Louise O. Fresco

CASSAVA IN SHIFTING CULTIVATION

A systems approach to agricultural technology development in Africa

DEVELOPMENT ORIENTED RESEARCH IN AGRICULTURE

ROYAL TROPICAL INSTITUTE - THE NETHERLANDS

STELLINGEN

1 De oorzaken van de lage landbouwproduktie in Afrika hebben een dusdanig karakter dat de discussie over de prioriteit van toegepast versus fundamenteel landbouwkundig onderzoek weinig zinvol is.
Eicher, C.K., 1986. Transforming African Agriculture. The Hunger Project Papers no 4.
CGIAR/TAC, 1985. TAC review of CGIAR priorities and future strategies. TAC secretariat, Rome.

2 Het belang van knolgewassen wordt in de door de Wereldbank gepubliceerde geaggregeerde cijfers over de voedselbeschikbaarheid per hoofd van de Afrikaanse bevolking, onvoldoende verdisconteerd. Hierdoor, en ook door het feit dat zij zijn gebaseerd op gegevens verzameld door nationale overheden, zijn deze cijfers misleidend.
World Bank, 1981. Accelerated Development in sub-Sahara Africa. Washington.
World Bank, 1984. Towards sustained development in sub-Sahara Africa. Washington.

3 De vergelijking van gewasopbrengsten zonder specificatie van het teeltsysteem waar deze gewassen deel van uit maken, heeft slechts beperkte waarde.

4 De door Ruthenberg gedefinieerde overgang van zwerfbouw- naar braaksystemen bij een R › 33, moet slechts als een grove indicatie worden opgevat en niet als een aanwijzing voor structurele verschillen.
Ruthenberg, H., 1980. Farming Systems in the Tropics. Oxford, Clarendon Press.

5 Indien het juist is dat het oogsten van cassavebladeren de symptomen van cassave mozaiek virus in verhoogde mate tot expressie brengt, vormt dit een additionele reden om verbeterde varieteiten in een vroeg stadium te screenen op velden van boeren.
Verhoyen, M., 1978. Some observations on cassava mosaic in Zaire. In: Maraite, H. & J.A. Meyer, 1978. Diseases of tropical food crops. Symposium Proceedings, Louvain-la-Neuve, pp 71-84.

6 In zijn algemeenheid doet de 'harvest index' als selectie-parameter bij veredeling van tropische voedselgewassen onvoldoende recht aan de wijze waarop deze gewassen door boerenhuishoudens worden gebruikt.

7 De keuze van lokale controlevariëteiten en plantverbanden in proeven waarbij verbeterde en lokale variëteiten worden vergeleken, dient met grote zorgvuldigheid te gebeuren.
Harrington, L. & R. Tripp, 1984. Recommendation domains: a framework for on-farm research. CIMMYT Economics program working paper 2/84.

8 Het begrip 'recommendation domain' ter aanduiding van homogene categorieën boeren berust op een cirkelredenering.

9 Kennis van en inzicht in teelt- en landbouwbedrijfssytemen in Nederland is ook voor tropische plantentelers van belang.

10 Het opvallende van het begrip 'kennissystemen' is dat het hier noch kennis noch systemen betreft.

11 De invoering van recombinant DNA-technieken kan niet gerechtvaardigd worden met een beroep op de mogelijke positieve effecten op het wereldvoedselvraagstuk.
Eindrapport van de Brede Recombinant-DNA commissie, 1983.

12 Het belang van vrouwen is zelden gediend met het opnemen van aparte stellingen of hoofdstukken over dit onderwerp.

13 Om de opera voor een groter publiek aantrekkelijk te maken, wordt van verschillende zijden, onder andere door de intendant van de Brusselse Opera, voorgesteld om de tekst van het libretto boven het podium te projecteren. De achterliggende suggestie, dat bijvoorbeeld de aria 'Casta Diva' door Maria Callas dankzij een scherm met digitale letters toegankelijker had kunnen worden, is onverdraaglijk.

Louise O. Fresco
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Cassava in shifting cultivation

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Cassava in shifting cultivation

A systems approach to agricultural technology development in Africa

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'Agriculture had to be "industrialized", a writer said one day in *Elima* (the official newspaper in Zaire), but not in the way "the old colonialists and their disciples have preached". The Belgians failed because they were too theoretical, too removed from the peasants, whom they considered "ignorant" and "irrational". In Zaire, as in China, according to this writer, a sound agriculture could only be based on traditional methods. Machines were not necessary. They were not always suited to the soil; tractors, for instance, often made the soil infertile.

Two days later there was another article in *Elima*. It was no secret, the writer said, that the agriculturists of the country cultivated only small areas and that their production was "minimal". Modern machines had to be used: North Korean experts were coming to show the people how. And there was a large photograph of a tractor, a promise of the future.

About agriculture, as about so many things, as about the principles of government itself, there is confusion.'

V.S. Naipaul, *A New King for the Congo*. (1975)

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PREFACE AND ACKNOWLEDGEMENTS

A little over seven years ago, I arrived in the Kwango-Kwilu, in central Zaire, in order to participate in a FAO project that was to investigate the agricultural and rural development potential of the region. For a number of reasons, I soon found myself as practically the only member of what should have been an international multidisciplinary field team. In close collaboration with several Zairois colleagues from the Ministry of Agriculture I was asked to deal with agricultural and rural development in an area of about 167,000 km^2.

What initially seemed an impossible task, slowly turned out to be a blessing in disguise. In a vast region where facilities for research and extension were very limited, I had to work out creative solutions. Close collaboration with non-governmental organizations, agronomic trials on farmers' fields and women as 'barefoot' extension workers would not have been part of 'my bag of tricks', had conditions been easier. It was the process of trying to bring about some changes in agricultural production that increased my understanding of the complex factors involved in crop production. The saying that one can only understand a system by trying to change it, frequently crossed my mind those years.

This book reflects this process of trial and error and the attempt to think in a multidisciplinary way. Its genesis is therefore very different from many academic studies. Rather than starting from a clearly defined research purpose and focusing for a number of years on the same few trial fields or villages, the research was inspired by the multitude of practical issues. These ranged from logistical problems to questions about the incidence of cassava pests and diseases, the marketing infrastructure in the region, and, in particular, the issue of shifting cultivation. The most frustrating problem was that so little was known about agriculture, or anything else for that matter, in the Kwango-Kwilu. There was no body of knowledge, no 'on the shelf' technology or even a diagnosis of the constraints on cassava production. Statistics were hard to come by and usually highly questionable. There was hardly a possibility to conduct serious research on, for example, soil fertility.

There were very few knowledgeable people to consult, but for the farmers, and in particular the women, who provided me with many answers and even more questions.

It slowly dawned upon me, that I was witnessing a process of rapid change in shifting cultivation, resulting from an adaptation to external pressures to produce a surplus for a growing urban and rural population. One related puzzling issue was that of per capita food production in the Kwango-Kwilu region. Whereas aggregate figures for Zaire and the continent as a whole show declining per capita food availability, the evidence from the Kwango-Kwilu suggested that production did not decrease. On the contrary, since 1960 the region had become a great exporter of food. The leading question became, therefore, through what changes in shifting cultivation the region had been able to produce this food surplus. Cassava apparently played a great role in this process of adapatation.

The extent of the changes in shifting cultivation may be illustrated by the following event, which took place approximately one year after my arrival in Zaire. Walking on the vast table lands near Kwenge in the central Kwango-Kwilu, I came upon a field where a young woman was hoeing. Dutifully, I questioned her about the field and the crops she was planning to grow. Surprised at the fact that she was not making any ridges, which was current practice in the savanna, if not in the forest, I asked her why. She said that she did not know how to make ridges. *'But surely your mother must have shown you how to do so?'* She replied: *'My mother did not have savanna fields.'*

Indeed, many things seemed to be changing: farmers' cultural practices, cassava varieties, crop sequences, yields. It was often difficult to observe these developments, however, as they had taken place so unobtrusively that they were not documented by anybody. In nearly every respect I was at a loss, because there were no quantitative data to underpin any of my impressions. Evidence was at best circumstantial, and even today some of my conclusions need to remain speculations. In order to gain a clearer perspective, I tried to understand the historical development of agriculture in the Kwango-Kwilu, reading many of the handwritten reports by the first Belgian agronomists who had worked in the region. I also conducted group interviews with young women farmers and their mothers or grandmothers.

While much evidence seemed to point to changes in shifting cultivation, this evidence was of a diverse nature. It ranged for example from changing agricultural and pricing policies to shifts in fallow vegetation. What I needed, therefore, was a framework to deal with this diversity of data in order to include the technical as well as the socio-economic aspects of agriculture.

About halfway through my four years' assignment (1979-1983), I was invited to attend a conference on on-farm experimentation at the International Institute of Tropical Agriculture in Ibadan. This was my first introduction to

farming systems research, of which, in the isolation of bush life in Zaire, I was completely ignorant. To my amazement, I was told by several people that my work was an interesting example of farming systems research. This provided sufficient encouragement for me to read through a great deal of farming systems research literature. It certainly was challenging and helpful, yet farming systems research did not seem to provide the framework that I needed. In the Kwango-Kwilu, I was dealing with shifting cultivation under very marginal conditions of soil fertility and rapid demographic change. I was uncertain whether farming systems research with its stepwise approach to agricultural technology could provide solutions in such a case.
Although, after my departure from Zaire, I had intended to look more closely at gender issues in agricultural production, I increasingly found myself turning to the fundamentals of farming systems research. I was frustrated by the vagueness of the concept of farming system, by the arbitrary way in which variables and parameters were sometimes defined. My problem statement shifted to the definition of a general systems framework that was relevant to shifting cultivation and allowed me to understand the changes that had taken place in the Kwango-Kwilu and other parts of Central Africa.

This book aims to do two things. Firstly, it attempts to develop a general systems approach to changes in shifting cultivation. In itself, the application of systems theory to agriculture is not new. What is new, I think, is the way in which I have tried to apply systems theory to shifting cultivation, not as an academic exercise, but with a view to formulating a framework for agricultural technology development. Secondly, this book provides a case study of shifting cultivation from an area which is rather typical of humid tropical Africa. It shows how and with what effects a shifting cultivation system has changed over the last thirty years. It also discusses the implications for technology development, in particular for cassava research.
The methodological and technical objectives are intertwined and cannot easily be separated, as will become apparent in the text. It is not my objective to test the analytical framework I am proposing. Such an undertaking would be impossible with the current set of data which has been used to identify the analytical framework.
The limitations of this study are several, and concern content as well as methodology. Firstly, the interdisciplinary approach does not always do justice to the complexity of disciplinary problems. Secondly, due to either the absence of quantitative data, or the limited validity of many of the existing statistical and survey data, no statistical treatment of the data has been attempted. Some of the conclusions rely therefore principally on circumstantial evidence. Partly, this evidence is provided by farmers' statements, who, after all, have witnessed many of the changes in their environment. The reader

is warned that, nearly without a single exception, cassava farmers in the Kwango-Kwilu are women. 'Farmer' therefore refers to women, unless indicated otherwise. Thirdly, a focus on crop production has led to a very superficial treatment of postharvest handling issues, which, in the case of cassava, is a serious shortcoming.
I can only hope that this study presents a starting point for future work on shifting cultivation, and that it is helpful for others who wish to analyse (and perhaps model) shifting cultivation systems.

Chapter 1 provides a overview of the issues in agricultural technology development in Africa. It discusses the 'African crisis' and the need for technology development for African farming systems. In chapter 2 the literature on the analysis of traditional agriculture as a system, in particular the farming systems research literature from Francophone Africa, is reviewed. Because farming systems research is considered too limited for the analysis of shifting cultivation, a qualitative model based on a hierarchy of systems is proposed in chapter 3. Chapter 4 discusses the data base and research methods used in the Kwango-Kwilu. From chapter 5 through chapter 8, each chapter presents a level of analysis in the hierarchy of systems, starting with the regional system (chapter 5). This means that the usual order of analysis in agronomy whereby the crop provides the starting point, is reversed. However, in the analysis of agriculture in a given region one is confronted with regional data first, so the 'top-down' order (regional to crop system) fits the methodological and technical experience in the field. Chapter 6 discusses farming systems in the valleys and table lands of the Kwango-Kwilu and shows, among other things how a reliance on cassava and female labour explains most of the flexibility of the system. Chapter 7 shows what changes have taken place in cropping systems in the course of the last 30 years during which agricultural output increased dramatically. In chapter 8 the crop system and the key role of cassava in the system is highlighted. The problem of measuring cassava yields and the evolution of yields is dealt with in chapter 9. How national and international cassava research before and after Independence provides a response to the constraints imposed by shifting cultivation, is discussed in chapter 10. The final chapter (11) draws conclusions, both with respect to technology development for cassava in shifting cultivation systems, and with respect to the use of a systems approach in the analysis of shifting cultivation.

I owe a great debt to many people, who in the course of my work have helped me in various ways. My first debt is to colleagues and farmers in Zaire, who took the time to explain to me what seemed obvious in their eyes. In particular, I have appreciated the collaboration with Citoyen Badjoko, my counterpart for nearly three years, with the Zairois Department of Agriculture, and with the team of the FAO/UNDP project and later of the World Bank/GTZ/Department of Agriculture at Kikwit. Mr Labbens, the UNDP Resident Representative during most of my stay, showed an unfailing interest in my reports 'from the bush'. Citoyenne Mubi looked after me like a mother and taught me Kikongo. I am grateful to the missionaries in the Diocese of Kikwit, in particular the Mission of Kikungi where I spent many hours walking through cassava fields with R.P. Peters. Mr and Mrs Mestriau always welcomed me to their house in Feshi and shared their knowledge of the Kwango-Kwilu with me.

Secondly, I am grateful to the Government of Zaire and to FAO for having provided me with an opportunity to broaden my perspectives during my assignment in the country, and for the permission to publish the data collected in the course of the project.

Thirdly, many people have encouraged me during the writing of this study. Prof. Michiel Flach and Prof. Niels Röling of the Agricultural University always seemed to have had great confidence in its outcome and provided many useful comments. I am very grateful that they never seemed to mind my transgressions into other disciplines. My colleagues at the Department of Tropical Crop Science patiently put up with endless phone calls for me, whenever I was busy at my word processor. Mr R. Boekelman and Mr P. Holleman provided the excellent drawings. The Word-Processing Centre of the Agricultural University kindly typed all the tables for me. I also need to acknowledge the challenging discussions with many students who were higly interested in the subject of systems analysis in tropical agriculture.

I have appreciated the support of Susan Legêne and her team at the Royal Tropical Institute's Publication Bureau.

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1 DEVELOPING AGRICULTURAL TECHNOLOGY IN AFRICA

The crisis in Africa: a debate

Anyone involved in agricultural development in sub-Saharan Africa has probably wondered about the limited transferability of the Green Revolution successes. If the entry of science into agriculture has led to tremendous increases in output per unit of land area in many countries in the world, including several least developed countries, why has this not been generally true in Africa? Why are yields per hectare in Africa stagnating, or, at best, increasing at a very slow rate? During the 1970s, African[1] food production growth grew by a mere 1.3% yearly, a rate not only well below the increase in total population, but also below that of the rural population. And where total output increased, it has largely been due to expansion of the area under cultivation (USDA 1981, World Bank 1981). The alarming figures on the declining per capita food availability in Africa (table 1.1) have led African and donor governments to speak of 'the African crisis' (FAO Regional Food Plan 1978, Lagos Plan of Action, 1980). Since the poor record of African agriculture has occurred over a period when the international community has focused more than ever on food production, the term crisis points as much to severe deficiencies in food supply as to the failure of present development strategies (World Bank 1984).

There have been many attempts at explaining the stagnation in African agriculture and its poor performance relative to other continents. The causes have been sought in constraints imposed by the African climate and soils, the nature of traditional (shifting) agriculture, as well as in the demographic, social, economic and political conditions of production. There is no doubt that the potential for increasing outputs in traditional agriculture is limited by a series of environmental constraints, such as the volume and distribution of rainfall in the semi-arid regions, and by erosion and leaching in the humid tropics of Africa. There is general agreement, however, that environmental constraints do not constitute a sufficient explanation of the African crisis.

Table 1.1 Average index of per capita food production in selected countries (source: *World Development Reports 1983, 1984, 1985*).

COUNTRIES	Average index of per capita food production 1979-81[1]	1980-82[1]	1981-83[2]
LOW INCOME COUNTRIES	111	110	111
China	116	124	119
India	103	101	108
Sub-Saharan Africa	–	–	94
Burkina	94	95	100
Central African Republic	102	104	94
Kenya	85	88	86
Malawi	96	99	101
Sudan	102	87	94
Tanzania	91	88	103
Zaire	87	87	93
LOWER MIDDLE INCOME COUNTRIES	110	111	105
Indonesia	118	117	121
Philippines	122	124	113
Peru	84	87	82
Colombia	122	124	106
Sub-Saharan Africa	–	–	93
Cameroon	101	102	84
Congo P.R.	82	81	99
Ivory Coast	110	107	108
Nigeria	91	92	98
Zambia	92	87	74
Zimbabwe	92	87	79

Notes
1 1969-71 = 100
2 1974-76 = 100

Anthony et al. (1979) in their review of eight field studies cite the following causes of varying productivity between farms and areas: resource endowments (soils, climate and population densities), the availability of improved technology, current farmer technology, access to markets, and individual differences between farmers with respect to land, labour and management. The World Bank (1981), in its well-known Berg Report, attributes the crisis in African agriculture mainly to political, institutional and economic factors. These include a scarcity of trained manpower, political instability, the lack of adapted institutions, high population growth rates, and the economic legacy of colonialism. Various external factors, such as the deterioration of the balance of payments, growing cereal imports and declining exports, are thought to have aggravated the situation.

But the World Bank's analysis is not shared by everyone. While the Berg Report undoubtedly provides a number of valid explanations at a general level, these are inadequate when it comes to dealing with the concrete problems of agricultural development in a specific area, let alone the formulation of research and policy recommendations. Berry (1983) even questions the notion of agricultural crisis itself, by showing that in Africa agricultural performance varies greatly from one area and crop to another. Aggregate production figures cannot do justice to the considerable diversity of African agriculture, and are subject to serious error. In some cases output may in fact have declined, but in others surplus may have been channelled into parallel markets or into higher subsistence consumption. Furthermore, the crisis in agricultural supply is likely to arise as much from poor distribution as from declining production.

The present study presents a case from the Kwango-Kwilu region of central Zaire, a country which is commonly thought to live through a serious crisis in agricultural production and food supply. It deals with changes in cassava production by low input farmers against the background of the debate on the nature and causes of the African crisis. Cassava, and root and tuber crops in general, have not been included in some of the key sections of the World Bank analysis of African agriculture (for example, World Bank 1981:65). This omission is all the more serious since roots and tubers account for a larger share of total calory production than cereals (Guyer 1984). In Central Africa, cassava is the dominant crop, and it may be gaining importance in other parts of the continent by gradually replacing traditional cereals and yams.

Since the publication of *Manioc in Africa* (Jones 1959) there have been very few comprehensive studies of cassava production, most of them dealing with cassava agronomy under controlled conditions. It is therefore unclear to what extent the current explanations of the African crisis hold true for this crop. Unfortunately, because of farmers' cultural practices, such as intercropping and staggered harvesting, cassava statistics are even more unreliable than those for other crops, so that it is impossible to draw firm conclusions on overall trends in cassava production. Hahn et al. (1979) attribute the increases in African cassava production nearly entirely to an expansion in acreages, while the yield increases account for less than 10% of the total production increase. However, this can only be a general figure, and little is known on how cassava production has increased or decreased in specific parts of the continent.

The case of the Kwango-Kwilu is also interesting because it can provide insight into the factors that influence cassava production, and in particular the evolution of yields, area and cultural practices over time. In Zaire it would seem that increased surplus production of cassava roots and leaves for urban consumers has been accompanied by a considerable expansion in area and declining or stagnating yields. This study aims to document changes in cassava production over time and relate them to changes in the agro-ecological and socio-economic environment.

The lack of improved agricultural technology in Africa

While there is obviously something like a crisis in Africa, its nature and causes are far from clear. One thing which transcends from the mass of literature and official documents is that science based technology[2] has had very little or no impact at all on food production in Africa, with the exception of hybrid maize. The lack of immediate, on-the-shelf technical solutions for the problems of African agriculture is often cited as an important explanation of the present crisis (USDA 1981, World Bank 1981). Many of the technologies required for an intensification of agriculture in less favoured areas of the continent are not available. In part, the weakness of agricultural research results from insufficient funding and the lack of adequately trained and motivated personnel. However, in recent years, the number of scientists as well as the expenditure per scientist have increased considerably (World Bank 1984).
The failure of research to develop technology for African agriculture stems mainly from the fact that much of the recent research efforts have been inadequately focused. Past research has concentrated on areas of high impact potential and short-term pay-off, such as irrigated and favourable rainfall and soil fertility zones (CGIAR/TAC 1985) and on export crops. Consequently, most improved technologies today cannot be transferred to the more marginal areas and to African staple crops. The direct transfer of technology developed elsewhere has not been successful in Africa (Eicher 1984) and such a strategy also needs to be questioned on theoretical grounds (Röling 1983).
The lack of agricultural technology applies to cassava as well. Although advances in the development of pest and disease resistant varieties of cassava are reported by IITA (IITA 1980-1983), there is no widely adapted variety or technological package that can be disseminated to small farmers in Africa.

