dependent on adequate moisture for plant growth, the risk of cash or labour invested in this technology is directly related to rainfall uncertainty.

Systems of annual food crop production in conjunction with perennial shrubs have been developed recently, notably the alley cropping system at IITA, as a solution to the forage shortage and as a means of maintaining soil productivity under continuous cultivation (Kang et al, 1981, 1984; Okigbo, 1984). However, although steps have been taken to introduce the system to farmers in southern Nigeria (Attah Krah and Francis, 1987), it is too early to assess its impact on food production. There are also no published data on labour productivity in this system.

The caution needed in relation to this type of technology introduction is nowhere clearer than in the case of animal draught. Attempts have been made to introduce the ox-drawn plough into African agriculture since early in the colonial period. Adoption has been very uneven, however, and appears to depend upon the amount of manual labour that is saved by its introduction (Pingali et al, 1986). Broadly-speaking, where soils have a high clay content and require a large labour input for their cultivation, ox-draught has often been adopted. Where soils are sandy and easily cultivated by hand, or where forage is scarce and animals have to be herded over long distances ox draught has failed to substitute hoe-cultivation (Delgado and McIntire, 1982). There is evidence that even in areas

where animal draught use is common the investment required is greater than many farmers can afford, giving rise to efforts to develop cheaper forms of animal draught use, such as the single-ox plough being tested by ILCA in Ethiopia (ILCA, 1986), and an ox-drawn ripper tine being experimented in Zimbabwe (Shumba, 1984). The widespread rejection by African farmers of animal-drawn wheeled tool carriers, such as the 'tropiculteur' developed as appropriate technology for West Africa, appears due to similar reasons: they concluded that a single large investment in a multiple purpose implement was a greater risk than a number of smaller investments in conventional implements (Starkey, 1987).

This brief review indicates that, with the possible exception of some new crop varieties, technologies 'for the small farmer' not normally associated with high costs or importation of inputs (as is the case with, for example, pesticide use) often imply increased investment of labour and/or cash in the production process. Whether this investment takes place depends on the precise physical and socio-economic circumstances within which the farmer operates, which determine also the level of risk that attaches to that investment. It was stated above that in well over half of sub-Saharan Africa uncertainty of the length of the growing season and the rainfall distribution within it constitute the major risk in farming. The remaining sections of this paper explore the way in which attempts have been made to increase water control in African agriculture, and the issues this raises for future prospects of increased food output in Africa.

5. PAST IRRIGATION PERFORMANCE IN AFRICA

In a number of recent reviews (Hocombe et al, 1986; Kay et al, 1985; Underhill, 1984; Moris et al, 1985) various terminologies have been used to describe different types of irrigation in Africa. In order to avoid confusion, the terminology used in this paper will be as follows:

- 'formal sector' irrigation uses 'modern' technology, such as dams, canal systems and pumps in order to obtain more or less complete control of surface or groundwater application to crops, and usually has involved external agencies in design, construction, and finance of the scheme.

- 'informal sector' irrigation uses indigenous technology such as planting with advancing or receding floods in river valleys, swamp cultivation, stream diversion, and the use of shallow groundwater with or without wells. These techniques may achieve only partial control of the amount of water received by the crops, and are generally organised by farmers without reference to external agencies.

While these definitions refer to different water control techniques in the formal and informal sectors, it is important to note that these are not exclusive. Thus, formal irrigation includes schemes for partial flood-control (e.g at Mopti, on the Niger river), and informal irrigation includes canal systems (e.g. in the Kilimanjaro area of Tanzania). The essential distinction between the two sectors is, therefore, that in the informal sector the water control technology is originated by small-scale farmers and is managed by

them, whereas in the formal sector control of the technology lies elsewhere.

5.1 The 'formal sector'

The formal sector has been estimated to correspond to about half of the total irrigated land (2.64 million out of 5.02 million ha) in sub-Saharan Africa (Hocombe et al, 1986), although this estimate is recognised as being very tentative. The sector includes areas farmed as estates, as smallholder schemes, and those farmed by European settlers. Approximately 50% of the area in this sector is estimated to produce food crops (Hocombe et al, 1986).

Irrigated estates, run by the state or by foreign corporate commercial interests, produce sugar, cotton, and fruit (e.g. pineapples and citrus) all or in part for overseas markets. As noted above, with the exception of some state farms in Tanzania and Mozambique, large-scale estates do not produce food for local markets.

Irrigation is a fundamental aspect of farming by European settlers in Zimbabwe and South Africa. The 90 000ha of irrigation on settler farms in Zimbabwe accounted for 60% of all irrigation in that country and corresponded to about 25% of the arable area farmed by settlers (4). This irrigation is responsible for practically all (40,000ha in 1982) of Zimbabwe's wheat and barley production - grown as a second crop during the dry (winter) season - and is extensively used for supplemental irrigation, when dry periods occur during the rainy season, for various crops including maize, cotton, soyabeans and tobacco (Mupawose, 1984; Shumba, 1985).

Smallholder agriculture in formal irrigation schemes in Africa has typically followed the model of the Gezira in the Sudan, which was started in the 1920's. In this model, water from a single diversion or reservoir on a river is supplied by central scheme management, responsible for the operation and maintenance of the main distribution infrastructure, to smallholders who farm the irrigated land as tenants of the scheme. As part of the conditions of tenancy, farmers are obliged to grow certain crops and, in some schemes, to carry out maintenance of the part of the watercourse (usually referred to as the 'tertiary level') which delivers water directly to their plots. Schemes with this pattern have been established in Kenya and on many of the principal rivers of West Africa. On large scale irrigation schemes for smallholders in northern Nigeria land tenure arrangements are different, as farmers are considered to own the land. However, supervision of farming operations appears to be as strongly centralised as in tenancy schemes (Wallace, 1981). Although major dams for such schemes are still under construction, the performance of existing projects has been so far below expectation that funding for new large-scale irrigation schemes is unlikely (Hocombe, 1986; Moris et al. 1985).