Strategies of agricultural technology development in Africa

But it is not just the lack of technology that hampers agricultural development in Africa, even the *strategies* for future technology development need to be questioned. The centralized breeding of widely adapted varieties is only possible in relation to relatively uniform environments, as in irrigated areas. For rainfed regions with great ecological and socio-economic diversity, location-specific research strategies are required. The African cassava belt, ranging from the humid to the semi-arid regions of Africa, is characterized by a great variation in climatic and edaphic conditions affecting both cassava growth and pathogen incidence. Future research strategies must therefore focus on the factors limiting cassava productivity with special reference to the effect of agro-ecological factors (Terry 1981). The case study presented here also intends to identify the specific set of ecological and socio-economic factors limiting cassava production with a view to defining research priorities.

There is general agreement in the scientific community that the occurrence of a Green Revolution in Africa is unlikely and – in the eyes of some – perhaps undesirable. The two crops that were responsible for the dramatic yield increases in Asia, wheat and rice, are not grown on a large scale in Africa. The remarkable production growth in maize as a result of the introduction of hybrids has been limited to parts of Southern and East Africa. Major breakthroughs in African staples such as millet, sorghum and root crops have not been achieved. Moreover, the strategy of the Green Revolution, to first improve yields by planting high yielding varieties on better, preferably irrigated lands, does not fit Africa, where rainfed agriculture dominates and only a tiny fraction of the total arable area will be equipped for irrigation by the end of the century. Land abundance, low population densities and relative labour scarcities prevailing in Central Africa in particular do not facilitate intensification. Bottlenecks in fertilizer supply and marketing and unfavourable pricing policies provide additional disincentives to a Green Revolution approach in Africa.

If uniform Green Revolution technology and research strategies are not suitable in the African context, the alternative is less than clear. On the one hand, growing reliance on rainfed areas for increased production will require more location-specific technologies adapted to complex and fragile ecosystems. Research aiming to adapt existing component and commodity research is needed to produce a range of technology options tailored to diverse environments.

On the other hand, even in Africa, a further expansion of the area is limited, which means that, ultimately, production can only be increased through *intensification*. Almost half of the humid lowland tropics of Africa are currently under some form of shifting cultivation (Ter Kuile 1984) and observations suggest that cassava figures in most cropping arrangements in shifting cultivation. Although shifting agriculture has been the subject of research efforts dating back to colonial times (e.g. de Schlippe 1956, Nye & Greenland 1960), resulting in various strategies for intensification, the record has been very unsatisfactory. In many areas the fragile ecological basis of shifting cultivation is rapidly deteriorating, thus further compounding the problem of agricultural technology development. Adapting existing component and commodity packages to the marginal conditions of shifting cultivation could ultimately be very destructive.

In other words, adaptive research is insufficient if it comes to developing the technology required to stabilize shifting cultivation. The development of such technology, that will allow increased productivity and sustainability of production in rainfed low-fertility areas is considered the frontier of agricultural research today and will require a concerted international effort in fundamental and strategic research (CGIAR/TAC 1985).

The need for intensification of low input agriculture raises questions about the future perspectives of agriculture in Africa. In the long term, it is to be expected that the agricultural sector will provide employment to a declining percentage of the total population, even if in the next decades small farmers will remain the backbone of agricultural production. The high growth rate of the urban population in Africa, 5-8% annually, underscores the need for the rapid introduction of yield increasing technology.

In terms of research strategy the issue is whether resources should be allocated to relatively favourable environments with a better potential for surplus food production rather than to the more marginal areas. Under conditions of low input use, research can only deal effectively with yield reducing factors (weeds, pests and diseases), but yield increases – through breeding for higher yielding varieties at low input levels – are ultimately destructive if soil fertility is not restored (van Keulen & Wolf 1984). The potential for increasing yield through improved varieties adapted to low input levels is necessarily limited (Parlevliet, undated; Byerlee & Harrington 1982).

Beyond natural resource endowments and input levels, population densities may also influence research strategies. Binswanger (1985) suggests that under land abundance and low technology levels the opportunities for technological breakthroughs are minimal, because the benefits of yield increasing technology are limited to labour reduction in land preparation, weeding and planting of the area saved. Yield increasing technology does not allow savings in land costs, nor in the costs of inputs as these are hardly applied. He concludes that under land abundance farmers will be less interested in fertilizers or improved cultural practices such as manuring or land conservation than in stress resistant varieties, quality enhancing innovations and laboursaving techniques. In inframarginally land-scarce areas, in the periphery of urban centres, the scope for yield increasing technology that requires inputs would be much greater.

Finally, an answer to the question of research resource allocation depends obviously on country and area specific factors. What is agronomically desirable, may not always be socially acceptable. These dilemmas are illustrated by the considerations on cassava research strategies in the Kwango-Kwilu. In the entire area shifting cultivation is under great stress, and further expansion of the cultivated area is not possible in many places. Some type of intensification must be envisaged beyond the adaptation of commodity technology packages (fertilizer, varieties). However, current cassava research in Zaire focuses on the development of pest and disease resistant varieties with little consideration for improvements in cultural practices. On the isolated southern table lands with low man/land ratios the scope for sustainable yield increases at present technology and input levels are probably minimal. In the more densely populated valleys, where inframarginal land scarcities are emerging, intensification could perhaps be brought about if research strategies would focus on developing alternatives to the traditional system of shifting cultivation. The effectiveness of the development and introduction of new farming systems would greatly depend on socio-economic and political changes.

Agricultural research methodology: farming systems research

More or less simultaneously to, and partly influenced by, the discussions on the African crisis and research strategies, agricultural research methodology itself has also been subject to heated debates. Agricultural research procedures, with their bias towards on-station work, do not easily allow the development of technology adapted to the great variety of ecological and farmer conditions. On-station trials do not reflect these conditions and, as a result, responses to experimental variables are likely to be biased in their magnitude as well as in the shape of the response function (Franzel 1983). Furthermore, researchers' criteria for evaluating new technology do not necessarily coincide with those of farmers, since the latter do not usually maximize single crop yields per hectare. Shifting cultivators especially, who produce a great diversity of crops under relative land abundancy, operate on a different production function from research stations.

There now seems to be a considerable body of opinion that on-station commodity and component research must be complemented by studies outside the controlled research environment. These studies involve both an inventory of farmer practices and constraints as well as on-farm testing of new technology. The purpose is not only to improve adaptive research procedures (multilocational testing by itself has been a long standing feature of varietal improvement research), but also to define priorities for technology development.

Off-station research is seen as a method by which farmers can participate in the development of new technology. Most researchers now acknowledge the importance of farmers' knowledge of land races and their understanding of the micro-variations in the environment. However, African smallholders are not organized in such a way as to make their experiences and needs known to researchers. A study of the successes of agricultural research in Europe, the US and Japan shows that farmer demand and support are essential to focus research (Binswanger & Ruttan 1978). It has been argued that control by users, i.e. farmers, is essential for the development of agricultural research and extension (Röling 1985). Unfortunately, the urgency of the African crisis now leads to considerable research commitments without strong farmer involvement. Consequently, the definition of research priorities must be undertaken with great care in order to balance the interests of the different parties. This puts agricultural research personnel in a difficult position, since the present organization of agricultural research leaves little room for treating farmers as anything but passive recipients of technology.

Farming systems research and related procedures involving on-farm testing claim to present a way out of this apparent deadlock. Farming systems research has evolved as a series of procedures for agricultural research aiming at increasing the productivity of small farm households through the development of adapted technology and complementary policies. Farming systems research views the farm household in a comprehensive way, i.e. as a system with natural and socio-economic components (Gilbert et al. 1980, Norman 1982). The central argument is that technology can only be successful in raising yields if it takes into account the biological as well as socio-economic constraints under which farmers produce their crops. In principle, farming systems research complements existing commodity research through farm level research in which farmers are active partners. The basic procedure involves the definition of homogeneous categories of farmers (recommendation domains) for which adapted technology is developed and tested (Byerlee & Collinson 1980, Shaner et al. 1982).

Farming systems research reflects a number of advances made throughout the 1970s in various areas of agricultural development, while also drawing upon earlier work such as farm management studies (Collinson 1972). In part, it may be considered a reaction to the unintended side effects of the Green Revolution (Pearse 1980) and the resulting awareness of the social and economic determinants of production. The discovery of the plight of the poor and landless (FAO 1979, Chambers 1980) and their survival strategies transformed 'the small farmer' into the target group of agricultural development (Röling & de Zeeuw 1983). The small farmer approach advocates technical assistance to homogeneous categories of farmers as one element of a comprehensive strategy. Indigenous knowledge and experimentation were also 'discovered' as important sources of technical change (Brokensha et al. 1980). Land evaluation procedures (FAO 1978, FAO 1980) demonstrated how actual and potential land utilization types could be defined by taking physical land conditions and crop suitability as starting points.

Regional planning methods (van Staveren & van Dusseldorp 1980) provided detailed guidelines and checklists for interdisciplinary teams. To a lesser extent, gender also became a variable to distinguish between potential beneficiaries of technology (Rogers 1980). These approaches have in common that development is viewed as an integrated process focusing on small farmers and comprising technical as well as socio-economic aspects. If they are applied to agricultural research, research procedures result that are now generally known as farming systems research or a farming systems approach.

Although it was recommended as early as 1978 that more research should be pursued within a cropping and farming systems perspective (CGIAR/TAC 1978), it is probably still too early to assess its impact on African agriculture. In particular with respect to the participation of farmers in designing and testing, the methodology of this type of research is still evolving (Matlon et al. 1984). Thusfar, farming systems research has been mainly concerned with the description of existing farming systems and with the development of on-farm methodology, to the neglect of new farming systems development (Simmonds 1985).

Conclusions

The agricultural crisis in Africa can be only partially attributed to the lack of technology. Modesty becomes any agricultural scientist in view of the overwhelming problems facing the African continent. Nevertheless, agricultural research can and must make a contribution, if only because of the technical problems of intensification under the current high rates of population growth.

With respect to technology development, it is argued here that a dual approach is required. On the one hand, adaptive research is needed to tailor existing technologies to the diverse and often complex production environments of small farmers. On the other hand, intensification of agricultural production requires more basic and strategic research (CGIAR/TAC 1985), in order to develop sustainable alternatives for those farming and cropping systems which are currently under great ecological stresses. Basic and strategic research, it should be emphasized, does not only refer to basic biological research, but also to research to further our *understanding of agricultural systems* in Africa. Farming systems research, per definition, is likely to present shortcomings in both respects, because of its limited focus on adaptive research and on the farm as the only unit of analysis. Nevertheless, farming systems research in its broadest sense has tried to study traditional farming as a system and this work merits further attention before embracing alternatives.

An understanding of the structure and function of agricultural systems in Africa should also clarify the complementarity between basic and adaptive research, and how agricultural research can be linked to institutional and policy measures. What is required, therefore, is a framework that allows the integration of technical and socio-economic issues in agricultural intensification and new farming systems development. This study attempts to develop such a framework, by drawing upon ecological systems theory and elements of farming systems research. Its centerpiece is the analysis of constraints and limitations on cassava yields at different system levels (see figure 9.2). Ultimately, this exercise aims to gain a broader perspective on the multitude of constraints and limitations on agricultural production. Understanding agricultural systems in Africa does not provide solutions to the crisis, but should help to produce technology that reflects fully the African potential for food production.

Notes

1 Africa is used throughout the text to indicate the states of sub-Saharan Africa, with the exception of the Republic of South Africa.
2 Technology is used here in a rather broad way to designate all technical (as distinct from socio-economic) improvements that lead to physical changes in input/output relations.

2 THE STUDY OF FARMING SYSTEMS – A PERSPECTIVE ON AGRICULTURAL TECHNOLOGY DEVELOPMENT

This chapter explores the ways in which traditional farming in Africa has been studied as a system. It aims to provide insight in methods and models that adequately describe farming systems, and how these influence strategies of component and commodity research. Most of the current farming systems literature is written in English and has been developed at US universities and the international institutes of the CGIAR. There exists also an extensive tradition of adaptive research in agriculture in France and French speaking Africa, including the work conducted by French and Belgian colonial and post-colonial institutes.[1] Neither the French language (Francophone) literature nor Anglophone farming systems research represents a unified approach: the differences between CIMMYT's Eastern and Southern Africa Economics Program and the on-farm research conducted by Njala University in Sierra Leone, for example, are considerable (Fresco & Poats 1986). However, these differences seem smaller than the differences in emphasis between Francophone and Anglophone farming systems research as a whole. Both these traditions will be contrasted briefly, not to give a full description (see Fresco 1984a), but to assess the potential contribution of farming systems research to the development of agricultural technology for African agriculture. First, however, some of the forgotten older traditions in research on traditional farming will be reviewed.

Older traditions in research on traditional agriculture

The study of farming systems is not as new as some would like to suggest. Already in the late nineteenth and early twentieth century agricultural scientists have put forward the idea that smallholder farming in the tropics must be considered in a holistic way and that its study requires inputs from several disciplines. In particular, Dutch researchers working on traditional cropping in Java developed concepts and methods that are strikingly similar to those of present farming systems research. Sollewijn Gelpke (1875, 1878) conducted trials on farmers' fields under farmer management methods. Scheltema (1923) attempted to map the interactions between the elements of small paddy farms, including the upland and garden components. De Vries (1931a,b) defined farm types on the basis of homogeneous land utilization units. The study of the influences of changes in one component on the structure of the farm became increasingly important. Vink (1946), for example, analysed how changes in sugarcane varieties affect labour and capital inputs, while Timmer in his dissertation on social agronomy (1947) showed that one subsystem, e.g. irrigated rice cultivation, occupies a unique position in each farming system. Consequently, paddy fields in different farming systems are not identical and may require different technical improvements.

The work of Pierre de Schlippe

Although his work has attracted little attention, Pierre de Schlippe may be considered one of the founding fathers of modern farming systems research. His study of shifting cultivation of the Zande (on the border of the Sudan and Zaire) led him to the conclusion that the development of agricultural technology in research stations must be preceded by a detailed analysis of local agricultural traditions and the rationale behind them (de Schlippe 1956a). Such an analysis, which involves agronomy as well as anthropology, aims to find ways to improve traditional agriculture without doing violence to the limiting framework of environment and traditions. Two central concepts of his theory, which he called agricultural anthropology, are the 'system of agriculture' and the 'field system'. A system of agriculture is '*the customary pattern of behaviour followed by the individual members of the ethnographic unit in the realm of agricultural technology, which results in typical sets of:*

a *land utilization in space (pattern of field types on their respective ecological backgrounds);*

b *of land utilization in time (pseudo-rotations*[2]*);*

c *of seasonal distribution of nutrition and other needs*' (de Schlippe 1956a:238).

Agriculture, in the views of de Schlippe – an agronomist by training – constitutes an essential part of the culture of any people, and involves therefore agricultural as well as cultural elements. Agricultural behavior is governed by social norms and knowledge of the environment. This knowledge is extremely detailed, ranging from criteria for the relative fertility of each soil-vegetation pattern, the exact timing of every operation in the process of raising each variety of each crop, the utilization of all sorts of fruits, seeds, leaves, woods, barks etc. The main elements of the system of agriculture are ecological concepts: types of fallow, soils, vegetation, hill to valley sequences of soil types (catena); and characteristics of every crop and variety of crop and the way to cultivate and process them, including subspontaneous crops. These elements have to be related to certain types of fields (de Schlippe 1956b). Shifting cultivators classify fields into a number of types according to crop associations and sequences, according to ecological criteria (topo-sequence, soil fertility, water supply, vegetation) and according to management methods (de Schlippe 1957). Among the Zande each smallest economic unit, i.e. each woman, possesses a complete set of field types. This fact allows them to make optimal use of the ecological environment and of the available labour. Field types evolve through time, because of the introduction of new crops, resettlements or because farmers happen to experiment with, for example, new cropping patterns.

The work by de Vries and others in Indonesia and by de Schlippe in Africa differs in two respects from current farming systems research. Firstly, it was mainly descriptive, and only to a limited extent geared towards providing inputs for agricultural research. De Schlippe recommended that agricultural research focus on an agro-economic analysis of field types. Because the concept of field type integrates cultural practices, crops and ecological constraints into a meaningful whole, it corresponds to the cropping systems. On-station research, according to de Schlippe, should simulate field types. For agricultural research it implies that specific technology must be developed for each cropping system, or field type, and that on-farm testing should take account of cropping systems. As Timmer (1947) already suggested, fields looking similar may nevertheless be managed in different ways, and different types of technology may be required. However, not even de Schlippe makes mention of the possibility of conducting trials on farmers' fields. Secondly, the analysis of traditional farming was always the work of a single individual, who spent many years in the field, and never of a multidisciplinary team. Yet their descriptions of the farm as a system, of its components and the impact of changes in one component on the farm as a whole, deserve further attention from present-day students of farming systems. In their emphasis on cultural elements and traditional knowledge de Schlippe and de Vries and others were far ahead of their times.

Farming systems research by INEAC

INEAC, the Institut National pour l'Etude Agronomique du Congo Belge, was created in 1933. Nearly forty research stations were established in the Congo and Ruanda-Urundi. As Drachoussoff points out, *'by its independence, its strongly centralized organization and the quality ... of its leaders, INEAC played a* *more important role ... than is usual for a research organization*' (Drachoussoff 1965:187). Extensive research was pursued on many aspects of agricultural development including traditional agriculture. '*The volume, scope and quality of the resulting research is unparalleled in tropical Africa*' (Miracle 1967:243). Particular emphasis was placed on increasing yield potentials under peasant conditions, and yield increases ranged from 87% (beans) to nearly 400% (cassava) (Jurion 1952).

The Congolese authorities were explicit about the need to transform traditional agriculture and stabilize shifting cultivation. Through its studies of the physical and human environment, of suitable plant and animal species as well as forms of socio-economic organization, INEAC was instrumental in elaborating the technical features of the colonial resettlement policy (Jurion & Henry 1967). In resettlement schemes, *paysannats*, traditional farmers were encouraged to use modern farming techniques. The *paysannats* never moved beyond the pilot stage, and in the decade of their existence (the 1950s) only about 200,000 farm households were ever included. The spatial reorganization of traditional agriculture was considered a key feature. In the *paysannats* the exact location as well as the necessary improvements of each spatial unit (the village, the fallows, the roads, the firewood lots etc.) were determined. Fields and fallows were laid out in *couloirs*, corridors of a width of 100 m, along an east-west line. The number of corridors equalled the total number of years of cultivation and fallow, so that alternated corridors were opened up annually. In contrast to the 'Experimental Units' in Senegal, the new farming system proposed by INEAC consisted of an improvement of shifting cultivation without totally eliminating the fallow. The productivity breakthrough in the *paysannats* never materialized and the institution has been severly critized for its paternalistic features (Dumont 1962). Within as well as outside[3] the *paysannats*, INEAC's methodology was not very different from that of IRAT in West Africa: the holistic view of farming, the detailed study of agrobiological and socio-economic aspects, and the gradual introduction of appropriate technical innovations with the profound transformation of agriculture as the ultimate objective.

Francophone West African research on farming systems

Francophone farming systems research, as it shall be conveniently called, evolved out of French colonial research on tropical agriculture. From the beginning it was strictly organized along commodity lines and this structure was also imposed in the former French colonies.[4] Over the years the institute responsible for research on food crops (IRAT) was instrumental in developing a systems approach to agricultural research.

The Experimental Units in Senegal

The evolution from a commodity to a farming systems orientation has been illustrated by the history of agricultural research in Senegal (Tourte, 1977). From an exclusive focus on export crop (groundnuts), a greater awareness of the constraints imposed by the soudano-sahelian environment led to detailed studies of agroclimatology and yield variability during the 1950s. When the technical basis for intensified cropping systems was established, researchers became more aware of the role and needs of small farmers in determining agricultural production. IRAT's research objectives of the late 1950s reflected a growing concern with the intensification of traditional farming. The failure of the extension service to transfer technology to farmers raised questions about the way this technology had been developed in the artificial context of research stations. The idea emerged that component and commodity research had to be combined into the development of new farming systems that were to be tested in reality.

In 1968, this resulted in the establishment of the 'Experimental Units' in the Sine Saloum in Senegal by IRAT, later with the collaboration of ISRA (the national Senegalese research program) (Faye & Niang 1977). An Experimental Unit was defined as a geographical entity of about 5,000 ha where the results of agricultural research were to be tested on a realistic scale. The purpose of the Experimental Units was to develop technological packages that took into account the interactions between the human and physical environments. Yield increases without environmental degradation became the ultimate objective of research. This required an assessment of the agricultural potential of the area and the identification of all kinds of constraints to farm level production increase. The steps in the transition from traditional to intensified farming systems were carefully defined. While conventional agronomic experimentation was also carried out, the Experimental Unit program was unique in the way new technology was being tested in existing farming systems, first under research supervision, later under farmer management. The real environment (*le milieu réel*) became the final test case. For the first time, traditional farming systems became not only subject of research, but their study was also institutionalized within the existing research structure. Although the Experimental Units turned out to be a very expensive program, beset with many difficulties, it has provided concrete results as well as an impact on research. Two new features were introduced into routine agricultural research: detailed procedures for data collection outside the research station, such as multi-annual case studies of farms (Billaz & Dufumier 1980); and permanent linkages between research and development organizations. A number of problems remained unsolved, and these are very similar to the problems encountered by many farming systems research programs today:

– the identification of the basic unit of analysis: the *carré* (residential unit) and *exploitation* (farm) did not necessarily overlap and were sometimes confused, which has lead to an overestimation of labour availability (Venema 1978). Certain technology may therefore not be adapted to households with a limited labour force;

– reaching all categories of farmers: in the Experimental Units the large influential farmers turned out to be the main participants in field trials, which is likely to have biased the results. The question remains how technology development can be directed at smaller farmers who, as has been.demonstrated for other parts of Senegal (Angé 1984), cultivate the poorest soils;

– extension and farmer participation: the development of methods for extension and farmer participation has lagged behind and there was no clear effort to involve women in any of the on-farm trial programs;

– although input delivery and marketing had been included as a special component of the Experimental Units, selfsustaining structures did not emerge;

– replicability and scale: the crucial issue remains how the Experimental Units approach can be extended beyond the experimental units to a larger region and to other countries. At least in part, the success of the Experimental Unit program has depended on the specific political and institutional context of Senegal, where decentralised research structures were already in existence and the agricultural sector plan left ample room for the inclusion of the low input farming sector. Thus, the integration of socio-economic variables into agricultural research did not seem a radical break from the past.

Theoretical concepts in Francophone farming systems research

The Experimental Units are only one, albeit perhaps the most well-known and best documented example of Francophone farming systems research. Other programs were carried out in Africa and Latin America. While there is no single Francophone approach to farming systems research, the central theoretical concept is the idea of 'research & development' (Lefort 1983). Research & development comprises three activities: the adaptation of intensified farming systems designed in research stations; the identification of the factors that limit production growth and the choice and testing of solutions to overcome these constraints; the development of policies and

Table 2.1 Levels of analysis in Franchophone farming systems research (adapted from DE MIRANDA AND BILLAZ, 1980).

Level	Unit of analysis	Study of:
1. Field/plot	a. cropping system (*système de culture*) b. livestock system (*système d'élevage*)	a. soils, agro-ecological history, crop/weed/ insect populations, micro-climate b. also: herds, grazing conditions
2. Farm	farming system (*système de production*)	means and methods of production, including non-agricultural work; recent history, past change in capital and technology utilization; labour films; houshould budgets
3. Village	village production systems (*système agraire/terroir*)	management of natural resources, land evaluation, climate, vegetation, morphology, etc., (social) control of natural resources and water
4. Subregion	subregional production system (système agraire/petite région)	idem but on a scale of 10,000 ha and over

methods to improve the socio-economic conditions of production (Billaz & Dufumier 1980: 19). Clearly, research & development encompasses much more than agricultural research alone. In practice, most Francophone farming systems research deals with issues that are also part of Anglophone farming systems research: laboursaving technology, the quantities and types of agricultural inputs (tools, seeds, fertilizer, machinery), and the management of farming systems. It is hardly ever possible to test hypotheses in the field of marketing or price policies (unless one uses simulation modelling). The ultimate goal of research & development is the gradual transformation of the biological, physical and socio-economic environment whereby a comprehensive package of innovations provides the starting point. In this way, it differs clearly from most Anglophone farming systems research which aims at incremental changes in existing farming systems. In the Francophone tradition the agricultural potential of the area and not the existing farming system constitutes the point of departure. Research & development involves therefore more than the study of farming systems. It operates at four levels of observation to which four units of analysis correspond (table 2.1): the cropping-livestock system, the farming system, the village production system and the subregional production system. In the Francophone tradition, farming system is defined as a combination of products and production factors applied by the farm household, including therefore all the subsystems of land utilization (crops, forests, herds, hunting and gathering grounds) (GERDAT 1982). The results of the analysis at field, farm, village and (sub)regional levels are integrated in order to analyse the impact of existing and improved production patterns on natural resource conditions, and vice versa the impact of natural resource conditions on yield.

While there is a clear difference in focus, the methodological sequence of research in Francophone farming systems research is not very different from, for example, CIMMYT's procedures in East Africa (Collinson 1982). Usually, the following, overlapping phases are distinguished (Ramond 1970; Tourte & Billaz 1982):

– an analysis of constraints on agricultural development leading to a *zonage*, the definition of homogeneous agro-ecological areas (similar to land utilization types), and a typology of farming systems. Zonage and typology together are roughly equivalent to CIMMYT's definition of recommendation domains (Harrington & Tripp 1984), although they may be more detailed (i.e. there are likely to be more zones and farm types than recommendation domains);

– the formulation of farm models[5], i.e. different combinations of improved technologies for each class of farms within an agro-ecological zone. Farms are considered of the same category if they are similar in area, labour force composition and per capita income. The definition of farm models, or new farming systems, is a typical feature of the Francophone approach;

– the design and implementation of multilocational trials. The hypotheses for testing are derived from the farm models (e.g. the feasibility of the introduction of animal traction or improved cultural practices);

– the evaluation and interpretation of the on-farm trials, leading to the definition of new research problems as well as to follow-up action with development agencies (e.g. with respect to input delivery).

Much more than Anglophone farming systems research, Francophone farming systems research is explicit about the need to define sequences of technology which will ultimately lead to an intensification of agricultural production and optimal land-utilization patterns. A distinction is therefore made between two types of technology. 'Light' or 'classical' improvements (*thèmes légers*) include changes in cultural practices and simple innovations such as new food crop varieties or fertilizer that could be added on to the traditional farming system without altering its structure. 'Fundamental' technology (*thèmes lourds*), however, consists of a coherent package aiming at an intensification of production and therefore a profound transformation of the farming system. In the case of West African farming systems, this involves the reorganization of land holdings, the use of heavy mechanical equipment, destumping, frequent fertilizer dressings, improved rotations in order to allow permanent cropping, reafforestation etc. The two sets of technologies are not necessarily diametrically opposed, but must be seen as complementary. While the *thèmes légers* constitute an efficient instrument to assist the rural population in its transition from a subsistence to a market economy, they are by no means an end in themselves. IRAT has clearly expressed its conviction that the 'light' technology is inadequate to develop the full agricultural potential of a country, for which the *thèmes lourds* are crucial (Tourte 1971). It is also argued that there is no unilinear development, i.e. it is neither necessary nor useful for all farming systems to pass through the *thèmes légers* first. Each type of farming system has its own development path. In this view, restricting research to the development of step-by-step improved technology will necessarily limit economic growth and may be ecologically destructive. Depending on the degree of land shortage, West African semi-sedentary and sedentary systems are most likely to need a radical restructuring, because the resource base is rapidly deteriorating (GERDAT 1982).[6]

Anglophone farming systems research

Given the wealth of papers on the theory and practices of Anglophone farming systems research, there seems no need here for an extensive review (see for example: Gilbert et al. 1980, Whyte 1981, Norman 1982, Shaner et al. 1982, Fresco 1984b, Simmonds 1985). As a result of the initiatives of CIMMYT, ICRISAT, IITA, ILCA and various US Universities, farming systems research is now rapidly expanding in Africa: in most countries farming systems research programs have been launched. While there are great differences between these programs, nearly all seem to focus on on-farm experimentation and offer procedures for:

1 the inventory of farmer constraints;

2 adaptive research with the farmer as an active participant. The first step, diagnostic research, concentrates on the farm household as a production and consumption unit. The identification of existing farming systems through informal surveys and case studies is followed by the definition and analysis of recommendation domains, homogeneous categories of farmers (Hildebrand 1981, Collinson 1982). The activities of the household are analysed through a simple systems model, whereby cropping, livestock production and off-farm work are seen as complementary subsystems. The farming system is defined rather loosely as the combination of all farm enterprises, management, and farmer goals and their interactions (CGIAR/TAC 1978, Shaner et al. 1982). There is substantial agreement that increasing the productivity of small farmers is the primary aim of farming systems research. Productivity may be increased through the development of relevant technology and complementary policies, and theoretically farming systems research is concerned with both. In practice, however, most farming systems research programs limit themselves to changes in cropping systems through the introduction of

improved varieties and cultural practices.

The most significant contribution of Anglophone farming systems research to date seems to be the development of detailed techniques for on-farm research, the application of which is, of course, not necessarily limited to farming systems research programs (Matlon 1982, Ashraf et al. 1985, Hildebrand & Poey 1985).

Francophone and Anglophone farming systems research: an assessment and a critique

The various approaches to farming systems research represent both a break with the past and a logical continuation of component and commodity research. In general, agricultural scientists in Africa have focused on three fields: varietal improvement, agronomy and cultural practices, and mechanization (Eicher & Baker 1982). Each of these provides essential inputs for farming systems research. It is a misunderstanding that farming systems research is a new discipline or constitutes a replacement for ongoing agricultural research. Its main contribution has been to provide a 'market' orientation to agricultural research through a clearer focus on the potential clients of technology. Farming systems research does not offer a development strategy, but only a set of procedures to improve the efficiency of agricultural technology development. This is achieved in three ways:

a through the analysis of constraints on agricultural production;

b through adaptive, on-farm research and

c by orienting on-station commodity and component research.

An important question remains how individual pilot programs with a farming systems research perspective can be integrated into the established structure of a national research service (Andrew & Hildebrand 1982, Waugh et al. 1983).

Francophone and Anglophone farming systems research deserve merit for having drawn attention to a number of neglected issues:

– a holistic view of the farm as a system, including livestock and non-agricultural work. Nevertheless both Francophone and Anglophone farming systems researchers have been remarkably unaware of intrahousehold issues, such as the sexual division of productive and reproductive labour, the allocation of resources and revenue between household members, and decision making processes within and between households (Rockefeller/Ford Foundations, 1984);

– the categorization of farmers into homogeneous recommendation domains for each of which specific technology is required. One important difference between Francophone and Anglophone farming systems research is that the latter often limits itself explicitly to one recommendation domain (usually the category of resource poor farmers). Francophone farming systems research, through its differentiation between small improvements *(thèmes légers)* and fundamental changes in the farming system *(thèmes lourds)*, aims at all categories of farmers within a certain geographical region. In any case, the notion of recommendation domain is difficult to maintain, because the research topic determines to a large extent the borders of the recommendation domain. Certain technologies, in particular pest and disease resistant varieties, may very well be appropriate to all farmers, irrespective of resource endowments;

– the detailed diagnosis of farm level constraints. Both the Francophone approach (more formal, multi-annual studies) and the Anglophone (rapid rural appraisals, *sondeos*) have their merits and are probably complementary. Their usefulness depends, among other things, on the existing data base, cost effectiveness, and the degree of detail required. There is general agreement that any analysis of constraints ought to involve several disciplines;

– the importance of genotype-environment interactions and, consequently, the need for location-specific research and adaptive testing of improved varieties and cultural practices. While the desirability of farmer participation is acknowledged, its practicalities in multilocational testing are far from being solved;

– the role of farmers' knowledge of climate, soils, plant and animal species. However, there has been a tendency in some farming systems research programs to idealize farmer knowledge. To a large extent, the African crisis today is also a crisis of local knowledge that is not adapted anymore to the rapidly changing circumstances, in particular the changing man/land ratios.

Francophone farming systems research appears as a more formal, long-term and large-scale research undertaking aimed at developing the potential of a geographical region. On the basis of an assessment of this potential, i.e. the maximum production that can be achieved given the ecological conditions and optimal input and management levels, the steps are defined that will lead farmers to a transformation of their farming systems. Short-term and long-term technical options are clearly defined. The Francophone tradition shows a very explicit concern for soil fertility and environmental degradation. Anglophone farming systems research, on the other hand, deals with the adaptation of existing agricultural research to provide technology for low resource, low external input farmers and it does not aim at a profound transformation of traditional agriculture but rather at incremental changes.[7] The Francophone approach seems to offer a more appropriate framework for research into the intensification of shifting cultivation and some of its elements will be used in the analysis of o-Kwilu cassava in shifting cultivation systems in the Kwango Kwilu.

Beyond farming systems research

Farming systems research in general has come under attack from various sides. Berry (1983) criticizes its evolutionist approach and its belief in the primacy of technology itself in determining agricultural production. In practice, many farming systems research programs tend to adopt a single factor approach to intensification, usually by focusing on increasing returns to land through the use of improved inputs. Others have argued that there is no guarantee that the needs of the poor will be met through farming systems research (Chambers & Ghildyal 1984). It has also been pointed out that too much emphasis on farming systems research could divert critical resources away from crop improvement (Kirkby 1984).

An other important shortcoming of all farming systems research is that it makes insufficient use of a systems approach to agricultural production. The models of the farming system in Anglophone farming systems research are usually very simple (Norman 1980, Zandstra et al. 1981), although they can be illustrative of broad differences between types of farming systems (McDowell & Hildebrand 1980). Francophone farming systems research carries this further by defining different levels of analysis, but does not provide a model for the analysis of relations between the elements within the farming system and between the farming system and systems at other levels. In particular, there is no agreement as to what variables must be treated as exogenous or endogenous at different levels, and in different time frames. Farming systems research, especially its Anglophone version, is essentially static. Consequently, it is impossible to bridge the gap between the analysis carried out at farm or crop level and data available about other levels.

The research accumulated since the publication of the studies by Nye & Greenland (1960) and Allan (1965), to name but two influential works, has greatly increased the understanding of traditional African farming systems. Nevertheless there seems to be a rift between the wealth of data present in micro-level studies and overall agricultural research and development policies. Broad generalizations used by the latter (shifting cultivation systems, savannna systems etc.) are inaccurate and suggest that standard solutions can be found for African agriculture (Richards 1983). At present farming systems research, nor any other theoretical framework, provides ways to integrate the results of the analyses carried out at different levels and by different disciplines. It follows, that even with a detailed analysis of farmer constraints, the implications for agricultural technology development and agricultural development policy are far from clear. Time seems to have come to look beyond farming systems research to a more encompassing approach that takes into account the different system levels in agricultural production and that can be linked with simulation models such as developed by theoretical production ecologists and macro-economists (van Keulen & Wolf 1984, sow 1981).

Notes

1 There is also an extensive tradition of adaptive research in Latin America and South East Asia, which contains many of the elements of farming systems research but which seems to have developed quite indepedently from the IARCS (I am grateful to Robert Hart and John Caldwell for drawing my attention to this fact).

2 Pseudo-rotations is a typical de Schlippe term, used by him to indicate multiple cropping arrangements such as crop sequences, staggered planting and rotations.

3 In the Kwango-Kwilu, a region were no *paysannats* were ever established, Drachoussoff (1954) proposed the establishment of large-scale trial units of several thousand hectares, to test improvements of traditional food production, quite similar to the idea behind the 'Experimental Units' in Senegal.

4 From 1924 onwards eight research institutes were created that dealt with livestock, oil crops, textiles and fibers, timber and forestry, coffee, cocoa and other stimulants, rubber products, agricultural machinery and, last but not least, food crops.

5 Farm models are not simulation models, although Francophone farming systems research has lately become more involved in computer simulation (René Tourte, pers. comm. January 1984).

6 GERDAT distinguishes the following types of farming systems in West Africa (GERDAT 1982):

A shifting cultivation systems: extensive, no real land shortage, mixed cropping;

B semi-sedentary systems: moderate land scarcity, cash crop production integrated with subsistence production at field level (i.e. crop associations or rotations), or at farm level (separate fields for cash crops and food crops), or at village level (permanent cash crop fields). Possible introduction of small-scale mechanization allowing increases in acreages and a reduction of mixed cropping. Traditional semi-sedetary systems can be both intensive and extensive, depending on weed control, use of organic matter, plant densities, with great differences in yields (De Miranda & Billaz 1980);

C sedentary systems: acute land scarcity, very short fallows depending, among other things, on the stability of soil fertility and technology. There are three types of sedentary systems:

a stable integrated livestock-crop systems, usually in woodland savannas, e.g. the Serer tribelands in Senegal;

b livestock-crop systems that have been destabilized by the introduction of cash crops and by population pressures but that have maintained a more or less satisfactory equilibrium through the use of improved technology, e.g. cotton growing areas in western Burkina Faso, southern Mali;

c monocrop (or crop association) systems, resulting from environmental degradation, whereby diminishing yields and overexploitation of the land have led to extremely low input/output levels, e.g. the Mossi plateau (Burkina Faso);

d livestock dominated systems: either (seasonal) nomadic, or herds integrated at village or farm level through animal traction.

7 The differences between the Francophone and Anglophone approaches to farming systems research may at least partially be explained by the way in which past agricultural research was financed. All colonial research in French speaking Africa was tightly controlled from France (or Belgium), whereas in the British colonies the local administration assumed financial responsibility for research (Yudelman 1975). Current Anglophone farming systems research depends nearly exclusively on short-term donor commitments.

3 APPLYING SYSTEMS THEORY TO THE STUDY OF TROPICAL AGRICULTURE

Systems theory

This chapter presents an attempt to apply systems theory to the study of traditional agriculture in the tropics, and to shifting cultivation in particular. The aim is to develop a framework that allows the integration of technical, biological and socio-economic factors that influence agricultural production. Agriculture in general can be described as the human activity that transforms solar energy at the earth's surface into useful (edible) chemical energy by means of plants and animals (de Wit & van Heemst 1976). It involves variables and parameters with very diverse characteristics and complicated interactions. The study of agriculture requires not only the contribution of many disciplines but also unifying concepts to make full use of the insight gained by component and commodity research.

General Systems Theory, first formulated around 1930 (von Bertalanffy 1968) provides such a unifying theoretical framework, central to which is the system. General Systems Theory tries to understand and predict complex phenomena by describing them as systems. In the course of the last fifty years it has become increasingly clear that very diverse phenomena, ranging from phytoplankton to national economies, display similar characteristics that can be explained by their behaviour as systems.

A system can be defined in many ways, but all systems involve an arrangement of parts (components[1] or subsystems) that interact according to some process (transform inputs into outputs) (Odum 1983). When systems involve humans, they are sometimes defined as a group of interacting components operating together for a common purpose (Spedding 1979). What matters, however, is not the definition but the *concept* of system.

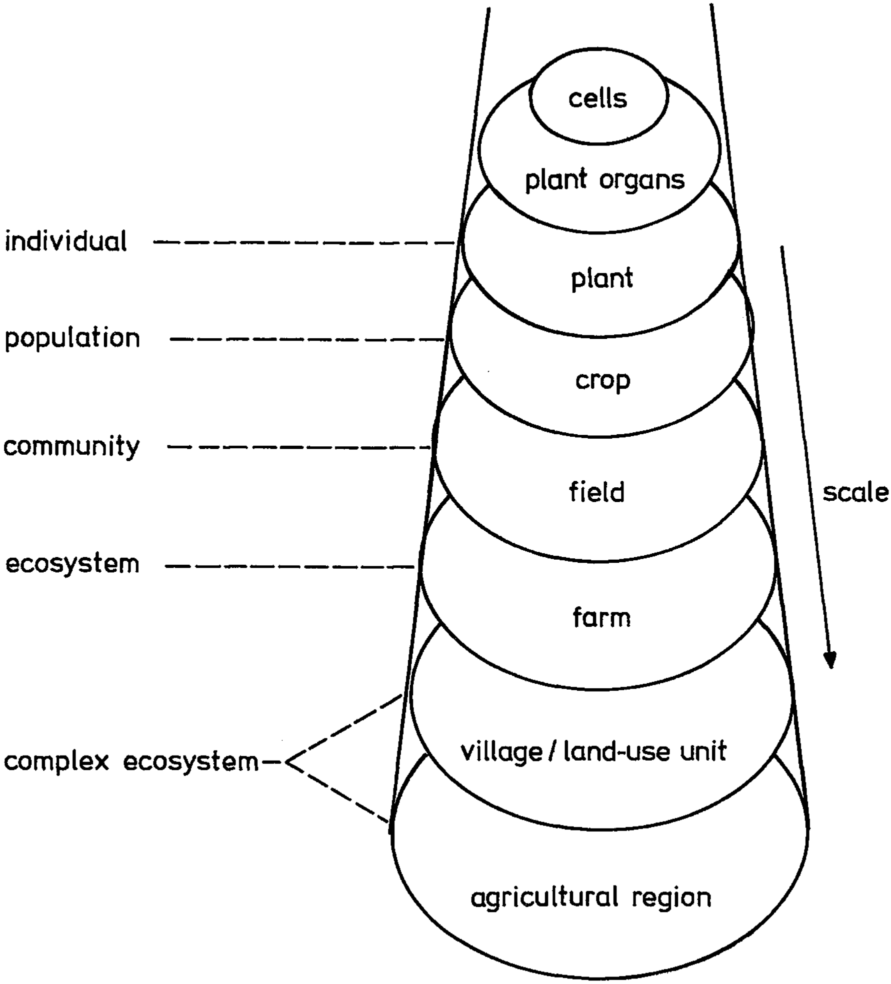
Systems display special properties that emerge from the interaction of components: a whole is different from and often more than the sum of its parts. Knowing only the parts, therefore, does not adequately predict the behaviour of the system as a whole. In all systems five elements are

distinguished: components, interactions between components, boundaries, inputs and outputs. The *structure* of a system is defined by the quantitative and qualitative characteristics of the components and the interactions between them. The way in which inputs are processed into outputs determines the *function* of a system. Boundaries are sometimes difficult to define in complex open systems. Within the boundaries all relevant interactions and feedbacks are included, so that all those components that are capable of reacting as a whole to external stimuli form a system. Some authors also consider the input-output environment as a part of the system (Odum 1984).
While specific methods are usually associated with systems research, it is more than just a method. Understanding the system helps to organize knowledge, to orient data collection and to direct interventions. Modelling and simulation are important tools in systems theory. A model is, per definition, a simplification of reality in accordance to the purpose one has in mind. While models vary according to their degree of abstraction (Dalton 1982), they can never represent all possible points of view.