The principal reasons for poor scheme performance have been inadequate physical and economic planning, and lack of provision for operation and maintenance.

Physical design failures, including cost-cutting errors such as the failure to provide adequate drainage, have led to waterlogging and salinization after schemes have been put into operation (Moris et al. 1985, p29). Flows and sediment loads of rivers in Africa are very

variable, and planning based on inadequate data for these parameters have resulted in inappropriate designs of reservoirs and pumping stations (Hocombe, 1986, p28). An even more prevalent deficiency of large-scale irrigation design is the failure to take full account of the economic or logistic conditions in which the scheme is to operate (Kortenhorst, 1983; Moris et al. 1984). As a result, construction costs (which often include infrastructure such as access roads) have been underestimated and crop production estimates have been over-optimistic (Hocombe et al. 1986). Displacement of existing agriculture has sometimes been grossly underestimated (Wallace, 1981; Tiffen, 1985).

Economic planning failures: the high cost of formal sector irrigation infrastructure - quoted variously as US\$10,000 - 25,000/ha (Hocombe et al. 1986; Moris et al. 1985) - requires scheme management to fulfill repayment schedules by maximising the commercially-oriented output, usually rice or cotton, and, less commonly, wheat (USDA, 1982). This has led scheme management into conflict with smallholders where the latter's primary interest in irrigation is to achieve security of supply of staple foods like millet, sorghum, maize (Wallace, 1981; van der Laan, 1984; Adams, 1981); or where labour demand for irrigated crops conflicts with labour needs of their other activities such as rainfed agriculture, cattle herding, non-farm work etc (Kortenhorst 1983). A major source of error in assessing production costs of irrigation schemes has been the assumption of 'free' or 'surplus' labour within farming households available for work on irrigated crops. The opportunity cost of labour has in practice been found to be high, as would be expected

from the multiple income pattern of African farming households noted earlier.

Lack of provision for operation and maintenance of irrigation infrastructure resulted in inadequate staffing of the main system management and failure of farmers to supply the expected labour for tertiary level maintenance due to the same erroneous assumption of 'free' household labour noted above. Accumulated failure to carry out maintenance on canals results in the need for 'rehabilitation' which is sufficiently expensive to require major (external) investment.

5.2 'Small-scale irrigation'

The poor performance of large-scale irrigation has led organizations like the World Bank and FAO to call for preference to be given to 'small-scale irrigation'. The definition of small-scale irrigation is variable, but appears to lie in the region of 300ha (tiffen, 1985) to 500ha (Hocombe et al. 1986). The major advantage of smaller size was felt to be that it did not justify the employment of full-time irrigation management staff, thereby reducing scheme overheads and ensuring a greater degree of control, and hence motivation, on the part of the farmers in the operation and maintenance of the scheme.

A large number of small-scale schemes were established during the 1970's notably as drought-relief measures in the Sahel and in Kenya. However, many of these small-scale schemes - including those funded by non-government organisations - have turned out to resemble miniature versions of large scale schemes, but with no lesser scale of problems and failure (Kortenhorst, 1983; Moris et al. 1984). In

some respects, the technological problems encountered by these small-scale formal sector schemes were more acute than for larger schemes: for example, inadequate vegetation cover on watersheds for small dams may present higher siltation risks than for larger dams (Moris et al. 1985 p27). But perhaps the most common problem was the use of motor-driven pumps for small-scale irrigation schemes in areas where fuel supplies and maintenance support were not reliable. In circumstances where water supply from pumping stations were unreliable, farmers reverted to the risk-minimising strategies they used when growing crops with uncertain rainfall (ie. with minimal investment in improved seed, fertilizer etc), so that yields in such schemes were lower than expected and schemes had problems in covering their production costs.

Further difficulties in small-scale schemes concerned 'farmer control' either because farmers failed to establish an organisational structure able to effectively operate and maintain the shared infrastructure and equipment (Kortenhorst, 1983), or because the autonomy of farmer control conflicted with the policy of a regional irrigation or water authority through which services had to be obtained and paid for (Adams, 1981). Finally, in addition to these problems, small-scale formal sector irrigation schemes have not proved consistently cheaper to build, per unit of irrigated area, than large schemes - an experience summarised somewhat bleakly by Moris et al (1985) in their report to USAID: "If in Africa small-scale projects are not necessarily cheaper to build, they are nevertheless easier to withdraw from;" (p62).

Although, a number of authors use 'small-scale irrigation' as synonymous with informal sector irrigation, as defined above, (Underhill, 1984; Kay et al. 1985) this recognition of indigenous African water control techniques is relatively recent, and instances are known of such technology being suppressed by colonial authorities - in Zimbabwe for example (Whitlow, 1983). However, and with what appears almost indecent haste, given the near impossibility of obtaining reliable estimates of the total area of millions of small plots of low-lying land distributed throughout the African landscape, the informal sector is now credited with about 50% of the total irrigation area of sub-Saharan Africa (Hocombe et al. 1986). But with few exceptions, such as, for example, in Sierra Leone rice cultivation (Spencer and Byerlee, 1976; Richards, 1986), and more recently in Zimbabwe vlei cultivation (Bell et al. 1986), understanding of the quantitative aspects of these technologies by formal sector irrigation specialists and agronomists does not extend much further than a classification of the main types and the areas where they are employed. Perhaps more important than such a classification, however, are three aspects which are relevant for technological development in small-scale African farming.

These are: firstly, that the technology is invariably used to produce food crops such as rice, maize, sorghum, millet, sweet potatoes and vegetables. Secondly, that this production is generally one component of a broader farming system which may include rainfed crop production and cattle herding. Finally, these water control technologies are used throughout sub-Saharan Africa, although the place they may occupy in farmers' overall economy varies. In many areas the cultivation of seasonally-flooded low-lying areas (called

variously bas-fonds, fadamas, dambos, vleis, machongos, mbugas etc) is principally, but not exclusively, for hot (wet) season production of staple grains for own consumption, although in some West African countries a significant proportion of rice grown in this way may be intended for sale (Richards, 1986). However, there are also areas where the principal value of this low-lying land is in the production of vegetables, for sale, during the cool (dry) season. This type of vegetable farming has been described in northern Nigeria (Carter et al. 1983, Chapman, 1984), Niger (Moris et al. 1984), and Zimbabwe (Bell et al. 1986), but undoubtedly exists in other areas where population density is sufficient to support a fresh vegetable market. This commercial production is labour intensive and individuals typically cultivate 'micro-plots' of about 0.1ha. Growers may rely on the water in the soil being sufficiently shallow for the crop, or may do some watering: by hand, or by shaduf (a form of bucket lifted by a lever) from small hand-dug wells. Very little is known about why techniques vary - often over small distances - but this may reflect variations in soil conditions.

In summarising this review of experience in Africa of irrigation as a means of improving food output, it may be said that the impact of highly-capitalised formal sector irrigation has been relatively small, and confined to some large schemes for rice production : by state-run mechanised farms in Tanzania and Mozambique; and by smallholders on schemes such as the SEMRY in Cameroun and the Niger river schemes in Mali. With these may be included the 'perimetres irrigues villagois' on the Senegal river valley, which, although consisting of small-scale units, are subject to close operational

control by a river valley authority whose role parallels that of 'main system management' in a large scheme, By contrast, the informal sector, is used almost exclusively to product food. With priority in African agriculture increasingly focussed on food production it is to these two sectors that irrigation policy is likely to be directed. The form that this policy may take is explored in the next section.

6. CURRENT POLICIES AND DEVELOPMENTS IN IRRIGATED FARMING IN AFRICA

In the previous section it was noted that investment policy for irrigation in Africa had concentrated on the creation of infrastructure for formal sector irrigation. The failure of much of this investment to produce the expected results has caused reassessments of policy and it appears likely that fewer new formal sector schemes will be planned in the future.

Rehabilitation of existing irrigation schemes will include not only work to recuperate the infrastructure by way of, for example, drainage construction, removal of sediment from canals, repair of control structures etc, but also the reorganisation of the management system. Preoccupation with lack of farmers' 'motivation' as a principal cause of the lack of maintenance, and hence of the deterioration of the irrigation works, has generated concern that the reorganisation of irrigation management should ensure greater farmer participation in the operation of the system. It has also been observed (All-party parliamentary group on overseas development,

1985) that any attempt to increase the production of food crops in 'successful' smallholder irrigation such as the outgrower sugar schemes operated by the Commonwealth Development Corporation, would also require managerial change in a similar direction. The present central managerial control depends largely upon monopoly purchase by a single central processing plant, which would not be applicable to food crops with a strong local market.

However, although farmer participation in irrigation management is commonly envisaged as being achieved through the formation of 'farmers' groups' or 'water users' associations' (Uphoff, 1986), it is very unclear how these will work in practice. Concern has been expressed that 'farmer participation' may in practice be "simply a set of attempts to persuade farmers to take up tasks which the agencies have found increasingly difficult to discharge" (Abernethy, 1987).

In policies to support the development of informal irrigation two paths are discernable, defined largely by whether or not access to irrigation water may be achieved by individual farmers (Underhill, 1984, p9). In general, where surface water is used for irrigation by gravity, water control is often beyond the means of an individual, and the necessary structures such as weirs, dykes and canals serve communities, or groups of farmers. A major requirement in the development of irrigation using water sources shared by farmers is an organisation through which operation and maintenance decisions may be made and implemented. In this way the situation is similar to that

of organising farmer participation on large-scale schemes farmed by smallholders, and the exact nature the initiatives that will be taken are unclear. Many authors stress the importance of making maximum use of indigenous experience of administering collective projects; with mosque building a frequently-cited example from West Africa (Tiffen, 1985; Diemer and van der Laan, 1983). Others have expressed concern that farmers' organisations dominated by traditionally powerful groups have resulted in discriminatory land allocations that has made other groups (notably women) worse off than before irrigation development. Moris et al. (1985, p72) have suggested that development agencies make assistance to informal irrigation schemes conditional upon equitable rights among cultivators on the schemes.

Instances of indigenous irrigation where control of the water source is accessible to single individuals most commonly concern the use of groundwater, and hence cultivation of low-lying lands, where the water table is near the surface (fadamas. vleis etc.). The high labour input required to cultivate these soils, or to irrigate them using traditional technology, have in the past kept plots small - the 'micro-plots' mentioned above. In recent years, farmers have been able to increase the area cultivated by purchasing small gasoline-powered pumpsets. The sale of these pumps and the drilling of the necessary boreholes has received World Bank support since the early 1980's in the fadama areas of northern Nigeria. A pump extracting water from a borehole was found to allow a vegetable grower to increase the area cultivated by at least 2 to 3 times, and farm income has been estimated to increase by roughly the same proportion

(Chapman, 1984). Although rather sketchy, the evidence from schemes of pump-introduction indicate the following pattern of development:

- pump ownership is uneven, with a tendency for pump owners to increase the number of pumps owned, and the area farmed correspondingly.
- as land area farmed by pump owners increases, there is increasing need to hire labour for weeding.
- increased areas cultivated by pump-owners are expected to increase rents, and, possibly, a move towards 'sharecropping' whereby farmers from neighbouring districts who move to the fadama for dry season cultivation may be offered water by borehole owners in return for labour (Tiffen, 1984).
- as the output of fresh vegetables is increased, the occurrence of market gluts is becoming more frequent, and a diversification of production, possibly to less labour-intensive crops on larger fields (eg. cowpea or wheat), may be foreseen.