Ecosystems

In the biological and ecological realm, the central concept of systems theory is the *ecosystem*. The ecosystem comprises one or several biological communities, composed of various populations, that interact with the physical environment. Each population consists of individual organisms that in turn consist of organs that consist of cells. Consequently, ecosystems are based on a hierarchical relationship: each subsystem is at the same time a system in itself with its own subsystems as well as a part of a larger system (also called the suprasystem).
The hierarchy involves successive energy quality transformations: at each step much of the energy is used in the transformation and only a small amount is transformed into higher quality (Odum 1983). A higher level in the hierarchy implies a higher level of energy, and a larger scale of time and space (compare, for example, a cell to a biological community).[2] Lower level units are much more numerous than higher level ones. According to some authors (e.g. Miller 1978) the hierarchy culminates in the world system, which is unique.
General Systems Theory is well known for its application to energy flows in ecological systems, the study of which has provided much insight into the nature of systems in general and has led to the development of generalized systems languages. Systems theory is now commonly applied to components of agriculture, in particular biological subsystems. Nevertheless, there have been relatively few attempts at applying general systems theory to the study of traditional agriculture in the tropics. Where systems theory has been applied,

Figure 3.1 Hierarchical levels in agriculture (crop production).



it has focused on the modelling and simulation of physical determinants of crop production (e.g. van Keulen & Wolf 1984), or on the application in development economics of methods like operations research that have (in part) been inspired by systems theory (Schweigman 1981). A well-known exception is Hart's study of traditional farming in Honduras (Hart 1982).

Agriculture as hierarchy of systems

In analogy to ecology, agriculture can also be described as a hierarchy. Figure 3.1 presents a very simple model of the levels of the agricultural hierarchy

according to increasing scale, from the plant cell to region. For the sake of simplicity animal production is disregarded for the moment. At the lowest levels, one finds the cell and the plant organs, followed by the plant itself. Plants combine into crops, and crops into fields that may carry crop populations of various species and variety, weeds and pathogens. The farm is situated at the next higher level. Groups of farms combine into villages or land-use units. These in turn combine into regions, which may cover a part of a country, an entire country or even a group of countries.
It appears immediately that the higher levels in the agricultural hierarchy are less easily defined than the lower levels. At the lower levels, the analogy with ecology poses no problems. The plant corresponds to the level of the individual, and the crop to the population, and the field to the community. The farm can be considered an ecosystem composed of interacting human, animal and plant populations. Farms, however, can be grouped in diverse ways, because they display many different facets. Depending on whether socio-economic or biological and physical aspects are studied, a model of the higher levels of the agricultural hierarchy includes farms combined into socio-economic, e.g. village, units or into physical land-use units, such as watersheds. At an even larger scale, for example of the region or country, ecosystems are increasingly complex and more difficult to map. The last two levels may therefore be expanded for the specific purposes of the model.
Going up the hierarchy from cell to region, the number of individual units decreases but the scale increases.

Hierarchical systems

The model in figure 3.1 is based on units – a plant, a farm – that can be observed in reality. Each of these units is also a system, since each involves an arrangement of parts that transform inputs into outputs. It is very important to stress that the concept of system is not an arbitrary one, since the term is often used in a rather vague way. A farm is a system because it consists of components that interact together according to some kind of process. Tools, for example, are not a subsystem of the farm, but an input, so it is incorrect to speak of tool systems. While models involve some degree of arbitrary choice, depending on what the researcher considers important levels of analysis, systems have very precise definitions. The concept of system loses its meaning if it is applied in an inaccurate way.
Each unit of the agricultural hierarchy in figure 3.1 consists of a system, and these are linked in a hierarchical way through the system-subsystem-suprasystem principle. Plants are subsystems of crops, which in turn are subsystems of fields. The field can be considered the suprasystem of the crop system, the farm the suprasystem of the field and so forth. Agriculture can therefore be

Table 3.1 Agriculture as a hierarchy of systems (crop production).

Ecological level	System	Components/subsystems	Inputs	Outputs	Unit of observation
Individual	plant system	organs (roots, leaves etc.)	solar energy, nutrients, water	biomass	plant
Population	crop system	crop(s), (plant systems) (including perennials)	solar energy, nutrients, water	biomass	crop
Community	cropping system	crop systems, weeds, pathogens, insects, soil	labour and management, external inputs	food, fiber, fuel, feed	field
Ecosystem	farming system	cropping system, livestock system, farm household	land, labour, capital	crop and livestock for consumption and sale	farm, farm household
Complex ecosystem	regional system (village, land-use systems)	climate, soils, vegetation, primary sector, secondary sector, tertiary sector, human resources	matter, information, energy	matter, information, energy	region (watershed, village)

described as a hierarchy of systems. Each system consists of components (subsystems), interactions between components, inputs, outputs and a boundary.

There is a problem, of course, with respect to the identification of systems in everyday life. There has been considerable debate over the question whether systems are real or abstract creations existing only in the mind of the observer. The point of view taken here is that what one sees is a unit-of observation, which may or may not correspond to a system. An agronomist walking in the field does not see farming or cropping systems but farmhouses and fields. His or her way of analysing a farm leads to the definition of the farming system. A farming system, therefore, does not relate to the individual farm, but to *the farm as a system*.

The agricultural hierarchy of systems is described in table 3.1. It identifies levels of analysis, systems, system components, inputs and outputs as well as units of observation. The levels below the plant system have been disregarded because they are less relevant to most agronomists (in contrast, for example, to plant physiologists). At the lowest level considered here, one finds the *plant system*, of which the organs (leaves, roots and so on) are the main components. Plants process solar energy, nutrients and water into biomass.

The next lowest level is occupied by the *crop system*, with crops, i.e. the plant subsystems and their interactions, as the main components. The crop system may involve plant populations of varying species and variety. Crop systems also process solar energy, water and nutrients into biomass. At this level, one is interested in interactions between plants rather than in individual plants.

The next higher system level is the *cropping system*, with the field as the corresponding unit of observation. The cropping system is a land-use unit that transforms plant material and soil nutrients into useful biomass. Cropping system components are the crop system (crops, weeds, pathogens, insects) and soil. Soil refers here to the soil characteristics of the field on which the crops are grown. The cropping system corresponds to the community level in ecology. Apart from solar energy, water and nutrients that are processed by crops, the most important inputs are labour and management. Labour and management are inputs provided by the next higher level in the hierarchy, the farming system. The cropping system may involve complex spatial and time arrangements of various crop species and varieties according to micro-variations in soil. Trees found in the field or around the homestead are included in the cropping system insofar as they interact with crops. Fields belong to the same cropping system if they are managed in the same way. The output of the cropping system is useful biomass that can be used by humans as food, feed, fiber (including thatch) and fuel.

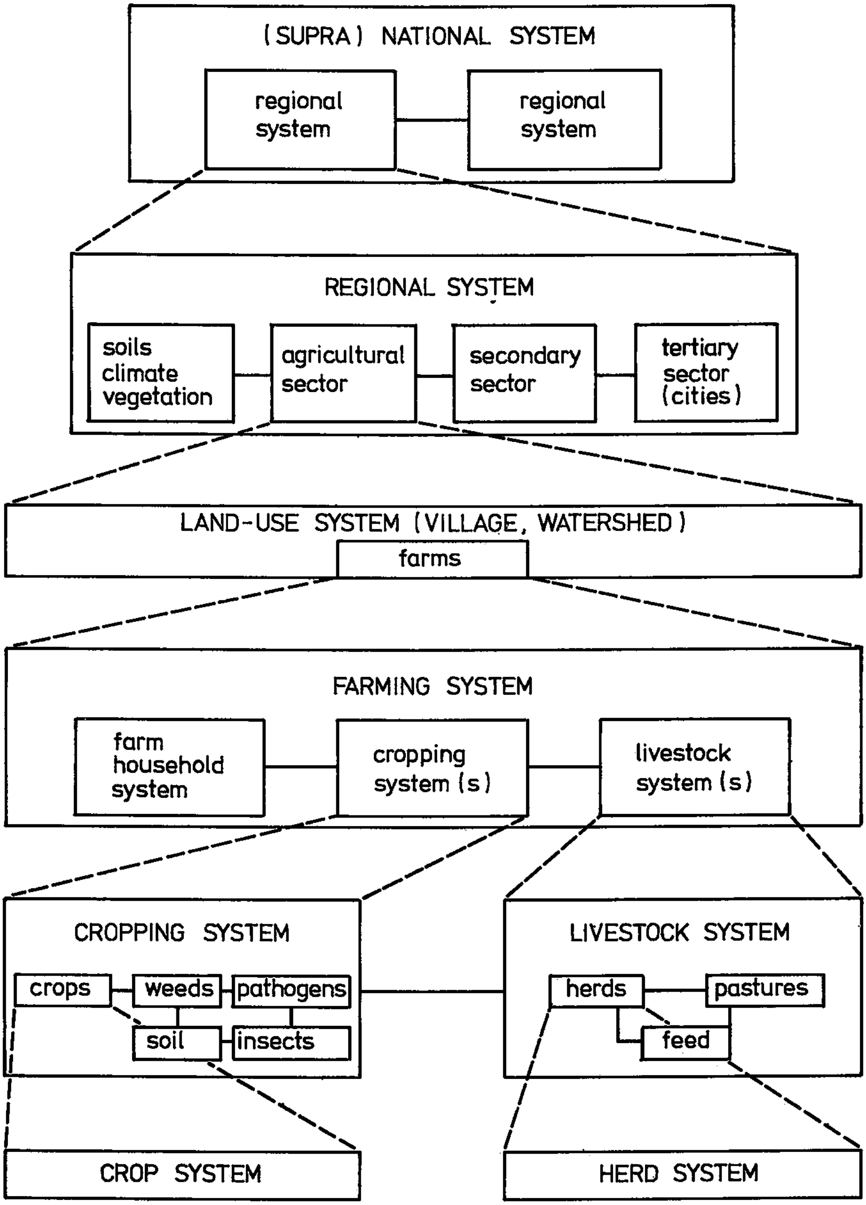
Cropping systems are examples of extremely open systems with major exports of outputs. Cropping systems differ from natural ecosystems in the use of auxilliary energy sources (human and animal labour and fossile energy) and in their reduced diversity through the selection of useful species and varieties. At least one crop or animal population is dominant and managed by the farmer.

The next higher level in the hierarchy is the farm. If the farm is studied as a system, it is usually called *farming system* (although farm system would be more correct[3]). The farming system is a decision making and land-use unit comprising the farm household, cropping and livestock systems, that transforms land, capital (and external inputs), labour (including genetic resources and knowledge) into useful products that can be consumed or sold. The farming system comprises the cropping system(s), the livestock system(s) and the farm household. Each of these consitutes a complex subsystem by itself. Farming system analysis is difficult, because it deals with variables of very different natures and rates of change. In the tropics, nearly all farms have more than one cropping and/or livestock system, e.g. upland crops as well as irrigated paddy fields as well as home gardens, in addition to farmyard animals or herds of small ruminants. Cropping and livestock systems frequently interact, e.g. if crop residue is fed to animals or manure and animal traction are applied to crops. The role of perennials and trees is also analysed at this level.

The *farm household* consists of a group of people, often related, who, individually or jointly, provide the management, labour, capital, land and other inputs for the production of crops and livestock, and who consume at least part of the farm produce. The farm household is thus the centre of consumption, resource allocation, management and labour, and can consist of more or less autonomous subsystems. Management, of course, is one of the crucial variables here. In systems terms, management regulates component interactions within the system, in such a manner that an optimal quantity of useful products is obtained. Management implies decisions on objectives (e.g. cash or food crops), on the way these are to be reached (e.g. cassava or other crops), and on how deviations from standards have to be corrected during implementation (e.g. replacing plants after pest attacks). Off-farm activities can be an important separate element in the farm household system. When humans are introduced as parts of ecosystems, their economic behaviour causes money and information to flow in countercurrent to the flow of commodities (Odum 1983). A study of farming systems must therefore also involve money and information exchanges.

All other system levels above the farming system have been summarized as the *regional system* in table 3.1. The regional system is a complex large-scale land-utilization unit which produces and transforms primary products and involves a large service sector, including urban centres. The term regional system, although awkward, must be preferred to agricultural system, because the latter does not indicate the level of analysis and does not do justice to non-agricultural activities. In regional systems agricultural and socio-economic processes are closely linked. Intermediate levels between the farming system and the regional system can be villages or geographic units such as watersheds, both of which can be considered systems. The regional system can be analysed from an ecological or socio-economic perspective. Ecologically speaking, it consists of climate, soils and vegetation and human resources. Soils (in plural) refer to land units as well as land-utilization units. Sometimes, the ecological components are considered external inputs from a suprasystem into the regional system, and not regional system components (e.g. Hart & Pinchinat 1982). This depends on the level of analysis and on how many levels are introduced above the farming system. In the economic sense, regional systems comprise a primary production sector, a secondary sector (processing of agricultural products) and a tertiary (services, marketing and urban) sector. The primary production (agricultural) sector comprises all the farms in the region. Social scientists may find it convenient to distinguish further between the region, the nation and supranational systems.

Figure 3.2 Agriculture as a hierarchy of systems (adapted from HART & PINCHINAT 1982, ODUM 1983).



Animal production and livestock

Animals process plant biomass and can therefore not be easily integrated into the crop production hierarchy in table 3.1. The animal system is not situated at exactly the same level as the plant system, although it still belongs to the 'individual level' in ecology. The same applies to herds in comparison to crops (population level), and livestock and cropping systems. The livestock system comprises the grazing lands and other feed sources (hedgerows, crop residue) as well as the animals involved. A hierarchy of animal production would involve animals, herds and livestock systems as levels.

System interaction

In figure 3.2 a simple graphical representation is given of the hierarchy of systems (from crop-livestock to regional system).The dotted lines indicate how systems at each level are made up of components that become systems with their own components/subsystems at the next lower level. Only a single system is shown at each level.

In reality, of course many systems exist at each level. Moving upwards from the plant system to the regional system, the number of units decreases. In other words, there are many plants in a crop population, several crops in a field, only one or two fields in a cropping system, and perhaps only two cropping systems in each farming system. The same applies to the higher levels in the hierarchy. In one single region, there may be a few subregions (or villages or watersheds), but each of these consists of a multitude of farms.

Systems interact both vertically, with systems at higher or lower levels, and horizontally, with systems at the same level. Farming systems, for example, interact with the regional system through flows of produce and money, as well as with one another, through exchanges of labour or goods.

The agricultural systems hierarchy presented here is comprehensive, as in ecology: each system is comprised in higher level system. The higher level system provides the environment and some of the inputs to the lower level system. The farming system provides labour and management to the cropping system. Conversely, subsystem outputs can be inputs into higher level systems. The outputs of the cropping system, for example, are inputs into the farming system, that may be consumed or sold according to needs.

Constraints and limitations

System output is limited by exogenous factors as well as by endogenous factors. Exogenous factors or *constraints* are those occurring at levels higher than that of the system involved. The cropping system, i.e. the combination of crops, soil, management, weeds and so on sets limits on crop system outputs, for example. Higher level constraints will affect all lower level systems, because the hierarchy is comprehensive (each system is included in the next higher level). Climate, prices and infrastructure are examples of factors at the regional system that may be constraining the outputs of all lower level systems. Higher level constraints may be subject to changes at lower levels, however. The limitations imposed by rainfall, a constraint in the regional system, may be modified at lower levels such as in the cropping system by soils and farmer management. Consequently, even if one is only interested in lower level systems, as in the case of crop physiologists and geneticists, who mainly work at plant and crop systems, constraints at higher levels must be acknowledged, such as soil nutrient limitations (cropping system level) and constraints imposed by labour peaks (farming system level) or consumer preferences (regional system).

Endogenous factors or *limitations* are set by subsystems within the system or by lower level systems. Farming system outputs, for example, are limited by labour inputs provided by the farm household (a subsystem) as well as by the genetic potential of crop varieties (crop system). The distinction between exogenous and endogenous factors is essential in understanding system performance.

Nevertheless, it must be realized that constraints and limitations do not determine system outputs in a rigorous way. Variations between systems at the same level may be considerable. This applies in particular to the farming system where farmers' choices play a role. Combinations of exogenous and endogenous constraints, for example the physical and biological environment, obviously set limits to potential production, but do not fix the ways in which the farming system deals with the physical environment. In the same agro-ecological (and economic) environment very different systems may be operational. In the savanna region of the Central African Republic, for example, hoe and ox farming exist side by side. What farming system prevails in a given case depends on household resources, access to inputs, the division of labour and cultural factors.

Similarity and classification

Systems can be considered similar if they are similar in structure, i.e. the characteristics of their components and component interactions, and in function, i.e. the way inputs are transformed into outputs. Similarity and degrees of similarity between systems provide the basis for a classification of systems. In the agricultural hierarchy, systems can be classified into types at each level. At the plant system level, for example a distinction is made between C3 and C4 plants according to photosynthesis pathways. Types of crop systems may be defined according to the dominant population, e.g. the cassava crop system. Cropping systems can be classified in many ways, for example according to the degree of land-use intensity (Eicher & Baker 1982, Ruthenberg 1980). Farming systems are usually distinguished with respect to the interaction of animal and crop production (e.g. Spedding 1978), but it may be equally important to consider access to resources and degree of market integration. The classification can never reflect all aspects, and depends to a great extent on the purpose one has in mind. A system type is defined as a group of systems that are similar according to a given set of criteria.

Types of cropping systems

It is obviously easier to differentiate between types of cropping systems than between farming system types, because of the reduced, even if still perplexing, complexity. Ruthenberg (1980) presents a very detailed classification of what, according to the hierarchy presented here, are sometimes farming systems and sometimes cropping systems, depending on whether crop-livestock interactions are included (farming systems) or not. Ruthenberg's classification is based on land utilization, and maintenance of soil fertility in particular. He distinguishes shifting cultivation systems, fallow systems, ley and dairy systems, systems with permanent upland cultivation, arable irrigation systems, perennial cropping and grazing systems.
Within each type of cropping system further differentiation is possible. In shifting cultivation systems, for example, a distinction can be made according to the dominant crops and rotations, fallow length and vegetation. In other words, this distinction is based on the characteristics of the components of the system. As shall be discussed later, two subtypes of shifting cultivation cropping systems can be distinguished in the Kwango-Kwilu region in Zaire, based on a series of agro-ecological criteria, involving grass and forest fallow and cassava-millet or cassava-maize intercropping arrangements. It is important that these differences between subtypes have sufficient empirical basis, that they can be recognized by the researcher when observing fields. Of course, individual variations between fields will always occur, and it requires skill to recognize that a field belongs to a certain subtype of cropping system. One farmer may grow groundnuts in between the cassava plants and an other may not, yet the two fields may belong to the same cropping system's subtype if there are no important structural and functional differences between the way the fields are managed. This always involves a degree of arbitrariness. Recognizing similarities between cropping systems is particularly difficult in

the case of cropping systems that are subject to rapid change, such as shifting cultivation systems under increasing land pressure.