Taken together, this evidence indicates that small pump technology for shallow groundwater use has the potential to transform farming productivity and may allow considerable expansion of the area cultivated by individual farmers where they can market high value crops. There is some evidence of similar development in Zimbabwe, where Bell et al. (1986) note a few farmers using pumps to irrigate areas of 4-6ha of vegetables on vleis at Chiota, near Harare.

It is important to note that small pumps are also widely used to draw irrigation water from rivers by both individuals (eg. along the banks of the Incomati in Mozambique) and groups of farmers (eg. the float-mounted pumps on the Senegal river) (5). However, at the scale of farming prevalent in Africa, small pumps are accessible to individual farmers whereas other water control technologies are not.

7. ISSUES IN THE DEVELOPMENT OF IRRIGATION FOR INCREASED FOOD PRODUCTION

Irrigation is more than ever regarded by both African governments and agencies funding development programmes as the appropriate response to recurrent drought and famine emergencies. However, at the same time there is widespread concern that irrigation technology, as practiced in the third world, is unsustainable from both technical and management points of view (New Scientist, 7.5.87, p27).

Many issues raised by this crisis reflect the interdisciplinary needs of a subject on which different professions have tended to work in isolation: irrigation systems are designed by engineers, operated by agriculturalists, and evaluated by social scientists. From this review it will be clear that irrigation development is as much about social and political organisation as about technical innovation.

There is evidence that over the past five years, as those concerned with irrigation have sought ways to improve the functioning of large-scale schemes and ensure farmer participation in newer, smaller-scale ones, the view has gained ground that improved irrigation performance

requires better 'software' rather than more 'hardware' (Bottrall, 1985; Moris et al. 1985; Abernethy, 1987). Moreover, this is not a uniquely African problem and, although there is a rapidly-proliferating literature on irrigation water management and farmer participation therein, most of the detailed work has been undertaken on Asian irrigation (eg. Duewel, 1984; Bottrall, 1985; Uphoff, 1986).

In the meantime, information about how decisions are taken about operation and maintenance remains extremely scarce. As Wade (1984) has it: "....it is an amazing fact that in an industry which expects to spend \$150 billion worldwide over the next 20 years there has never been a scientifically respectable study of the actual performance of a well-established irrigation canal in the tropics. Irrigation investment is made, management structures devised, laws are passed, in benign ignorance of what actually happens on the ground."

It may be added that in the African context this ignorance is compounded by the fact that irrigation is frequently not 'well-established', but recently introduced into a farming system of which the irrigation designers had only a rudimentary understanding. The current interest in water management should not obscure the fact that this is only a component of the management of irrigated crops. The operation of large-scale irrigation by corporate management involves continual assessment such as crop analysis, soil salinity and water table monitoring, pest assessment etc, which requires staff and laboratory support, and which is needed to 'fine tune' the technology

employed (fertilizer rates, water application intervals, tillage and residue-disposal methods etc). In this respect management of modern irrigated agriculture is as location-specific as indigenous irrigation methods: fine-tuning takes time and experimentation. It is evident that for many large-scale smallholder schemes this process has barely begun, and it is by no means certain that water-management per se will be given the same priority for improvement by farmers as by irrigation engineers. For example, it has been widely observed that an associated feature of irrigation development is a pronounced increase in weed infestation of crops (Moris et al. 1985). It seems entirely feasible that in some cases this may be a more urgent priority in 'rehabilitation' from a farmer's viewpoint, than improved water management. In informal irrigation systems, research has hardly been begun to indicate the limitations and possible improvements, and the extent to which they are likely to have to accommodate changes due to altered groundwater levels or streamflows resulting from dam construction, or changes due to increased cultivation intensity.

In the same way that water management is a component of irrigated farming, so the experience of irrigation in Africa reviewed above makes clear that for small-scale farmers irrigation, whether formal or informal, is generally only a component of farming systems that may also embrace rainfed crop production and/or livestock herding. As observed by Richards (1986), this runs counter to agricultural research orthodoxy, in which irrigated and rainfed farming are often portrayed as if they were exclusive alternatives. This dichotomy is

seen when attempts are made to assess the contribution of irrigation to African food supplies. For example FAO (Hocombe et al. 1986) estimates that irrigation is currently responsible for about 12% of grain production in sub-Saharan Africa, and that, with foreseeable increases of areas and yields in both formal and informal sectors, irrigated food crops are likely to correspond to only 14% of the cereal requirement of the (much increased) population in the year 2000. Accordingly, with the exception of eight countries with little scope for increased rainfed crop production (6), FAO concludes that food requirements of African populations are likely to be met more quickly and cheaply by concentrating on improvements in rainfed production. However, as argued earlier in this paper, the uncertainty of rainfall in much of the region means that the fundamental improvement necessary to rainfed farming is improved water control.

There are indications that future policy in Africa will see irrigation as complementary to rainfed (Mupawose, 1984), and that future irrigation development may therefore be governed by criteria other than the need to maximise the 'Economic Internal Rate of Return' (Tiffen, 1987) on the irrigated component alone. However, an important consequence of the separation of 'irrigated' and 'rainfed' farming by research and development institutions is that little is known about resource allocation between the two when farmers operate both within the same farming system. It is not known, for example, what happens to rainfed crop production when farmers are able to secure their food supplies with irrigated land (a tendency much

lamented by administrators of African irrigation from the Gezira onwards).