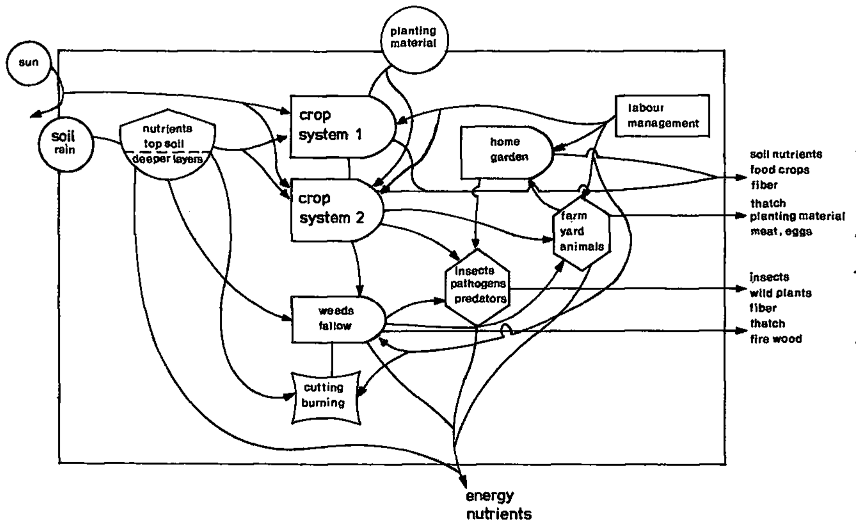
A systems approach to shifting cultivation

The focus in this study is on cropping systems, and on shifting cultivation and cassava based cropping systems in particular. The general principles of systems analysis and of the agricultural hierarchy outlined above are thus applied to a concrete type of cropping system. In order to understand higher level constraints and subsystem limitations, the regional, farming and crop system also need studying. Endogenous limitations in the crop and cropping systems will be discussed in sofar they relate to agronomy: the impact of cropping techniques (densities, planting times, soil fertility) are included but not crop physiological and genetic limitations on outputs.

General characteristics of shifting cultivation

Shifting cultivation refers to a set of traditional cultural and land-use practices in which crop production alternates with extended periods of fallowing (Nye & Greenland 1960, Allan 1965, Jurion & Henry 1967, Ahn 1974, Ter Kuile 1983). Shifting cultivation systems can be classified in various ways according to fallow length and vegetation, dominant crops, the spatial organization of cropping, and the presence of more intensively managed plots such as ash-dependent fields, home gardens, or permanent river gardens (Miracle 1967). Characteristic elements of shifting cultivation are the use of fallows to restore soil fertility and to limit pest and weed incidence, and the prevalence of mixed intercropping. Several indicators are used for the relative length of fallowing and cropping.[4] Ruthenberg (1980) distinguishes between shifting and fallow systems. The latter replace the former when R exceeds 33, i.e. when more than one third of the land area is under annual cultivation. Fallows are usually classified according to the nature of the vegetation. FAO (1974) differentiates between forest fallow (closed tree canopy), bush fallow (dense woody vegetation without trunks), savanna fallow (a mixture of fire-resistant trees dominated by grasses) and grass fallow (without woody vegetation). As a result of fallowing, the location of fields shifts in time, and in the past, before government settlement policies were enforced, the location of villages shifted as well, although not as frequently as the fields. Burning is a nearly universal method of land preparation (often in combination with other methods, see Miracle 1967).

Figure 3.3 A conceptual model of shifting cultivation with two cropping cycles (energy symbols after ODUM 1983 – see annex).



The main components of a shifting cultivation system is the crop system which usually involves intricate spatial cropping arrangements, and the soil and fallow components. These components interact with one another as well as with other components such as weeds, pathogens and insects. Inputs into the cropping system are solar energy, water, soil nutrients, seeds and planting material, labour and management. Shifting cultivation relies little on externally acquired inputs, the main one being labour (and management) provided by the farm household. Soil nutrients are concentrated within the system. Plant material is usually, but not always provided from internal sources.

A systems model of shifting cultivation

A simplified qualitative model of shifting cultivation is presented in figure 3.3. It uses energy symbols common in ecological systems analysis (Odum 1983, see also annex). Producer components are the crop systems and the fallow. Two succeeding cropping systems and a home garden are depicted. Sources (of inputs) are the sun, soil, rain and planting material. Consumption units are farmyard animals, consuming crop residue, and insects, pathogens and predators feeding on crops and fallow vegetation. The single most important flow to observe in any shifting cultivation system is the flow of soil nutrients over time. Nutrients stored in the topsoil are used in crop production. The cropping period is followed by a fallow during which fertility is restored. The extent of fertility restoration depends on fallow length, vegetation and soil characteristics. The nature of the fallow in not specified here. Burning, while adding mineral nutrients in the ashes, results in the loss of organic matter in the vegetation and leaf litter. Fires also destroy the insect and pathogen populations. Labour and management are shown as inputs within the system, connected with the important components. They are required for the operations of crop and animal production, clearing and burning. Labour inputs are the second most important flow in understanding a shifting cultivation system.

Outputs of the shifting cultivation system are biomass used as food, feed, fiber (thatch) and fuel. Soil nutrients are also removed through crop harvesting. Typically, the outputs of a shifting cultivation system are partially produced by the fallow and partially by the crop system. Planting material is also an output, which is usually recycled as an input in crop production. In open systems such as this, energy and nutrients are always dispersed (as indicated by the flow from each subsystem towards the bottom of the diagram). Nearly all shifting cultivation systems also involve a more or less stable home garden and some farm yard animals (chickens, goats). The latter provide small quantities of manure to the home garden and feed on crop residue and fallow grasses. Livestock is rarely a component of shifting cultivation (with the exception of trypano-tolerant cattle breeds in parts of West and Central Africa), but small ruminants such as goats are commonly kept.

Changes in shifting cultivation

Shifting cultivation systems in which fallow length is sufficient are an example of steady state systems: storage is likely to become constant with the balance of inflows and outflows, although small losses may take place. Temporary changes or oscillations such as occur in the periodic harvesting of crops are a feature of steady states, but these changes do not affect the structure of the system.[5] System replacement occurs when, for example, shifting cultivation is replaced by a fallow system or perennial cropping (Ruthenberg 1980). An essential question in the study of shifting cultivation is to what extent a higher land-use intensity leads to system replacement or to adaptation. Changes in shifting cultivation result from changes in the environment, in particular an increasing man(person)/land ratio, as well as from changes in system elements (for example changes in crops or in labour allocation).[6] Both exogenous constraints, e.g. population growth (regional level), and endogenous limitations, e.g. pests and diseases (crop system level), affect the performance of shifting cultivation systems.

In ecological systems, control over system performance is exercised through endogenous limitations, exogenous constraints and feedback mechanisms. A key issue in the analysis of shifting cultivation (and cropping systems in general) is that human needs interfere with internal feedback loops. In subsistence agriculture the farm household itself acts to some extent as an internal controller in responding to internal feedback. Subsistence farmers will adjust planting decisions to their perceptions of rainfall, soil fertility etc., as observed from soil and vegetation characteristics. However, in a market-oriented agriculture, remote controllers that determine marketing opportunities, prices, transportation etc., shape the decisions of the farm household. These remote controllers do not respond effectively to the internal feedbacks within the system. As shall be demonstrated, in the Kwango-Kwilu, the urban demand for food has led to increased cassava planting, notwithstanding the negative feedback from the cropping system (declining soil fertility, increased incidence of weeds and ultimately declining yields).

Feedback mechanisms provide control over deviations of actual system performance in comparison to a given standard. In degraded shifting cultivation systems of the Kwango-Kwilu, the planting of cassava at higher than optimal densities or the shift from cereal crops to cassava are good examples of feedbacks. In the first case the standard is the maintenance of total yield levels in the face of declining yields per plant; in the second case the maintenance of a certain caloric level at fixed labour inputs. Because time lags occur in feedback, the adjustment is imprecise, leading to fluctuations, as in the case of farmers' reaction to changing market prices.

Important steps in the analysis of shifting cultivation systems are the description of system components and the identification of constraints and limitations. Data from the Kwango-Kwilu will be used for futher indentification and description of system elements in order to refine the model in figure 3.3. The use of historical data is particularly important in view of the slow rate of change of some of the elements. Unfortunately, historical data on shifting cultivation in the Kwango-Kwilu, and Africa in general, are often lacking.

Notes

1 The term 'components', although confusing to agricultural scientists who tend to relate it to component research, is nevertheless retained here because of its general use in systems theory.

2 There may be some confusion over the term 'level'. Level does not imply any value judgment about the importance of phenomena, but relates to the hierarchy, i.e. to energy quality and scale. The term system itself is neutral, in the sense that each system, independent of level comprises the same formal elements.

3 The term farming system is now commonly used to designate the components of a farm, and may even be incorrectly used to refer exclusively to the farm household (as in 'the farming system and its resources'). Ruthenberg (1980) coined the term farming system to refer to a class of similary structured farms (or farm systems). Hart & Pinchinat (1982) also speak of farm systems.

4 Most common are the land-use factor L, (L=(C+F)/C with C=length of cropping and F=length of fallow period) (Allan 1965), or R, the land-use intensity factor (R=(C*100)/ C+F) (Ruthenberg 1980).

5 Fluctuations occurring at regional level also affect shifting cultivation, as in the case of fluctuations in energy flows in a New Guinea society (expressed in pigs, warfare and mortality) (Rappaport 1971).

6 Repeating changes which cause tempory changes in output levels but do not change the structure of the system, such as occur when female labour inputs are reduced because of childbearing and child care, should not be confused with changes in system function.

4 DATA BASE AND METHODS

Data requirements for systems analysis in agriculture

The analysis of the hierarchy of systems in traditional agriculture presents a number of methodological problems that are treated in this chapter. Since different processes and components are involved at each system level, a specific set of data is required for every level. Consequently, data collection procedures have to be adapted to regional, farming, cropping and crop systems.

Generally speaking, understanding systems of any level involves:

a observing the system in reality;

b identifying system elements;

c describing, in qualitative and where possible in quantitative terms, component interactions, input-output flows and their variations, and

d formulating hypotheses (equations) that can be tested (and / or simulated).

The first and third steps are especially difficult, for they require an extended time frame. The nature and permanency of changes in system elements are often hard to grasp unless one has the opportunity to monitor system performance throughout many years.

The nature of the system determines to a great extent the data collection process and the time frame. Most regional level data stem from secondary sources (statistics, government reports), whereas direct observation (primary data) becomes increasingly important in lower level systems. System elements change more rapidly at lower than at higher levels. Consequently, the need for long-term data series decreases with system level. At the plant system level, the physiologist will be interested in daily changes in respiration rates throughout the growing season. At the other extreme, the agronomist analysing regional flows of nutrients will need crop production, crop export, fertilizer and agroclimatic data covering several decades. In this study, it will be demonstrated that cassava yield – an output of the crop system – is affected by changes at every system level. Cassava yield is therefore taken as a proxy for the performance of the entire hierarchy of systems. An important focus of data collection has been to obtain cassava yield figures or other indications of yields for a maximum number of years in order to illustrate system changes.

In general, a sequential approach to both primary and secondary data collection was followed. Throughout the four years of the project, data collection increasingly focused on priority problems as they emerged. Regional level data, obtained from government offices in the capital and in the region during two rapid appraisals, supplied the starting point for research at all system levels. Data collection at different system levels is of course complementary. Every observation of a system leads to questions about its supra- and subsystems. The first eighteen months, and in particular the farm household survey (1980), were mainly used to develop a broad overview of agricultural production in the Kwango-Kwilu. From 1981 onwards, the focus was on an analysis of cropping systems and cassava production in particular. At each stage of data collection, each six months' period, data were evaluated with a view to assessing gaps and the need for additional information. The collection of primary data triggered a need for more secondary information and vice versa, in particular as the importance of historical changes in cassava production emerged.

The reliability of statistical data

Unfortunately, the Kwango-Kwilu region has been relatively neglected by the pre- and post-Independence (after 1960) governments. As a result, the existing secondary data base is very poor and often of dubious quality, in terms of available statistics as well as academic studies in and field. Data covering more than a few years are scarce, and even recent data present serious internal contradictions. The poor quality of the data highlights an unexpected feature of the systems approach, namely the relevance of a predominantly descriptive approach. While the analysis would undoubtedly have gained from a quantitative analysis of system flows, even a relatively simple description obtained with limited means provides the basis for an understanding of the systems involved.

It is appropriate here to raise a number of issues, resulting from data gathering procedures, that are common to all post–1960 official statistics. Each year, data on the number of farmers, the area and crops cultivated are collected by the extension staff in each collectivity – the lowest administrative unit comprising several villages. These data are also used by the authorities to supervise the compulsory cultivation regulations (see subsequent chapters) and to collect taxes. It should be no surprise that farmers are therefore most reluctant to cooperate in this exercise. Even disregarding the misleading information that farmers may supply, other biases occur as well. The number of farmers and fields is almost certainly biased, because only men are considered farmers. Since they are frequently absent from the village, the officially imposed fields are cultivated by their wives, who may choose not to do so, or to cultivate a smaller area or a different field.

Furthermore, production data are probably even more inaccurate. Nearly without exception, farmers are illiterate and do not keep any farm records. Crop production is measured in local weights, usually baskets. Extension staff depend entirely on verbal records supplied by farmers, who refer to local weights, and on their own observations. While extensive weighing of baskets of varying shapes suggests that 'standard' baskets may exist for cassava, this is not so for the other crops. But even in the case of cassava, the actual production varies considerably with the dry matter content of the dry product *(cossettes)*. Production figures based on farmers' statements expressed in variable units are likely to be very inaccurate. In theory, extension agents are also supposed to witness any sale of crops, but in practice a considerable percentage of commercial transactions takes place outside their control. In the course of four years in the region, no extension agent has ever been seen with scales, and his ability to estimate weights and area, let alone his skill for arithmetics are more than doubtful.

Consequently, agricultural statistics in the Kwango-Kwilu are subject to serious error. It is unclear, however, to what extent they are systematically underestimated or exaggerated. The lack of control by the authorities and the escape mechanisms developed by farmers would suggest that data could be underestimated. On the other hand, there are strong pressures on the local authorities to achieve the targets of annual production growth, since the allocation of budgets and other amenities depends entirely on their performance. In several cases, it has been observed that extension staff refrain from collecting raw data, but 'calculate' production figures on the basis of previous years, using, say, a 10% increase. In final instance, it seems more likely that production and area figures are consistently overrated.

The reader is warned therefore, that statistical data concerning the period after 1960 are sometimes lacking, frequently confusing (because of changes in administrative boundaries) and nearly always internally inconsistent, in the sense that statistics provided by the various administrative authorities (national, regional and subregional) are contradictory. The inconsistencies in the raw data consulted are also due to errors in transcription and calculation, leading, for example, in the regional cassava figures to errors of three (80%) in 1976 and five million tons (90%) in 1978 respectively. While this is a serious handicap, it should not prevent an understanding of the structure and function of the agricultural system in the Kwango-Kwilu.

Data collection at each system level

Regional system data

Regional system data consist mainly of secondary data from various sources, that have been complemented by observations on system components. Observations were necessary to identify various aspects of the tertiary sector (marketing, infrastructure, support services to the agricultural sector and so on), which are not clearly reflected in statistical data. Secondary sources mainly refer to agricultural production, physical and human resources. Key informants were also consulted with respect to the interpretation of regional statistical data. All observations and interviews were conducted by the author. In the last quarter of 1979 two *rapid rural appraisals* (Hildebrand 1981, Beebe 1985) were carried out, one in the southern Kwango-Kwilu, and one in the centre and north of the region, each lasting about twenty days. The distinction between the north and the south was made on the basis of soil and vegetation maps (Nicolai 1963) and corresponded roughly to the distinction between table lands and valleys. The rapid appraisals involved the collection of secondary data from government offices at the region, subregion, zone and collectivity levels, as well as informal interviews with various government officials, traders, missionaries and staff of several development projects. The appraisals yielded substantial qualitative information on the main problem areas in the Kwango-Kwilu. These were identified as low soil fertility, poor nutrition, inadequate transportation, price disincentives and political pressures on farmers, including the use of extension agents for purposes of data collection and political control. Subsequently, each of these issues became a subject for further regional data collection.
The most important source of regional information on the colonial period is provided by internal reports of the INEAC agricultural research station at Kiyaka, production figures of the Ministry of Colonies in Brussels, and by a doctoral thesis on the Kwilu (Nicolai 1963). Secondary data collection entailed the collection and cross checking of official statistics provided by various government agencies, as well as research in the colonial archives (African Library) of the Ministry of Foreign Affairs in Brussels, and in the archives of the Institut National pour l'Etude Agronomique du Congo (INEAC), also in Brussels. This research was carried out in 1984–85. Details of the documents that were consulted, are provided in the references.

Recent *official statistics* presented here refer either to the Kwilu subregion only, or to the Bandundu province of which the Kwango-Kwilu region is a part, or, whenever possible, to the Kwango-Kwilu alone. Although the Kwilu is now administered independently from the Kwango, the two subregions constitute one ecological and socio-economic entity. Before 1955 the two subregions were administered jointly as the Kwango.[1] The majority of the older data, therefore, refers to the Kwango as a whole. The last agricultural census was conducted in 1970, while the results have been published in a preliminary form in 1975. Regional and national demographic data included in this study are projections based on various administrative and political censuses (République du Zaire / Département du Plan, undated). Nearly without exception, officially published agricultural and demographic data refer to regions (provinces) rather than subregions, in this case to the Bandundu. One of the greatest problems was therefore to obtain valid data disaggregated by subregion and collectivity (the lowest administrative unit).

Farming system data

The data on the farming system stem from many different sources. As little information existed on the farming system or farm households, most of the data reported here concern primary data, collected for the purpose of farming systems analysis. No information with any degree of detail has been found concerning the pre- Independence years.

The regional statistical data and rapid appraisals yielded the first information on the farming system, such as average data on farm household composition. During the rapid appraisals, farms were visited and farmers, male and female, interviewed along the roads whenever possible. This led to an initial assessment of problems relating to agricultural production at farming systems level. The importance of women in all stages of food production and postharvest handling was highlighted. The role of women farmers became a key area for further data collection.

Subsequently, in the course of 1980, a formal *survey of farm households* was conducted. The rapid appraisals had confirmed that the Kwango-Kwilu could be subdivided into two distinct areas: the sandy table lands in the south and the forested valleys in the centre. The agro- ecological differences corresponded to demographic and infrastructural differences, as obtained from the combination of maps 2, 3 and 4. However, it became also apparent that this distinction was not absolute since many collectivities covered both valleys and table lands and most farmers cultivated savanna and forest fields. Furthermore, the two agro-ecological zones shared a considerable number of common problems. Nevertheless, it was decided to hold a separate survey in each of the two agro-ecological zones.

Stratification and sampling for the formal samples were seriously constrained by the absence of a sample frame, the lack of any previous information, in particular standard deviations, on critical variables such as farm size, income, and cultural practices. A multistage sampling procedure (Idaikkadar 1979) was used, whereby collectivities were used as the primary and villages as the secondary sampling units. In each of the two agro-ecological zones, one collectivity was selected that could be considered representative of the zone with respect to population density and total population, infrastructure, the presence of services (clinics, schools, missions), crops grown and volume marketed. These indicators were obtained from official statistics. The selection of the collectivities was discussed with the authorities and key informants. In the central Kwango-Kwilu (valleys), the collectivity of Due was selected, whereas in the south (table lands), Mungindu was chosen. In each collectivity the same procedure was used to select representative villages, three in Mungindu (where villages are smaller) and two in Due. As there seemed no reason to assume any significant differences in standard deviations between the two collectivities, roughly the same sample size per collectivity was maintained, depending also on the size of the villages selected, about ninety households. For the purpose of the survey, household was equated with residential unit. The total sample size was 187 households. Within each village, all traditional farm households were included in the survey, i.e. any 'modern' farmers with official title deeds *(fermiers)* were excluded. As the number of *fermiers* is very small, about 2% of the total number of farmers, and 6% of the total area, and because the survey focused on small farmer production, it was felt that they should be excluded. *Fermiers* were included in the farm management survey.

On the basis of the problems identified in the rapid appraisals (regional and farming system data), an interview and observation checklist was drawn up, that covered subjects ranging from household composition, agricultural labour inputs, farm household expenditures, farmer perceptions on development priorities, fallow length and crop production. The interview checklist was written in the vernacular, Kikongo, and has not been included here. Farm household budget data were estimated on the basis of an exhaustive list and a two-week recall of purchases and sales, as well as a 12 months recall for large expenses. A checklist rather than a formal questionnaire was used, as the experience during the rapid appraisal soon demonstrated the difficulties of putting any questions at all to farmers. A formal questionnaire would have been even more threatening to farmers and might have led to serious difficulties with the authorities who would have insisted on screening the questions beforehand.

All interviews were conducted in Kikongo, the local vernacular. Interview checklist were pretested once, in two villages near Kikwit. As interviewers national staff from the FAO project and university students were involved. All were given a three days' training in interview techniques and field measurement procedures. Each of the five teams consisted of a male and a female interviewer. Each farm household visit included a joint interview of adult female and male household members, a separate interview of adult women on food crop production and processing, measurements (pacing or visual estimates) and observations of the household's fields, the homestead and homestead garden and the granary. Each visit lasted about half a day (three to four hours).