It is in this respect that the recent development of FSR might be expected to make a contribution to irrigation management. However, the FSR programmes currently being developed in various African countries under the auspices of USAID, and CGIAR institutes like CIMMYT and ILCA, have not included systems with irrigated components (Moris et al. 1985). This may be partly due to the historical development of these institutes' FSR programmes in areas in which irrigation is not a significant system component (CIMMYT in highland maize production, ILCA in pastoral systems). However, the failure of CGIAR to fund a proposal for research in irrigation water management (Baum, 1986) in 1982 points to the possibility of a widening gap in CGIAR's perceptions of technology constraints in African food production. Of particular relevance is the identification in its FSR methodology of the 'farm-household' as a discrete economic decision-making unit, which, as noted earlier, weakens its ability to take inter-household relationships into account in the analysis of constraints to increased food production. That this 'nuclear' household orientation underlies CGIAR's research more generally, beyond the FSR programmes, is indicated in a recent article (Hartmans and ter Kuile, 1984), in which the Director-General of IITA described the farmer upon whom future African food supplies depended (and by implication the beneficiary of IITA's research) as: "the upwardly mobile smallholder, ... who traditionally is a subsistence producer for 50-100% of his (sic) produce, but who is motivated economically

and/or socially to expand his production and his cultivation to achieve a market production of 50-100%."

The demise, described earlier, of the somewhat colonial model of large-scale irrigation, where smallholders had tenant status and farming activities were closely regulated by central scheme management, in favour of more 'farmer-managed' systems may create opportunities for irrigation to be used by individual farmers to achieve the kind of expansion favoured by IITA. In particular, the development of small pump technology for use with shallow boreholes, noted above, suggests that this pattern of development is already under way in fadama areas of Northern Nigeria. However, it is important to note two aspects of this development which may inhibit a similar process elsewhere. Firstly, individual land ownership has been accepted in northern Nigeria for some time (Wallace, 1981; Tiffen, 1985), but this is not the case in many other areas of Africa. Secondly, the technology employed implies that an important part of farmers' costs are for imported goods (pumps, fuel, parts), and therefore subject to conditions of currency exchange which may be beyond the farmers' control. At the very least, the acute shortage of foreign exchange throughout Africa make this a high-risk technology.

In contrast, this review has indicated that there are many instances in both formal and informal irrigation where water sources or control systems are shared by a number of farmers. In these cases the smallholder may find that increases in output can only be achieved by

some form of joint action with other members of the water management group. A study of irrigated smallholder farming in the Limpopo valley, for example, indicated that, although farmers were keen to grow a cool season maize crop following wet season rice, this could only be achieved through the collaboration of farmers on neighbouring plots: if plots were not drained simultaneously after the rice crop then infiltration of water from undrained plots made ploughing and planting maize on individually-drained plots impossible (Woodhouse et al. 1986). As Bottrall (1984) has observed of water users' associations in Pakistan: "Water-related co-operative activity cannot be developed on a purely voluntary basis. For effective co-operation all farmers on a particular watercourse must be members of their channel-based association and abide by its rules - no-one can opt out." With the likely emphasis on farmers groups in irrigation rehabilitation programmes, it seems pertinent to ask whether the 'small farmer' and commercial orientation underlying much current agricultural research effort is appropriate.

8. FUTURE DIRECTIONS FOR RESEARCH

This paper has examined a number of the trends in irrigation and agricultural research which underlie policies of investment to improve the technology of food farming Africa,. It has indicated that, although past errors have been widely acknowledged, there are aspects of current approaches which weaken their ability to contribute to increased food security. In particular , not enough attention is paid to the organisation, as well as the productivity,

of existing small-scale farming technology, especially where interhousehold organisation is concerned. This is of particular relevance to the high drought risk conditions of more than half of sub-Saharan Africa, because the key technologies which allow a reduced element of risk in crop production - those of improved water control - often require interhousehold collaboration, as they cannot be managed effectively at the scale of the individual small farm.

If research is to address an organisational dimension in its assessment of likely outcomes of policies to promote technological change (wherever the technology has been originated), it must go beyond the collection of information about the resource-base of different types of farmers and provide a clear picture of how farmers interact in agricultural production. Only in this way will it be possible to assess how a change of technology might affect farmers' community of interest - and conflicting interests - and thus assess the consequences of its adoption in terms of food security and increased food production.

However, there are few methodological precedents for achieving this objective. A review of farming systems literature has to date yielded only one reference to a survey methodology for analysis of farming at village or community level rather than at household level. This is the 'meso-scale' agroforestry diagnosis and design methodology outlined by Raintree (1987). Significantly, this was developed for the analysis of agroforestry policy options because it was found that "not all the land use problems experienced by people

originate within a single farm, nor can they always be solved by action at the individual household level" (Raintree, 1987). This rationale evidently echoes that put forward in this paper in relation to water management, but it is not possible to say at this stage, however, how relevant this 'meso-scale' methodology will be to the development of research on improved water control in African farming.

A further methodological uncertainty lies in the approach to field surveys. Much has been written about multi-disciplinary "farm survey" techniques in the farming systems research literature. However, Chambers and Jiggins (1986) have recommended that large multi-disciplinary research teams of the kind established in international agricultural research institutes be avoided for field surveys on the grounds that they are expensive and produce unwieldy data requiring sophisticated processing capability. Moreover, they argue that the "farmers views" are likely to be distorted when they emerge from interviews between individual farmers ('heads of households') and large groups of researchers. A number of alternative survey techniques have been proposed but few cases of their use have been documented fully.

The discussion in this paper of issues in the development of irrigation for food production indicates a need for the study of water management within partially-irrigated farming systems that are likely to predominate in small-scale agriculture in Africa. Changes in water management technology need to be assessed in terms of effects on food production, food security, and levels of agricultural

investment that farmers are prepared to undertake. In conducting such research so as to make clear the interhousehold linkages, as has been argued to be necessary in many water management situations, the methodological issues outlined above will need to be resolved. The development of appropriate methodologies may therefore be regarded as a first priority for this research.

NOTES

- (1) IARCs operating in Africa are principally the International Institute of Tropical Agriculture (IITA), in Ibadan; the International Livestock Centre for Africa (ILCA) in Addis Ababa; the International Laboratory for Research in Animal Diseases (ILRAD) in Nairobi. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), based in India, also has research centres at Niamey and Bulawayo. CIMMYT, based in Mexico, has collaborative programmes throughout southern and eastern Africa.
- (2) A number of early references to central American FSR methodologies are given by Jones and Wallace (1986).
- (3) Defined by FAO (1986, annex II) as at least 4 occasions of one dry year succeeding another in a 50 year period.
- (4) Statistics of "commercial large-scale farming" do not allow separation of farms in corporate ownership from those operated by individual settlers. However, since corporate interests are principally in sugar, the exclusion of the area of this crop from statistics for irrigated and unirrigated areas in the commercial large scale sector give an approximate idea of irrigation as a proportion of cultivated land on settler farms. Figures for 1982 (later years are distorted by the effect of prolonged drought) indicate 24% of cropland was irrigated (cereals, oilseeds, vegetables, tobacco, cotton, tea, coffee,

fruit, fodder crops and sown pasture). Source: Agriculture Statistics, Central Statistical Office (1982), Harare.

- (5) It is worth noting that in both these cases income from (migrant) wage labour is important as a means of financing the purchase and/or running costs of the pumps.
- (6) The eight countries are: Senegal, Burkina Faso, Niger, Mali, Mauritania, Somalia, Kenya, and Botswana.

REFERENCES

- ABALU, G., N. FISHER, & Y. ABDULLAHI (1987). Rapid rural appraisal for generating appropriate technologies for farmers: some experiences from northern Nigeria. *Agricultural Systems* 25, 311-324.
- ABERNETHY, C. (1987) An agenda for further research; Closing lecture, Symposium on Irrigation Design for Management, Kandy, 16-18th Feb. 1987. Overseas Development Unit, Hydraulics Research Limited, Wallingford.
- ADAMS, A. (1981) The Senegal River Valley. in J Heyer et al. *Rural Development in Tropical Africa*. Macmillan, London.
- All-party Parliamentary Group on Overseas Development (1985). *UK Aid to African Agricultural*. Overseas Development Institute, London.
- ATTAH-KRAH, A. & P. FRANCIS (1987). The role of on-farm trials in the evaluation of composite technologies: the case of alley farming in southern Nigeria. *Agricultural Systems* 23, 133-152.
- BAUM, W. (1986). *Partners against hunger*. The Consultative Group on International Agricultural Research. World Bank, Washington D.C.
- BELL, M., R. FAULKNER, C. ROBERTS, P. HOTCHKISS, & R. LAMBERT (1986). Use of dambos in rural development. Interim project report No.4 water and Engineering Development Centre, Loughborough University.
- BINSWANGER, H. (1986) Evaluating research system performance and targeting research in land-abundant areas of sub-saharan Africa. *World Development* 14, 469-475.
- BOTTRALL, A. (1985). Managing large irrigation schemes: a problem of political economy. Agricultural Administration Unit Occasional Paper No.5 Overseas Development Institute, London.
- BYERLEE, D., S. BIGGS, M. COLLINSON, L. HARRINGTON, J. MARTINEZ, E. MOSCARDI, & D. WINKELMANN. (1980) Planning technologies appropriate to farmers: Concepts and Procedures. CIMMYT, Mexico.
- BYERLEE, D., L. HARRINGTON, & D. WINKELMANN (1982) Farming systems research: Issues in research strategy and design. *Amer. J. Agric. Econ.* 64, 897.
- CALLEAR, D. (1984) Land and food in the Wedza Communal area. *Zimbabwe Agricultural Journal*. 81, 163-168.

- CARNEY, J. (1988) Struggles over crop rights and labour within contract farming households in a Gambian irrigated rice project. *Journ. Peasant Studies*. in press.
- CARTER, R., M. CARR, & M. KAY. (1983) Policies and prospects in Nigerian irrigation. *Outlook on Agriculture* 12, 73-76.
- CHAMBERS, R. & J. JIGGINS (1986). Agricultural research for resoucre poor farmers: a parsimonious paradigm. IDS Discussion paper 220. Brighton, University of Sussex.
- CHAPMAN, N. (1984) second Fadama Seminar, 6-8th March 1984, Bauchi State Agricultural Development Programme. Northern Zone, Azare, Nigeria.
- CHRISTIANSEN, C. & L. WITUCKI (1982). Food problems and emerging policy responses in sub-Saharan Africa. *American Journal Agricultural Economic*. 64, 889-896.
- COLLINSON, M. (1982) Farming Systems Research in Eastern Africa: the experiences of CIMMYT and some National Agricultural Research services 1976-81. MSU International Development Paper No.3, Dept. of Agricultural Economics, Michigan State University, East Lansing.
- DELGADO, C. & J. MCINTIRE (1982) Constraints on oxen cultivation in the Sahel. *Am. J. Agric. Econ.* 64, 188-196.
- DIEMER, G & E VAN DER LAAN (1983) Using indigenous skills and institutions in small-scale irrigation: an example from Senegal. *Irrigation Management Network paper 8b*, Overseas Development Institute, London.
- DINEHAM, B. & C. HINES (1983) *Agribusiness in Africa*. Earth Resources Research Limited, London.
- DUEWAL, J. (1984) Central Java's Dharma Tirta WUA 'model': Peasant irrigation organisation under conditions of population pressure. *Agric. Admin.* 17, 261-285.
- FAO (1981) *Agriculture: Toward 2000*. FAO, Rome.
- FAO (1986) *African agriculture: the next 25 years*. Annex II the land resourcé base. FAO, Rome.
- FRANKE, R. & B. CHASIN (1981) Peasants, peanuts, profits, and pastoralists. *Ecologist* 11, 156-168.
- HARTMANS, E. & C. TER KUILE (1983) IITA's views on current and future trends in tillage in the humid and subhumid tropics. 5th Session of the FAO panel of experts on agricultural mechanization. FAO, Rome.