The interviews and the measuring of farm sizes, production, expenditures were greatly handicapped by a number of political factors. Firstly, there was little freedom with respect to the choice of villages and farmers. The introduction of 'objective' criteria (representative collectivities and villages and complete coverage of farm households within each village) allowed at least some degree of scientific rigor. At random selection of farm households, which was tried during the pretests, appeared to be unacceptable. Secondly, given the strained relations between the administration and farmers, any questioning of farmers by whatever outsider was automatically met with suspicion from all parties. Thirdly, as a rule the interviewers were not allowed to visit farmers by themselves without the supervision of the local political authorities. Finally, the results were further biased by the poor training of the interviewers and their reluctance, in some cases, to carry out observations on farmers' fields. Also the separate interviewing of women met with great difficulties. Logistical problems, in particular the lack of vehicles and fuel, further limited the work.

Consequently, the results of the survey have to be interpreted with care and cannot be considered very reliable, although subsequent work has confirmed the general trends. Figures on labour inputs and farm household budgets are estimates based on data provided by farmers, and do not constitute direct measurements. Labour input data were further refined during 1982-83. Because of the poor quality of some of the figures, only mean values are presented here, however unsatisfactory this is bound to be.

Two additional *exploratory surveys* of aspects of the farming system were conducted jointly by a team of the Department of Agriculture and FAO in the course of 1980. One concerned a survey of farm management, while the other survey dealt with child nutrition. The nutritional survey was conducted in two collectivities, representative of the two types of environment: the sandy plateaus and the forested valleys. In each area, one representative collectivity (group of villages) was chosen, on the basis of its demographic structure, its infrastructure and its agricultural production. In each case, two villages were selected on the same criteria. All children of each of the four villages were included in an anthropometric assessment, using the Harvard/WHO standards

of height, weight and age (King 1966). Household consumption of staple foods was also estimated.
The farm management survey was conducted according to the FAO FARMAP procedures, in the same villages, but on selected farms, covering both traditional and modern farmers (*fermiers*). As these farmers were selected by the local authorities, the results have to be interpreted with great care.
Village level data were not collected separately, but in the course of the farm household survey and other visits to villages. As a matter of routine, infrastructure, marketing, water supply, the presence of clinics and schools, the total population and area as well as other relevant information on the village system were recorded.

Cropping system data

Apart from the general data on agricultural production recorded in the farm household survey (farm sizes, number of fields, fallow length, volume of the major crops produced and marketed and postharvest handling) specific data on cropping systems were collected in various ways. Firstly, as soon as it became apparent that the farming system involved more than one cropping system, unstructured interviews were held to clarify the existence of several types of fields. This happened frequently in the course of other work, as the author was visiting villages.
Secondly, an informal survey of cassava fields took place in the Feshi zone (table lands), in the collectivity of Lobo, during the second rainy season and the dry season of 1982. Extensive interviews with farmers were conducted during a ten months' period. In this case, no effort was made to select representative or random fields. Because the subject was defined as purely technical, and concerned only a small group of women farmers, and because the author was by then well accepted in the area, this informal survey was carried out under much less strain and political control than the formal farm household survey. Repeated visits to the farmers in the Lobo area became a matter of course and drew little or no attention. Twenty farmers who participated in a cassava improvement program launched by the FAO project in collaboration with the RC mission at Kingungi were interviewed together with their mothers, mothers-in-law, grandmothers, daughters, or older and younger generation women as these were available in the neighbourhood. The purpose of these simultaneous interviews was to obtain an idea of changes in cassava cultural practices as they were reflected in differences in cultural practices between various generations.
An interview guideline was drawn up, involving the following subjects: duration of fallow and occupational period, field selection, planting dates,

planting techniques, plant densities, weeding, intercropping and crop sequences, and general crop production strategies. All interviews were conducted by the author, in Kikongo. Only when the farmers did not speak Kikongo, but their tribal language, a female interpreter was used. The sizes of each farmer's fields were visually estimated, cassava yields, pests and diseases, varieties and cultural practices, including mixed intercropping and weed incidence, recorded. Crop densities were measured by counting all individual plants along a diagonal line of 25 m long and 2 m wide. All stems resulting from one cutting or set were counted as one individual plant. In some fields where the distribution of plants and plant species was very irregular, this did not yield adequate results. In those cases, the area of each 'subfield' (e.g. a corner with yams or sweet potato) was visually estimated, densities were measured according to the standard procedure and a weighted average was calculated. The distinction between various cropping systems (savanna and forest fields, old village sites, gardens, borders) greatly helped to limit these cases. Unfortunately, chemical properties of the fields could not be recorded because of the absence of a soil analysis service. Five farms were studied in depth at 3 three-months intervals, with a view to correcting estimates on labour inputs, fallow lenghts and yields.

Crop system data

Most of the data concerning the crop sytem was recorded during the field survey which yielded some basic data on crop densities, crop sequences and varieties. Crop system analysis focused on assessing the impact of changes in the cropping system on the population of cassava, and to a lesser extent, other crops. Furthermore, data on weeds, pests and diseases were also recorded. As it was not possible to screen large numbers of fields for pest, disease and weed incidence, information on these subjects is mainly qualitative. The results from the field survey were used to highlight additional areas for qualitative information gathering. In particular, the way in which farmers classify cassava varieties was investigated in depth. A collection was made of cassava varieties encountered on different fields.

Cassava yields were estimated during the field survey density measurements, by selecting plants from within the same diagonal 25 x 2 m area, the number of plants depending on the frequency with which the species occurred (usually five to ten plants were harvested). All measurements recorded fresh weights, which were then converted to standard dry weights if necessary. Yield estimates were completed with farmers' estimates of the number of baskets harvested. Pest and disease rating took place according to IITA standards on a five point scale (IITA annual reports).

Key informants were also interviewed in order to understand more about the changes in cassava production throughout the last thirty to forty years. These included several Belgian agronomists who had worked in the Kwango-Kwilu before 1960 (in particular Dr Drachoussoff), Zairois agricultural assistants who had been trained during the colonial period, and missionaries with a long experience in the area.

In summary, data referring to the regional, farming, cropping and crop systems in the Kwango-Kwilu have been derived from the following sources:

1 two rapid appraisals conducted in the last quarter of 1979;

2 a farm household survey conducted in the course of 1980;

3 secondary data collection in Zaire, throughout the four years of the project;

4 secondary data collection in the colonial archives in Brussels, during 1984-85;

5 a survey of farmers' cassava fields conducted in 1982;

6 interviews with farmers of two or three generations, conducted between 1981 and 1983;

7 interviews with other key informants on the pre-Independence period, in the course of 1983-85;

8 case studies of selected farms, carried out in 1982.

Note

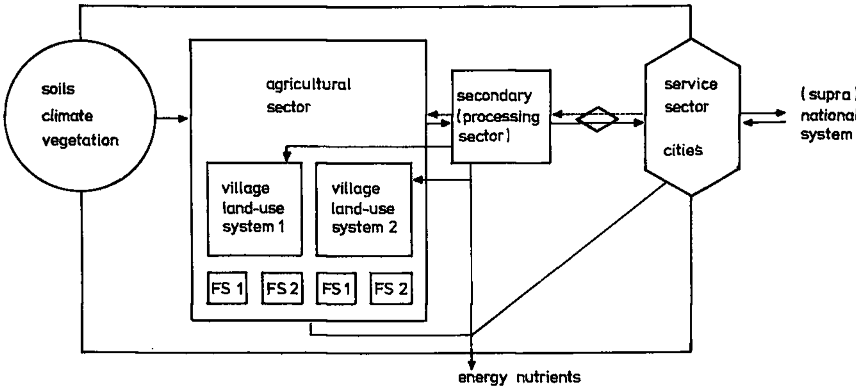
1 In 1890, the Kwango was created as the 12th district of the independent State of the Congo. Its territory coincided more or less, but not completely, with the present Kwango-Kwilu. Bandundu (called Banningville till after Independence) became the capital of the Kwango in 1911. It was only in 1954 that the Kwilu was made into a separate administrative district, of which first Kikwit, and later Bulungu became the headquarters. The current administrative structure in the rural areas comprises the following levels: village – collectivity – zone – subregion – region. Collectivities were established in 1973 as the basic unit of local government and administration.

5 AGRICULTURAL PRODUCTION IN THE KWANGO-KWILU THE REGIONAL SYSTEM

Definition and boundaries

The analysis of the agricultural hierarchy of systems in the Kwango-Kwilu starts with the highest level, the regional system. The regional system constitutes a complex large-scale land-utilization unit that produces and transforms primary products and involves a sizable service sector, including urban centres. It is the suprasystem of all systems below it. Figure 5.0 depicts a simplified model of the regional system, using the systems symbols proposed by Odum (1983). The agricultural sector includes smaller land-use systems, such as the village or watershed, that in turn consist of farming systems. The regional system itself is a subsystem of national and supranational systems. Like other systems, the regional system's elements are components, boundaries, component interactions, inputs and outputs.
The main components are: the natural resource base, human resources, agricultural (primary) production, secondary production and the tertiary (service) sector and their interactions. The natural resource base, i.e. climate, soils, vegetation and fauna, can be considered external inputs (e.g. Odum 1983:513) as well as components of the regional system. They are components of the system to the extent that they are changed in interaction with other components, but at the same time they provide the environment in which the entire hierarchy of systems is situated. In figure 5.0 the natural resource base is therefore partly drawn within the regional system boundary and depicted by the symbol for source. Human resources are not shown separately as they are part of the primary, secondary and tertiary sectors and do not exist outside these components.
The unit of observation corresponding to the regional system is the region itself. Regional system boundaries coincide with the administrative boundaries of the Kwango-Kwilu subregions. The Kwilu and the Kwango are both part of the Bandundu province in Central West Zaire, which also comprises a third subregion, the Mai Ndombe, situated in the Congo Basin

Figure 5.0 The regional system (energy symbols after ODUM 1983 – see annex).



FS 1, 2 groups of similarly structured farming systems

(map 1). The Kwilu covers 78,000 and the Kwango 89,000 km². They extend from approximately 3° to 8° S latitude, and from 15° to 20° E longitude. There is, because of strong economic interactions, some ground for considering the major town, Kikwit, and the area surrounding it, as a separate regional subsystem.

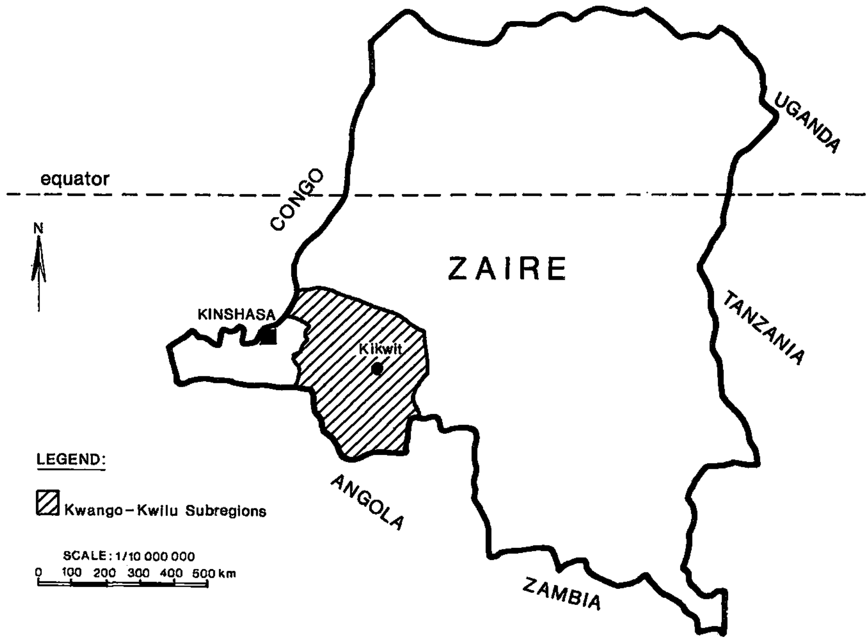
Because agricultural production in the Kwango-Kwilu has been subject to important changes in the recent past, this chapter starts with an introduction on some aspects of the region's recent history. The analysis of the regional system begins with a description of system components, whereafter the most important interactions between components are defined. The overall objective of the analysis is to identify regional constraints that affect agricultural production at the farming and cropping systems levels.

The Kwango-Kwilu in historical and national perspective

A full understanding of the structure and function of the regional system is only possible in relation to the region's recent history and to currrent political developments in Zaire.

Before Zaire's Independence in 1960, the Kwango-Kwilu had drawn little interest because of its low agricultural potential and its lack of mineral resources. The soils were considered too poor for the introduction of cash crops, while cattle ranching was discouraged by sleeping sickness and the limited carrying capacity of the table lands (over 5 ha/animal). Although coffee and cotton were introduced, they were never grown by traditional

Map 1 The Kwango-Kwilu subregions in Zaire.



farmers. The low nutritional status of the population incited the colonial administration to undertake some studies of food crops. Their scope remained limited, however, as it was soon demonstrated that the use of fertilizer in traditional agriculture was not interesting from either an agronomic or economic point of view (Jurion & Henry 1967:135). Until 1960, agriculture was nearly exclusively geared towards subsistence. With the exception of small quantities of groundnuts and maize, food crops were not sold (Nicolai 1963:227). However, palm oil, and in a more limited way also *Urena lobata* (Congo jute) constituted the basis of the economic exploitation of the region. *U. lobata* was introduced in the valleys during the 1930s, and is said to have caused widespread destruction of gallery forests. The palm-oil industry was established as early as 1911, but it was based nearly exclusively on the exploitation of subspontaneous palm groves. The length of the dry season in the Kwango-Kwilu allows the oil palm to dominate the Guinean forests, but the development of plantations was never an economic success. Only 22,000 ha of plantations were ever established producing an average oil yield of 700 kg/ha without fertilizer. About 20% of the adult males were occupied on a regular basis as cutters of palm fruits (Traugott 1979). The effective exploitation of the resource necessitated an extensive road and river transport system. Of the hundred factories in operation in the 1950s, only a few are still functioning today. Before Independence, one third of the Congo's total output in palm oil came from the Kwango-Kwilu.

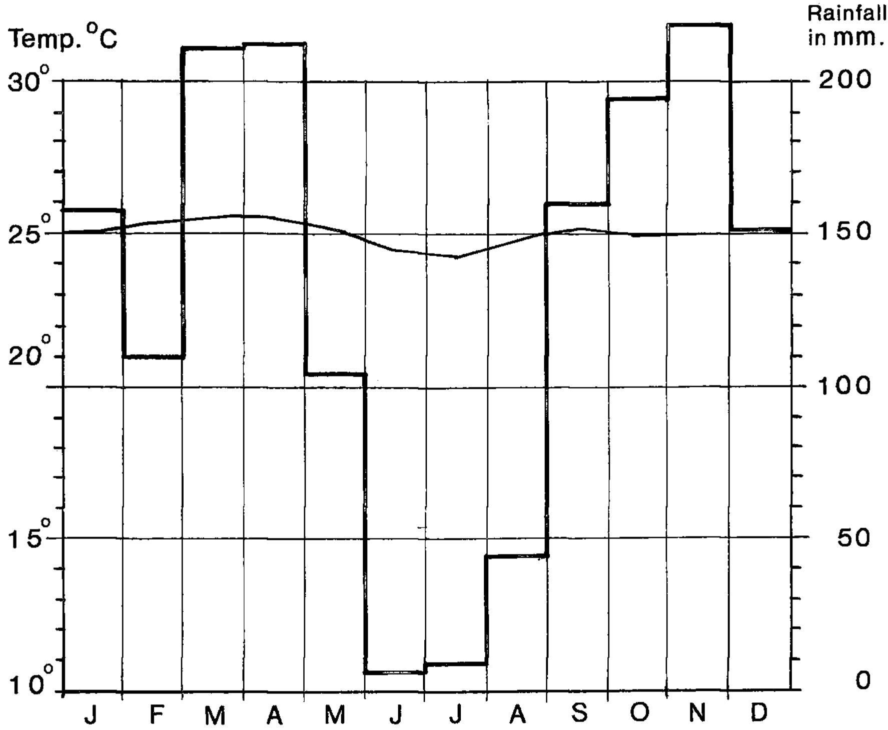
The impact of colonial rule on rural life in Zaire cannot be underestimated. The country's extraordinary wealth led to massive exploitation in a relatively short time. Belgian colonial policy did not allow the creation of a modern elite, except, perhaps, within the Roman Catholic Church. Evangelization, mass primary education and urbanization all contributed to a loss of cohesiveness of tribal societies (Weiss 1967). The sudden withdrawal of the colonial administration in 1960 created a vacuum of authority and expertise which could not be filled by the ill-prepared national government. All throughout Zaire, the first years after Independence were marked by widespread civil disorder, to a great extent initiated by the example of the Kwilu rebellion (1963-66) (Fox e.a. 1965).

In the years following 1966, little attempt was undertaken to develop the Kwango-Kwilu. It was only in the late 1970s, partly as a result of the 1978-79 drought in Bas Zaire which had hitherto been the main supplier of cassava to Kinshasa, that attention focused to the underexploited areas of the Kwango-Kwilu. UNDP, and later the World Bank and other donors financed a regional development program in the region.

Up till 1973 Zaire's recovery from turbulent 1960-66 period seemed remarkable. An authoritarian centralized state, a single political party and the president's complete control over government, legislature, justice and party created a short-term stability and allowed the inflow of foreign capital. When in 1974 the copper prices dropped dramatically, oil prices rose and the Benguela railway was closed, a US$ 500 million turnaround in the terms of trade resulted. These conjectural factors brought to light a deeper crisis (Young 1978). High government expenditures (over 50% of the GDP), massive foreign borrowing, and an annual inflation rate of 80% led to a balance of payment deficit of US$ 1.3 billion in 1978. The country's exclusive dependence on the mining sector and the total neglect of the rural areas were leading to a disaster. The inflation and the erosion of public sector wages encouraged corruption at all levels. Any unrest was met by hightened repression. The 'Zairization' and 'Radicalization' measures, implying the confiscation of commercial enterprises from foreign owners caused widespread shortages. When the measures were turned back in 1976, the damage was already done.

The consequences for Zaire's population were disastrous. Real minimum wages in 1977 stood at the lowest point ever and were below the 1910 level (Ryneman 1977). Urban purchasing power in 1980 represented only 25% of its 1970 value (FAO 1980a). Through official and unofficial taxes the local authorities managed to extract an estimated 50% of the farmers' cash revenues. In combination with a chronic lack of transportation and roads, this

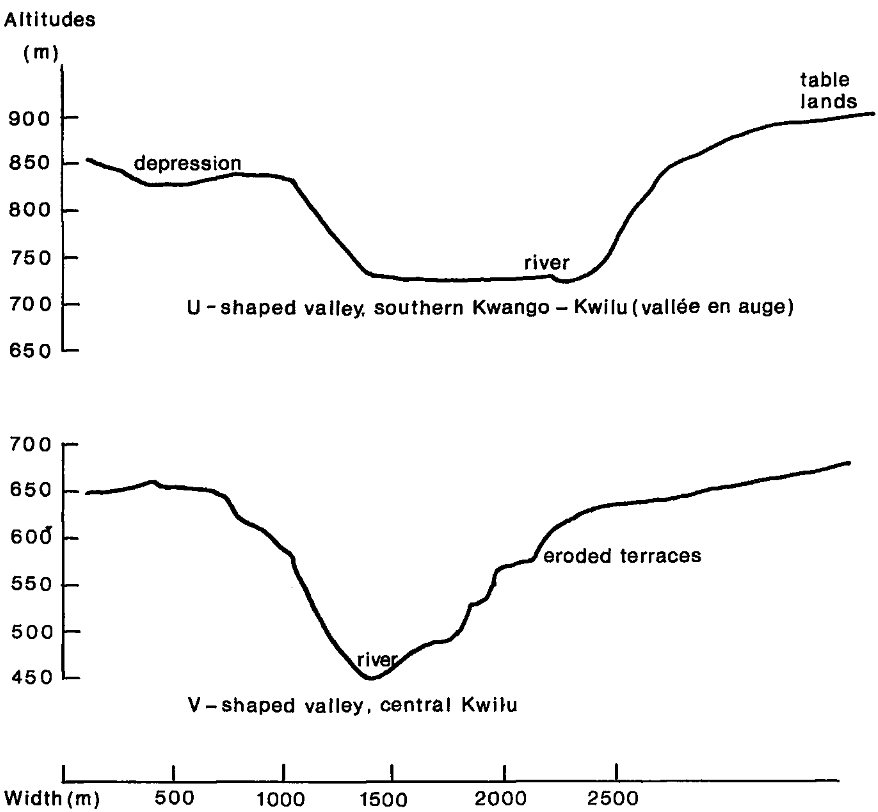
Figure 5.1 Rainfall and temperature (monthly averages, Kikwit, 1940-1953) (source: NICOLAI 1963).



open plains in the north, bordering the Kasai river. The morphology of the table lands is defined by its sandy soils resulting in slopes with a convex profile and U-shaped valleys. In the central Kwilu the landscape is more dramatic: waterfalls and rapids accompany the transition from U-shaped valleys to narrow gorges that widen in the north. The table lands change into rolling hills. The slopes of the central valleys have been eroded into natural terraces as illustrated in figure 5.2. Five main rivers running parallel from the Angolan border to the north shape the hydrography. The depth of the river beds varies between 50 to 300 m below the table lands, depending on the age of the rivers. Springs are found in the lower half of the slopes. Water resources are certainly not scarce, but usually far removed from the homesteads.