- HASWELL, M. (1963) The changing pattern of economic activity in a Gambia village. H.M.S.O., London.
- HERBERT, R. (1983) Kraal manure. Bull. Agric. Research. Botswana 1. Dept. Agric. Research Ministry of Agriculture, Gaborone, Botswana.
- HILL, P. (1963) Migrant Cocoa farmers of southern Ghana: a study in rural capitalism. Cambridge University Press, Cambridge.
- HILL, P. (1986) Development Economics on Trial. Cambridge University Press, London.
- HOCOMBE, S., P. KIDANE, A. JAZAYERI, & M. GADELLE. (1986) Irrigation in Africa south of the Sahara. Technical Paper No.5, FAO Investment Centre, FAO, Rome.
- IBRD (1981) 'Accelerated Development in sub-Saharan Africa'. International Bank of Reconstruction and Development, Washington D.C.
- IFPRI (1987) Annual Report, 1985/86. International Food Policy Research Institute, Washington D.C.
- ILCA (1985) Annual Report 1985/86 International Livestock Centre for Africa, Addis Ababa.
- JONES, C. (1986) Intrahousehold bargaining in response to the introduction of new crops. A case study from north Cameroon. in: J. Mook, Understanding Africa's rural households and farming systems. Westview Press, Boulder, Colorado.
- JONES, J. & B. WALLACE (1986) Social science in farming systems research. in J. Jones and B. Wallace (Eds) Social Sciences and farming systems research. Methodological Perspectives on Agricultural Development. Westview Press, Boulder, Colorado.
- KANG, B., G. WILSON & L. SIPKENS (1981) Alley cropping maize (*Zea mays* L) and *Leucaena* (*Leucaena leucocephala* Lam) in southern Nigeria. Plant and Soil 63, 165-179.
- KANG, B., G. WILSON & T. LAWSON (1984) Alley Cropping. A stable alternative to shifting cultivation. International Institute of Tropical Agriculture, Ibadan, Nigeria.
- KAY, M., W. STEPHENS, & M. CARR (1985) The prospects for small-scale irrigation in sub-Saharan Africa. Outlook on Agriculture 14, 115-121.

- KORTENHORST, L. (1983) summary Report, Workshop on small-scale irrigation in Kenya, Nairobi, 14-18 Feb. 1983. International Institute for Land Reclamation and Improvement. Wageningen.
- VAN DER LAAN, E. (1984) Factors contributing to the rapid development of small-scale irrigation schemes along the Senegal river. *Agric. Admin.* 17, 203-213
- LONGHURST, R. (1984) The energy trap: work, nutrition, and child malnutrition in northern Nigeria. Cornell International Nutrition Monograph Series No.13. Cornell University, Ithaca, N.Y.
- LOW, A. (1986) Agricultural development in southern Africa. Farm household-economics and the food crisis. James Currey, London.
- MOOCK, J. (Ed.) (1986) Understanding Africa's rural households and farming systems. Westview Press, Boulder, Colorado.
- MORIS, J., D. THOM, & R. NORMAN (1984) Prospects for small-scale irrigation in the Sahel. Water Management Synthesis-II project Report 26. Utah State University, Logan.
- MORIS, J. & D. THOM (1985) African irrigation overview - summary. Water Management Synthesis-II project Report 37. Utah State University, Logan.
- MUPAWOSE, R. (1984) Irrigation in Zimbabwe. in M. Blackie (Ed.) African Regional Symposium on Small Holder Irrigation, 5-7 Sept. 1984, Harare. Second edition (1987), Hydraulics Research Limited, Wallingford.
- NORMAN, D. (1967) An economic study of 3 villages in Zaria Province. 1. Land and labour relationships. Samaru Miscellaneous Papers No.19. Ahmadu Bello University, Zaria, Nigeria.
- NORMAN, D. (1972) An economic study of 3 villages in Zaria Province. 2 Input-output study, vol. ii: text. Samaru Miscellaneous Papers No.37. Ahmadu Bello University, Zaria, Nigeria.
- NORMAN, D. & B. BAKER (1986) Components of farming systems research, FSR credibility, and experiences in Botswana. in: J. Moock (Ed) Understanding Africa's rural households and farming systems. Westview Press, Boulder, Colorado.
- NORMAN, D., J. FINE, A. GODDARD, W. KROEKER, & D. PRYOR (1976) A socio-economic survey of 3 villages in the Sokoto close-settled zone. 3. Input-output study, vol.1: text. Samaru Miscellaneous Papers, 64. Ahmadu Bello University, Zaria, Nigeria.