The geology of the Kwango-Kwilu may be described as secondary and tertiary sedimentary formations of continental origin deposited on cristalline parent rock. The formations belong to the Karroo and Kalahari systems, the latter, eolian sands, covering the former (Devred et al. 1958) (map 2). Nearly all (zonal) soils belong to the group of Oxisols (Nye & Greenland 1960). The FAO classifies them as Dystric Nitrosols and Ferralitic Arenosols (PNE/FAO 1981).

Figure 5.2 Cross-sections of river valleys typical of the southern and central Kwango-Kwilu.

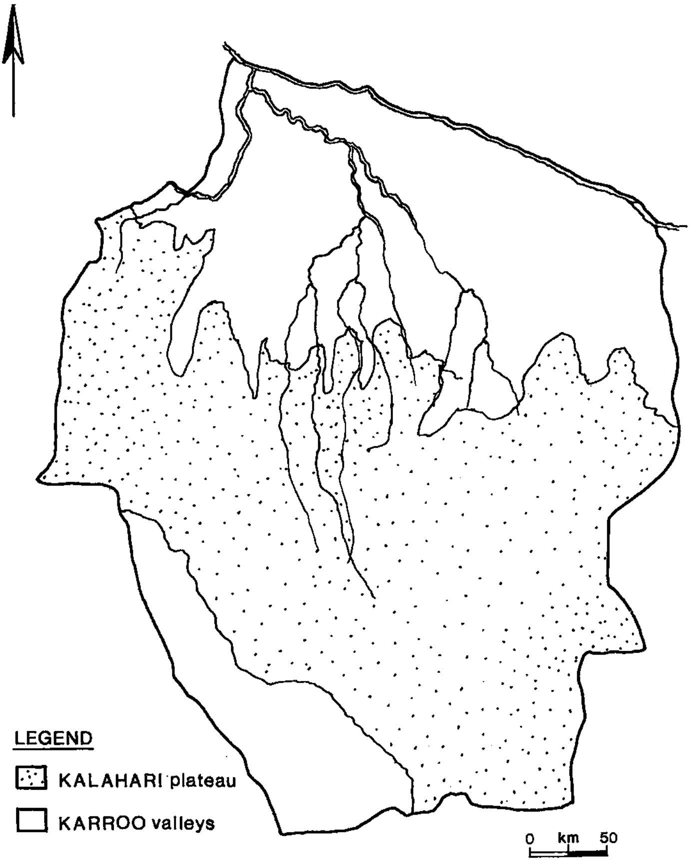


From an agronomic point of view two categories of soil series are important:

a soils derived from *Kalahari sands* with less than 5% clay and an average level of exchangeable bases of 1.5 m eq/100gr. These soils are common on all the southern table lands and in the U-shaped valleys (with the exception of hydromorphic soils). Kalahari sands are very permeable with a low organic matter content. The pH varies between 4.1 and 5.0. The nutrient levels recorded in the soil vary considerably depending on the degree of degradation of the soil but are very low in the majority of cases: total available N 11-101 kg/ha, P 22-162 kg/ha, K 0-84 kg/ha;

b soils derived from *Karroo formations* that appear in the central valleys where the rivers have eroded the sandy table lands. The average level of saturation with exchangeable bases is 1.5-3 m.eq. Though not as poor as the Kalahari sands, these soils are also deficient in major nutrients: total N 11-95 kg/ha, P 22-112 kg/ha, K 28-252 kg/ha. pH levels are similar to Kalahari soils. Toposequence variations related to relief are considerable. A survey of both

Map 2 The geomorphology of the Kwango-Kwilu.



soil types carried out by the national fertilizer program concluded that all of 21 samples were deficient in N, 20 (95%) in K and 8 (38%) in P (PNE/FAO 1981). The *vegetation* belongs to Guinean formations in the north, to Soudano-Zambezian formations in the south, while a combination of both types occurs in the central Kwango-Kwilu (Devred 1960, Jurion & Henry 1967) (map 3). The vegetation patterns closely reflect the geomorphology of the area. The most important formations are the following (Renier 1955, Devred 1957, Devred et al. 1958, Nicolai 1963)[1]:

a (semi)-evergreen seasonal forests and derived secondary forests, prevailing in all the major river valleys well into the southern Kwango-Kwilu;

b derived secondary forests with a predominance of light-demanding umbrella trees and subspontaneous oil palm. The latter is usually protected by farmers when clearing fields. Both these types of forests are rapidly declining as a result of frequent burning. Table 5.1 gives the area covered by various types of forest. Although more than one third of the area was still covered with

Table 5.1 Repartition of forests in the Kwilu (based on SICAI, 1977a).

Zones	Uninterupted forests		Gallery forests		Swamp forests		Forests as % of total surface	
	Km²	%	Km²	%	Km²	%	Km²	%
1. Bagata	–	–	4,970	29.4	659	3.9	5,629	33.3
2. Bulungu	–	–	7,205	53.4	52	0.4	7,257	53.8
3. Gungu	26	0.18	2,446	16.8	338	2.3	2,810	19.3
4. Idiofa	29	0.15	9,200	48.6	535	2.8	9,764	51.6
5. Masi-Manimba	–	–	5,128	35.8	271	1.9	5,399	37.7
Total Kwilu	55	0.1	28,949	37.0	1,855	2.4	30,859	39.5

Table 5.2 Key demographic data (Kwilu) (adapted from the following sources: *1970 census;* DE SAINT MOULIN, 1976; *Perspectives démographiques 1975-85*).

	Bagata	Bulungu	Gungu	Idiofa	Masi-Manimba	Kwilu
Total population (x 1000)[1]	158	482	278	526	411	1,854
Sex ratio[2]	96	89	88	91	86	89.5
Area (1000 km²)[3]	16.9	13.4	14.7	18.6	14.3	79
Population density/km² [4]	10	39	19	25	29	23.5
Annual growth rate (%)	1.9	2.7	1.0	2.1	2.3	2.6
% under 15 years[5]	46	46	42	43	–	43

Notes
1 Various figures for 1977-79; estimates for Masi-Manimba.
2 Males per 100 females (estimates).
3 Total for the Kwilu the towns of Bandundu and Kikwit; rounded figures.
4 Estimates (FAO 1983).
5 Estimates; no figure for Masi-Manimba.

forest in the late 1970s, 97% of this consisted of hardly accessible gallery and swamp forests;

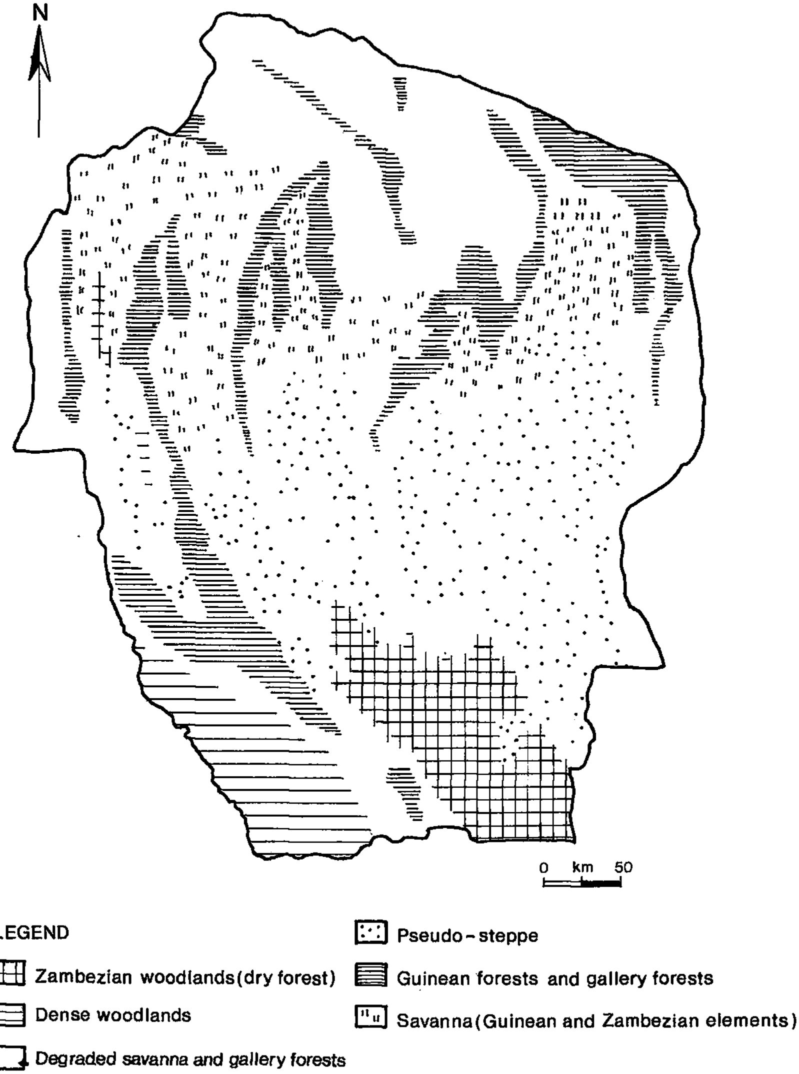
c savanna derived from semi-evergreen seasonal forests dominated by coarse grasses and ferns;

d broad-leaved woodlands and derived savannas: undisturbed woodlands are scarce, in most savannas tall grasses dominate;

e 'pseudo-steppe' (Devred et al. 1958) characteristic of the higher table lands. Vegetation depends on water table, season and toposequence. There is a negative correlation between the agricultural potential and varietal complexity of these pseudo-steppes. Frequent fires leave the soil virtually uncovered until the onset of the rains.

The natural resources also comprise the fauna. Unfortunately, no data can be reported on this subject.

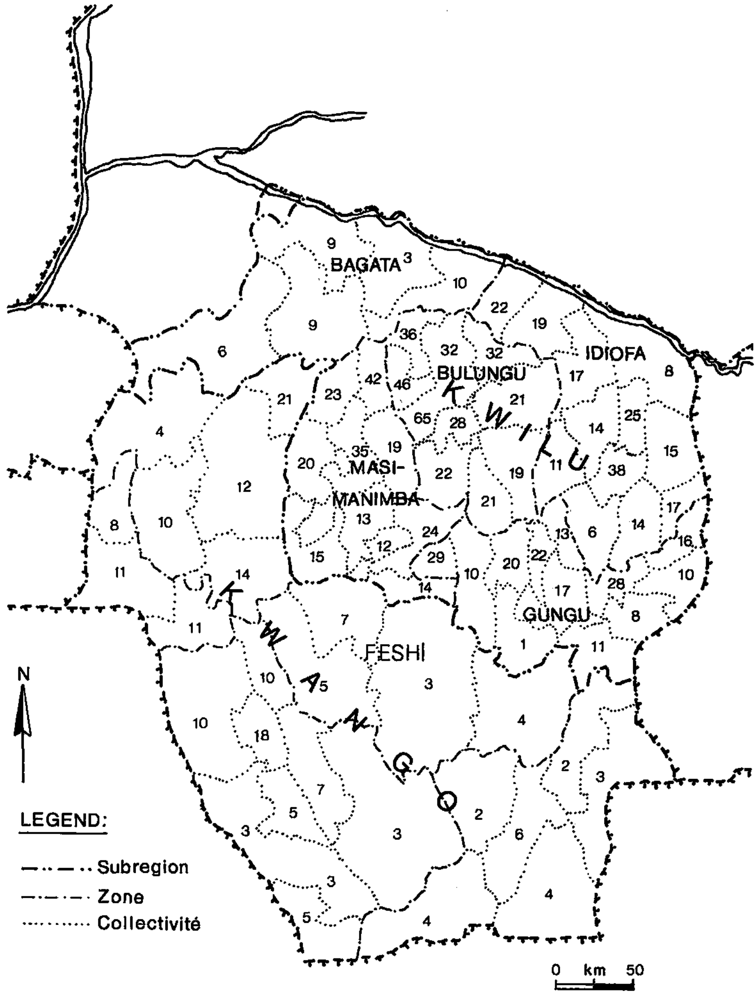
Map 3 The vegetation of the Kwango-Kwilu.



Human resources: population, population densities and migration

The total population of the Kwango-Kwilu is estimated at 2.2 million people (1976), including the towns of Kikwit and Bandundu (187,000), or about 10% of Zaire's total population. Key data for the administrative zones of the Kwilu (table 5.2) show a sex ratio of around ninety, an annual growth rate of 2.6% and an average population density of 23 inhabitants/km^2. The population

Map 4 Average population density per *collectivité* in the Kwango-Kwilu.



densities per *collectivity* – the lowest administrative unit composed of about thirty villages covering an average 1,600 km^2 – are shown in map 4. In comparison to the rest of the country, the Kwilu, and to a lesser extent the Kwango, is a relatively densely populated predominantly rural region with 90% of the people living outside centres of over 5,000 inhabitants. In Zaire as a whole, over one third of the population lives in towns and the average population density is below $10/km^2$.

In 1957, the average population density for the Kwango-Kwilu was only $13/km^2$ (Devred & Hardy 1957). Population densities varied from less than $3/km^2$ in the southern Kwango, to over 20 in what is now the Bulungu zone.

There are no figures on rural-urban migration before Independence, but the number of migrants must have been very low.
Of the rural population in the Kwango-Kwilu, 80% is involved in agriculture. Migration of young males is the direct cause of the relatively low sex ratio.[2] Of the regional migration flows into the capital Kinshasa, the one from Bandundu province is the largest and has increased considerably over the last decade. Furthermore, the town of Kikwit is one of the fastest growing towns in the country. This is aptly illustrated by the fact that only 3% of Kikwit's heads of households were born in that city and that 40% of its population has been a resident of Kinshasa at some time. Migratory patterns are complex, involving long stays in Kikwit before migrants move to Kinshasa, while a prolonged but temporary return to village life is also frequent. Conversely, many male residents of villages may spend a considerable part of the year in towns. Adult illiteracy is estimated at 55%.
There are indications that the nutritional status of the population is poor. During the brief survey conducted at the end of the 1980 dry season, the incidence of children under 80% of the WHO weight for age standard was found to be 56% (FAO 1983). This figure was later confirmed by a general estimate for the Bandundu which puts the percentage of malnourished children at sixty, and the daily calory intake at 1,700 per head (Ceplanut 1982).
The ethnic groups of the Kwango-Kwilu number over thirty. Without exception they are of matrilinear descent and most have virilocal residence patterns.

The agricultural (or primary production) sector

The objective of the regional analysis, to study the effect of regional level processes and constraints on agricultural production, requires some understanding of the agricultural sector as a whole before the details of farming and cropping systems can be analysed.

Land-use intensity

Shifting and fallow systems (Ruthenberg 1980) are the basis of agriculture in the Kwango-Kwilu. The value of the land-use intensity factor, R, can be estimated to vary between 12.5 in sparsely populated areas, to 30 on the table lands and may be as high as 50 in some of the valleys in the central Kwilu.[3] If various statistics on agricultural production are combined (République du Zaire 1975, 1980), the area under annual cultivation, excluding fallows, can be assessed at 375,000 ha in the Kwilu, or less than 5% of the total area. For Zaire

as a whole, this figure is no more than 2%, as it may be in the southern Kwango. Nicolai (1963) estimated that in the late 1950s 1.8% of the Kwilu was under cultivation of the six most important crops (cassava, maize, groundnuts, millet, rice and Congo jute). Given the fact that, with exception of rice, all crops are intercropped with cassava, an other way to arrive at a rough estimate of the area under annual cultivation is to take the total acreages of rice and cassava combined. This estimate can only be tentative, since figures for the Kwango are not available and those for the Kwilu do not distinguish between cassava planted in the current year and the cassava remaining in the field from the preceding year. Data from the agriculture department for 1978 indicate an area of 320,000 ha under cassava and 32,000 ha under rice, i.e. about 4.5% of the total area of the Kwilu. This gives adequate support to the earlier figure of less than 5%. A final check on the cassava acreages is the total number of farmers. As all cassava farmers are women who cultivate approximately slightly less than 1 ha of cassava, and demographic data suggest that there are some 360,000 adult women in the Kwilu, one would arrive at a figure of less than 360,000 ha, which is in line with foregoing estimates.
These figures are based on the total area of the Kwilu, not on the land potentially suitable for agriculture, since that is unknown. A rough indication of the area now used for traditional agriculture is three million ha or less than 40% of the Kwilu (assuming an average fallow period of seven years).
Consequently, the average population density on land now used for agriculture is 53/km^2, excluding the non-agricultural population in townships and land used for non-food production. Land required for livestock and oil palm in the Kwilu may be roughly estimated at 386,000 and 140,000 ha respectively.

Types of farms

Data from the last agricultural census (held in 1970, published in 1975) illustrate current trends in the evolution of the agricultural sector of the Kwilu. The total number of farms was approximately 190,000, including both *paysans* (traditional farmers) and *fermiers* (farmers with official land titles), as well as a tiny modern sector (a concept not defined in the census, presumably cattle ranches belonging to private companies).[4] Tenancy and shareholding are unknown. The *fermiers* constitute about 2% of the total number of farmers and cultivate about 6% of the total area. In 1975, 8,600 *fermiers* were recorded of whom about half had officially received title; this number has remained constant during the 1970s.
The structure of the traditional sector is shown in table 5.3. Nearly all farms (95%) are smaller than three ha, and over 80% of the farms are smaller than

Table 5.3 The structure of the traditional agricultural sector in the Kwilu[1] (1970). (Calculated from data of the Institut National de la Statistique[2]).

Size (ha)[3]	Number of farms	% of farms	Population	Total area (ha)	Area/farm (ha)
Less than 1	59,109	31.2	295,308	45,281	0.77
1-2	95,953	50.6	596,204	145,681	1.52
2-3	23,408	12.3	184,923	59,971	2.56
Over 3	11,286	5.9	114,143	47,683	4.22

Notes

1 Including *FERMIERS* (i.e. who have official title to land).

2 As the agricultural census data do not give these details, the INS (i.e. subregional) figures have been used.

3 It is not clear from the literature whether the classes are inclusive or not.

Table 5.4 The evolution of traditional farms between 1970 and 1980 (Kwilu) (based on 1970 census data and FAO survey results and estimates).

	1970	1980	
A. Characteristics of individual farms	(no separate data for *fermiers* and *paysans*)	*paysans*	*fermiers*
1. Available work force	2.8	2.15[1]	7.3[2]
2. Area cultivated: total (ha)	1.65	1.4	7.0
of which: annual crops (ha)	–	1.3	2.0
perennials (ha)	–	0.1[3]	5.0[4]
3. Large cattle (heads)	0.34	0.3	3.1
4. Small ruminants (heads)	1.22	0.8	8.3
B. Characteristics of the agricultural sector			
Total number of farms	190,000	250,000	5,000
Total area cultivated	316,000	350,000	25,000
Total agric. population	1,190,000	1,600,000	

Notes

1 Average composition 1.1 female, 0.8 male and 0.25 child.

2 Including temporary labourers and relatives.

3 *Paysans* only grow oil palm and fruit trees near homesteads.

4 Mainly coffee – this figure is probably overestimated.

two ha (annual cultivation). Since the census data are not very recent, they have been compared with data obtained during the farm management survey in 1980 to obtain an idea of changes in the composition of the agricultural sector (table 5.4). Although the results must be interpreted with some reservations, they show that between 1970 and 1980 the number of traditional farms has increased in proportion with the total population, i.e. with approximately one third. However, the total area under (annual) cultivation

Table 5.5 Production, area and yield of the major food crops in the Kwango-Kwilu (1979) (calculated from Dept. of Agriculture figures[1]).