- NWEKE, F. (1980) Farm labour problems of the small landholder cropping systems in south-east Nigeria. *Quarterly J. Internat. Agric.* 19, 123-134.
- OKIGBO, B. (1984) Improved permanent production systems as an alternative to shifting intermittent cultivation. in *FAO Soils Bulletin No.53. 'Improved production systems as an alternative to shifting cultivation.'* FAO, Rome.
- PEARSE, A. (1980) *Seeds of plenty, seeds of want: social and economic implications of the Green Revolution.* Clarendon Press, Oxford.
- PINGALI, P., Y. BIGOT, H. BINSWANGER (1986) *Agricultural mechanization and the evolution of farming systems in sub-Saharan Africa.* World Bank - John Hopkins University Press.
- RAINTREE, J. (1987). The state of the art of agroforestry diagnosis and design. *Agroforestry Systems* 5, 219-250.
- RHOADES, R., D. HORTON, & R. BOOTH (1986) Anthropologist, Biological Scientist and Economist: the three musketeers or three stooges of farming systems research? in J. Jones and B. Wallace (Eds) *Social sciences and farming systems research. Methodological Perspectives on Agricultural Development.* Westview Press, Boulder, Colorado.
- RICHARDS, P. (1985) *Indigenous Agricultural Revolution. Ecology and food production in West Africa.* Hutchinson, London.
- RICHARDS, P. (1986) *Coping with hunger: hazard and experiment in an African rice farming system.* Allen and Unwin. London.
- RODEL, M. & J. HOPLEY (1973) Investigations into systems of farming suitable for tribal trust lands. *Rhodesia Agric. J.* 70, 1-18.
- SHUMBA, E. (1984) Reduced tillage in the communal areas. *Zimbabwe Agric. J.* 81, 235-239.
- SHUMBA, E. (1985) On-farm research priorities resulting from a diagnosis of the farming systems in Mangwende, a high potential area of Zimbabwe. *Zimbabwe Agric. J. Special Report No.5.* Harare.
- SPENCER, D. & D. BYERLEE (1976) Technical change, labour use and small farmer development: evidence from Sierra Leone. *Amer. J. Agric. Econ.* 58, 874-880.
- STANNING, J. (1983) Production costs of farming in Zimbabwe. *Zimbabwe Agric. J.* 80, 57-60.
- STARKEY, P. (1987) Animal-drawn wheeled tool carriers: a case for caution. *Appropriate Technology* 14, 10-12.

- TIFFEN, M. (1985) Land tenure issues in irrigation planning, design and management in sub-Saharan Africa. working paper 16, Overseas Development Institute, London.
- TIFFEN, M. (1987) The dominance of the internal rate of return as a planning criterion and the treatment of O and M costs in feasibility studies. ODI/IIMI Irrigation Management Network Paper 87/1b. Overseas Development Institute, London.
- TOMMY, J. (1984) Shifting cultivation and possibilities for improving it in Sierra Leone. in FAO Soils Bulletin No.53, FAO, Rome.
- UNDERHILL, H. (1984) Small-scale irrigation in Africa in the context of rural development. FAO, Rome.
- UPHOFF, (1986) Getting the process right: improving irrigation water management with farmer organisation and participation. Working Paper, Cornell University, Ithaca N.Y.
- USDA (1982) 'Food Problems and Prospects in sub-Saharan Africa: the Decade of the 1980's' United States Department of Agriculture, International Economics Division, Africa and Middle East Branch, Washington D.C.
- WADE, R. (1984) Managing a drought with canal irrigation: a south Indian case. Agric. Admin. 17, 177-202.
- WALLACE, T. (1981) The Kano River Project, Nigeria: the impact of an irrigation scheme on productivity and welfare. in J. Heyer et al. (eds) Rural Development in Tropical Africa. Macmillan, London.
- WHITLOW, R. (1983) Vlei cultivation in Zimbabwe. Reflections on the past. Zimbabwe Agric. J. 80, 123-135.
- WILLEY, R. (1979) Intercropping - Its importance and research needs. Part 1, Competition and yield advantages. Field Crop Abstr. 32, 1-85
- WOODHOUSE, P., H. JIMENEZ, W. HEEMSKERK, M. SPITTEL & W. SLOBBE. (1986). Smallholder farming systems research in the Chokwe irrigation area. FAO documentation number 86:59981. FAO, Rome.
- YOUNG, A & A. WRIGHT (1980) Rest period requirements of tropical and subtropical soils under annual crops. Report of the 2nd FAO/UNFPA Expert Consultation on Land Resources for Populations of the Future. FAO, Rome.

The Development Policy and Practice research group was set up the Open University towards the end of 1984 to promote research on development issues. Its members have a wide range of disciplinary backgrounds (engineering, sociology, economics, education and geography). At present, research is focussed in three areas: food markets - particularly in sub-Saharan and South Asia; the development of finance and banking; and links between small and large scale production.

DPP is a relatively small research group with limited funding. In order to increase our efficacy we are keen to enter into collaborative arrangements with other groups and development agencies where appropriate. DPP will also be acting as a centre to focus the development concerns of the Open University by arranging seminars and workshops.

DPP can be contacted at the following address:

Development Policy and Practice
Technology Faculty
The Open University
Walton Hall
Milton Keynes
MK7 6AA
United Kingdom
Telephone: 0908 652103



DEVELOPMENT POLICY AND PRACTICE:

WORKING PAPERS

DPP Working Papers are available either to exchange with journals or with other paper series, or on payment of £3.50 per paper. Please make cheques or International Money Orders payable to 'The Open University (Development Policy and Practice)'.

Papers marked by an * have been published in journal or book form, and are no longer distributed as working papers.

<u>Paper No.</u>	<u>Author</u>	<u>Title</u>
1*	M Mackintosh	Agricultural Marketing and Socialist Accumulation: a case study of Maize Marketing in Mozambique.
2	L Harris	Finance and money with underdeveloped banking.
3*	H Bernstein	Capitalism and Petty Commodity Production.
4*	B Crow	US Policies in Bangladesh: The making and the breaking of famine.
5*	M Mamdani	Extreme but not exceptional: towards an analysis of the agrarian question in Uganda.
6	B Crow	Plain tales from the rice trade: indications of vertical integration in foodgrain markets in Bangladesh.
7	T Painter	Migrations, social reproduction, and development in Africa: critical notes from a case study in the West African Sahel.

<u>Paper No.</u>	<u>Author</u>	<u>Title</u>
8	N Amin	Characteristics of the international rice markets
9	M Mackintosh & M Wuyts	Accumulation, social services and socialist transition in the Third World: reflections on decentralised planning based on Mozambican experience