Crop	KWANGO Volume (x 1000 t)	KWANGO Area (x 1000 ha)	KWANGO Yield (t . ha^{-1})	KWILU Volume (x 1000 t)	KWILU Area (x 1000 ha)	KWILU Yield (t. ha^{-1})
Cassava (fresh weight)	891	113	7.9	5,368	366	14.6
Maize (grains)	43	52	0.8	193	181	1.0
Groundnuts (unshelled)	31	40	0.8	118	140	0.84
Rice (paddy)	1.4	2.3	0.6	27	32	0.84
Millet (P. *typhoides*)	2.2	2.8	0.8	36	51	0.7
voandzou, (vigna subterranea)	1.7	4.8	0.3	8.8	12	0.7
Sweet potato	5.2	1.2	4.3	49	9	5.4
(Irish) potato	0.2	0.6	0.3	0.4	0.07	5.7
Yam (various species)	12.3	1.7	7.2	38	8	4.7
Squash (various)[2]	3.2	14.2	0.2	79	144	0.55
Banana[3]	4.6	2.0	2.3	33	7	4.7
Sesame	–[4]	–	–	3.6	2.9	0.8
Beans (several species and genera)	–	–	–	0.9	1.1	0.8

Notes
1 Gross inconsistencies in the data have been adjusted where possible; figures have been rounded.
2 Presumably this concerns oilseed yield only.
3 Includes plantain.
4 No data available.

has increased with only one fifth, half of which is accounted for by the *fermiers*. On traditional *paysan* farms the available work force per farm has declined with one fifth, while the area cultivated annually per farm has declined only slightly. This trend appears to reflect that, notwithstanding substantial male outmigration (temporary or permanent), women continue to cultivate nearly the same surface. The reduction in the number of small ruminants, usually considered as investments, could reflect the increasing poverty of the rural areas, while the stagnation in the number of large cattle per farm shows the limited impact of development programs and farmers' lack of capital.

Agricultural production: crops and volumes

Table 5.5 presents data on agricultural production in the Kwango-Kwilu from the regional statistical office. *Cassava* is by far the most important crop in terms of volume, total area and, as shall be demonstrated, economic value. Throughout the 1950s cassava production generally did not surpass one million ton, with the exception of the year 1954 (Colonial Agricultural Service for the Kwango). According to the figures presented here, production seems to have increased considerably to well over six million tons in 1979.

Maize is the second crop in terms of area and volume. It was strongly encouraged by the colonial authorities. Today, it remains a cash crop destined for the breweries (only unripe cobs are consumed occasionally). Around 80% of the maize crop is grown in the central Kwango-Kwilu. The annual maize production in the Kwilu varied around 20,000 tons during the late 1950s, whereas production seems to have increased to 193,000 tons in 1979.
Groundnuts were one of the few subsistence crops of interest to the colonial traders and they still constitute an important food and cash crop. Production in the Kwilu has also increased considerably from about 10,000 tons in 1959 to an alleged 118,000 tons in 1979. Millet (*Pennisetum typhoides*) is the traditional staple of the southern table lands. It used to be intercropped with sorghum which has now completely disappeared. While several species and genera of legumes are cultivated, only *voandzou (Vigna subterranea)* are marketed in significant quantities. Other starchy staples such as yam, sweet potato and plantain are only of local importance. Upland *rice* has become an important crop in the forested valleys of the Bulungu and Idiofa zones (central Kwango-Kwilu) as a result of various development projects. According to official figures from the regional statistical office, 20% of the farmers in these zones grow an avergae of 0.3 ha of rice, most of them probably non-traditional farmers. In some collectivities elsewhere, rice is one of 'imposed' crops, but it is hardly grown for lack of seeds. It is the only food crop grown in pure stands and with considerable male labour inputs. Squashes and sesame are grown as oilseeds for local consumption.
It is difficult to assess the validity of these aggregated figures. They are likely to be more indicative of the relative importance of crops than of absolute volumes. This becomes particularly clear when cassava production is considered. The divergence of cassava yield figures between the Kwango and the Kwilu require some discussion. According to national statistics obtained from the Department of Agriculture in Kinshasa for the Bandundu province as a whole for the 1970-76 period cassava yields are situated around seven tons/ha, i.e. about half those quoted by the regional statistical office (table 5.6). As it is most unlikely that yields have doubled in the three years following 1976, it is difficult to explain this discrepancy. In any case, the difference cannot be explained by the inclusion of the Kwango and the Mai Ndombe (in the national figures) since these two subregions together produce only 30% of the total cassava volume. Nevertheless, it may be concluded that cassava production has increased considerably over the last twenty to thirty years. Given the importance of cassava in the regional system, cassava production growth will be further addressed in the following chapters.
Agricultural production in the Kwango-Kwilu mainly concerns food crops. The only two export crops, tobacco and coffee, deserve mentioning although

Table 5.6 Cassava production in the Bandunda province (national data).

Year	Production (x 1000 t) (fresh weight)	Area (x 1000 ha)	Yield (t. ha^{-1}) (fresh weight)
1970	1,725	238	7.2
1971	1,671	242	6.9
1972	1,710	248	6.8
1973	1,794	256	7.0
1974	1,900	262	7.2
1975	1,960	269	7.3
1976	2,015	277	7.2

neither has ever been of great importance in the Kwango-Kwilu. Gathering of wild plants is a minor activity today. Over 3,000 tons of wild rubber, *Landolphia lanceolata*, were produced annually in the 1930s and 1940s, but the production decreased rapidly after the sudden fall of the world market prices in 1952. Congo jute and other fibers were once important sources of income, but at present the production stagnates at about 3,000 tons. The bark of *Rauwolfia spp* is still collected on a limited scale. The palm-oil industry is in decline. The high costs of collection of the fruits do not allow the necessary investments to upgrade the pre-Independence factories. Current wages for palm fruit cutters are low and few men are interested in the work. As a result, large areas of oil palm forests are being destroyed and replaced by cassava and maize.

Livestock was first introduced in the Kwango-Kwilu in the 1920s but remained unsuccessful until the colonial research institute, INEAC, undertook extensive studies to determine feed requirements and veterinary care. Carrying capacities vary between six ha/animal (250 kg) on the table lands to three ha in the valleys. From 1956 onwards the local population was allowed to acquire livestock. Most cattle owners are *fermiers*. The health status of their herds is poor, due to the lack of veterinary services. According to official figures, there would be about 92,000 heads of cattle in the Kwilu, about two thirds of which would be owned by farmers (the remainder by private companies).

The secondary and tertiary sectors

The secondary (processing) sector and the tertiary (service) sector include government as well as private institutions. Cities are also part of the tertiary sector, but have already been briefly referred to in the section on human resources. This section discusses various aspects of the relation between the government and private sectors and farmers.

Zaire has known a long tradition of government intervention in the rural areas (Gran 1979). Primary agents are the political authorities at region, subregion, zone and collectivity levels. Typically, the staff of the agriculture department is responsible for much of this control. In each collectivity, the lowest administrative unit, an *agronome* heads several *moniteurs agricoles* or extension workers. Their role is to see to the '*adequate use of land by farmers*'. The moniteurs agricoles are mainly occupied with the collection of demographic, agricultural and price data, control of markets and with annual land allocation.

Land allocation

While ownership of the soil is the exclusive right of the state, individuals may receive the right of usufruct. In shifting cultivation systems, land for annual cultivation after fallowing is attributed to farm households by the traditional village chief, under supervision of the extension agent. With respect to land two types of farmers are distinguished:

a traditional farmers or *paysans* residing in villages where their clans have customary landrights. They may freely dispose of clan land for annual cropping. Formally, therefore, in rural areas, landlessness does not exist;

b modern farmers with officially registered title (*fermiers*) who are established outside their area of origin. They have the right to grow both perennial and annual crops. No restriction is placed on land titles with respect to area or duration.

Women usually retain claims to land and sometimes plots in their native villages, although marriage entitles them to an annual allocation of land for shifting cultivation from their husbands' clan. First generation migrants to urban areas do not seem to lose their landrights.

The practice of government control of the allocation of new swiddens stems from the colonial policy of *Cultures Imposées* or compulsory cultivation. A forerunner of the *Cultures Imposées* was a head tax introduced in 1910. This tax, to be paid in kind was excessively high, representing the equivalent of 45 days of work (Smith 1976:13). In 1917, legislation was passed to authorize the imposition of compulsory cultivation (Miracle 1967:242), which was further specified in 1933. The Belgian administration considered it necessary to enforce the cultivation of a minimum land area per adult male, in order to ensure an adequate food supply to a population which still depended very much on hunting and gathering. On the compulsory fields new techniques were also to be applied under the supervision of the extension staff (Drachoussoff 1954). The effective control of the compulsory fields required the establishment of a network of indigenous extension workers headed by a colonial officer. The minimal area allocated was 0.21 ha. After Independence the law was not enforced until its reintroduction in 1976. Its negative effects on agricultural production have been described elsewhere (Fresco 1982). At present, the status of the *Cultures Imposées* is far from clear, but in practice instructions are still issued by the regional authorities with respect to minimum acreages and crops.

The allocation of land for shifting cultivation, the supervision of the implementation of the system and its enforcement through fines are the task of the extension staff. This task is complicated by the fact that the compulsory acreages are also used as a basis for data collection and the setting of production standards (République du Zaire/Programme National de la Production Vivrière, undated). As no indication is given of the extent of intercropping, total area of all crops allocated to each adult male amounts to 1.6 to 1.8 ha in the Kwango-Kwilu (République du Zaire/Programme National de la Production Vivrière, undated). In practice, however, about one hectare is allocated. The formal instructions are often confusing and usually interpreted in a loose fashion by the extension agents, leading to variations between and within villages. In some cases farmers will continue to farm other plots outside the control of the extension staff. This variation is difficult to investigate in view of the sensitive subject.

The effects of government intervention in traditional land allocation are several. Firstly, it leads to an overburdening of women. The acreages imposed on men are in fact cultivated by their wives with little or no male assistance (with the exception of rice). The average obligation of one hectare is larger than most women can cope with, possibly enhancing labour bottlenecks in weeding and planting. Secondly, government control affects agricultural output in various ways. A large area requires more (healthy) plant material and seeds than are often available. Furthermore, extension agents seem to prefer to allocate the fields in such a way that they can be most easily inspected, i.e. along the roads (which follow the watersheds) or at the top of the slopes. These slope fields are likely to aggravate erosion and to be less productive. Finally, inspection requires that fields are grouped closely together, which goes against farmer preference for small dispersed plots, and may enhance the spread of pests and diseases.

Extension and agricultural inputs

Although an extension service exists in name, it may be clear from the foregoing that the extension staff is only concerned with the implementation of administrative rules and statistical data collection. This situation leaves no room for any tranfer of knowledge, new techniques or inputs to farmers. In any case, extension staff do not dispose of any means to do so. Their training, usually a few years in an agricultural college after primary education, has in no way prepared them for the problems faced by traditional farmers. On average each of them deals with 380 households. They lack the means of transportation, teaching materials, and above all, motivation. Salaries are poor, irregularly paid, if at all. Transfers occur frequently, at the whim of higher authorities. Farmers are very distrustful and sometimes even hostile. There are no female extension workers in the region. Consequently, the extension service has no technical inputs whatsoever in traditional agriculture. Furthermore, contacts between agricultural research stations and extension service are non-existant.

In a few cases, missionary organizations have trained private extension agents, but their impact remains limited. On a very small scale, missions supply agricultural inputs to selected farmers. In general, however, credit and agricultural inputs are unavailable to traditional farmers.

Infrastructure and marketing

The present road network, once one of the best in the country, is totally inadequate, less than 2,400 km in the Kwilu (of which about 200 are sealed) or 3 km of roads per 100 km^2. An adequate road network would require the construction of an additional 24,000 in the Kwilu alone (FAO 1983). Bridges are lacking almost completely, so that at least thirty ferries are needed for the main through-roads. Road maintenance is poor and infrequent. Although extensive stretches of the rivers are navigable, port facilities are very limited and barges are only used by the palm-oil factories. The volume of food crops transported by river is negligeable.

Even where roads exist, trucks do not, or are in an appalling shape because of a chronic lack of spare parts. Traffic from the Kwango-Kwilu into Kinshasa varies with the availability of fuel. Between 80-90% of the volume transported by road consists of dried cassava *(cossettes)* in 50-kg bags. A typical local trader in the Kwango-Kwilu possesses one old 6-ton army truck and collects produce from the villages in his neighbourhood. Since the late 1970s, i.e. since the cassava shortages in Kinshasa due to the drought in Bas Zaire, large traders from the capital have emerged in the Kwango-Kwilu to buy produce in Kikwit and other centres. Although the prices paid to primary producers are but a fraction of the ones obtained on retail markets in Kinshasa, profit margins for traders are probably low and occur mainly on the backload of manufactured goods (Reid 1981). Storage facilities at collection points in the rural areas do not exist, resulting in serious losses in cassava and maize.

The establishment and frequency of markets is controlled by the collectivities

Table 5.7 The evolution of official und unofficial (minimum and maximum) prices of selected crops and consumer goods, Kikwit market (1974-1982)[1].

Year	Cassava (dried)		Maize (grains)	
	Official	Unofficial	Official	Unofficial
1974	–[2]	0.07	–	0.30
1975	–	0.17	–	0.35
1976	–	0.34	–	0.40
1977	–	0.34	–	0.40
1978	0.30	0.46	–	0.40
1979	0.70	0.46-1.25	1.50	0.40-1.53
1980	0.80	0.46	1.50	0.40
1981	1.50	0.90-1.20	3.50	1.30-2.00
1982	4.00	1.80-3.00	6.00	1.70-2.00

Notes

1 Exchange rates Zaires to one US$ (yearly averages):
1970-1975: Z 0.5; 1976-1977: Z 0.8; 1978: Z 1.0; 1979: Z 2.02; 1980: Z 2.98; 1981: Z 5.46; 1982: Z 5.74.

2 – no information available.

and no selling or buying is officially permitted outside these markets. Nevertheless, this occurs on a large scale. Given the few traders operating in the Kwango-Kwilu, a kind of monopsony or rather oligopsony has developed. Women, who are responsible for carrying produce to the local markets, will sell even at very low prices rather than having to return home with their baskets. They are also disadvantaged by the use of very inaccurate scales and an arbitrary system of grading produce, which is sometimes applied by merchants or extension agents. As a result, farmers may receive considerably less than the official price.

Breakdowns in the marketing system are frequent, usually because of the lack of cash, trucks or fuel. The consequences may be disastrous, as Kinshasa's estimated three million inhabitants now rely for over half over their cassava supply on the Kwango-Kwilu. In 1981, for example, an estimated 25% of the maize crop in the Kwango-Kwilu was lost for want of buyers. In response to the need for marketing services, non-governmental organizations such as church groups are increasingly involving themselves in marketing and transportation.

Agricultural prices

Although farm gate minimum prices were set by government, black-market prices were widely practiced till 1982, reflecting the worsening terms of trade between agricultural and consumer goods. In practice, the official minimum price was often interpreted as a maximum by farmers and traders, especially

Groundnuts (unshelled)		Cotton material (4 yards)		Salt (18 kg bag)		Sardines in oil (tin, 90 gr)	
Official	Unofficial	Price	Index	Price	Index	Price	Index
–	–	1.65	100	1.60	100	0.14	100
–	–	2.35	142	7.50	469	0.16	114
–	–	7.00	424	8.60	537	0.22	157
–	–	11.50	697	9.00	562	1.20	857
–	–	13.00	788	9.50	594	1.30	928
2.30	–	26.00	1575	12.70	793	2.20	1571
3.00	–	90.00	5454	36.30	2268	4.50	3214
5.00	2.60-3.50	–	–	–	–	–	–
10.00	3.00-5.00	145.00	8787	50.00	3125	5.00	3571

in remote areas where a de facto monopsony exists. As shown in table 5.7, unofficial prices of food crops have dropped well below the official minimum prices, while the prices of manufactured goods have increased dramatically. Only in 1979, during the drought in Bas Zaire, the unofficial cassava price exceeded the official one. The low maize price reflects the lack of interest from the breweries, for whom it is more economic to import maize than to buy it in the Kwango-Kwilu. Before the fuel crisis of the last quarter of 1981 which induced massive food shortages in Kinshasa, real agricultural prices had not evolved significantly since 1974. In May 1982 agricultural prices were liberalized, implying that the government established farm gate floor prices were abolished.[5]

Real prices fluctuate considerably throughout the year. All agricultural prices reach a peak in October-December before the new harvest, when heavy rains render most roads impassable. Cassava, which is harvested for subsistence needs throughout the year, is yet subject to some degree of price fluctuation. During the dry season labour is not a bottleneck and cassava can easily be dried. Labour for cassava processing increasingly becomes a problem in August through to January. Cassava shortages may occur in October and November when it is impossible to dry the roots. In maize and groundnuts, seasonal fluctuations are marked in December, before harvesting, and in August at the time of seed purchases.

With the exception of cassava, the sale of food crops is restricted to a fixed period. This rule was originally imposed by the colonial administration to prevent early harvesting which would cause losses and to allow the recording and taxation of production. In the 1970s, the official selling period which was fixed by the provincial authorities would usually not start before April. Widespread evasion of the rules occurs, of course, since most crops are harvested in January. Nevertheless, food prices in urban centres, where tight control is exerted, tend to rise dramatically and a lively black-market results.

Table 5.8 An estimate of the value of the marketed production of the major food corps in the Kwilu, at 1978 hypothetical prices.

	Production		Marketed	
	(1000 t)	%	Volume (1000 t)	% unofficially
Cassava (dried)	1,642	60	985	75
Maize	157	80	126	25
Groundnuts	109	30	33	66
Rice	26	95	24	20
Millet	34	20	6	–[3]
Squash seeds	69	33	22	–[3]
Totals	2,037		1,196	58.7

Notes

1 Price = (% unofficially marketed x average unofficial price) + (% officially marketed x official price) / 100

2 Exchange rate (official) US$ 1.00 = Z 1.007.

3 Squash seeds and millet are mainly locally consumed (within the Bandundu region) and there is no unofficial market of any importance.

Table 5.9 Estimated annual removal of N, P and K in harvestable produce of cassava, groundnuts and maize in the Kwilu (1978).

Crop	Annual production in tons	Nutrients kg.t^{-1}			Nutrient removal (T)		
		N	P	K	N	P	K
Cassava roots (dried)[1]	1,642,000	2.7	1.7	19.0	4,433	2,791	3,1198
Groundnuts (unshelled)[2]	109,000	35.0	3.5	12	763	381	1,308
Maize (grains)[3]	157,000	14.2	3.2	3.3	2,229	502	518
Totals					7,425	3,674	3,3024

Notes

1 Cassava: Nijholt (1934/35), Flach (1980).

2 Groundnuts: excluding an assumed 80% of N derived from fixation; Kessler and Ohler (1983).

3 Maize: Kessler and Ohler (1983).

It is expected that the price decontrol measures proposed by the World Bank and the IMF will also lead to the abolishment of the official selling period.

Non-agricultural activities

Although the Kwilu, in contrast to the Kwango, is relatively well endowed with institutes for higher education, primary schools and agricultural training are hardly functional in most of the Kwango-Kwilu. A considerable part of the

Price	Value of the production (million Z)			
Z/T[1]	Marketed	Total	% of total volume	% of marketed volume
420	413.7	689.6	66.2	82.4
350	44.1	54.9	5.3	10.5
1800	59.4	196.2	18.8	2.8
700	17.3	18.2	1.7	2.0
400	2.7	13.6	1.3	0.5
1000	22.7	69.0	6.7	1.8
	559.9	1,041.5	100%	100%

schools (75%) and health facilities (60%) are managed by church organizations. The lack of sources of income, the isolation of villages and the absence of shops and clinics as well as the tight control by government and clan leaders, was cited by high school students as reasons for seeking employment in town (FAO 1983). In rural areas no employment opportunities exist outside agriculture, with the exception of a limited number of jobs in the administration or in church organizations. Incidentally, formal employment in the agricultural sector is possible with the palm-oil companies.

Regional flows

Regional flows involve interactions between system components as well as inputs into and outputs from the region. The characteristics of the components determine the structure of the system and the nature and volume of the interactive flows. The components of the regional system interact through flows of energy, materials, information and money. Some of these interactions have already been discussed, such as the impact of government control (tertiary sector) on the agricultural sector. Not all flows can be quantified. This depends on the nature of the flow (information flows are difficult to quantify in a satisfactory manner) and the available data. The most important flows of materials are discussed below.

Agricultural commodities

Because of the extensive black-market, it is difficult to estimate the volume and the value of agricultural commodities exported from the Kwango-Kwilu.

Officially, only 18% of the production is marketed (République du Zaire, undated), but it may be assumed that 65% of the cassava, 80% of the maize, about 50% of the groundnuts, nearly 100% of the rice and about 10% of the millet are sold (FAO 1983, Reid 1981). Table 5.8 gives estimates of the volume and value of the main crops in the Kwilu, based on a hypothetical price which takes into account the black-market, and for want of other sources, based on the regional production statistics. While these estimates are necessarily very rough, they give an indication of the importance of the various commodities. Cassava constitutes by far the most important source of revenue and represents over four fifth of the total volume shipped from the Kwilu. Cassava, maize and groundnuts together account for 90% of the marketed volume of food crops.

Soil nutrients

As a producer and exporter of a large volume of crops, the Kwango-Kwilu loses considerable quantities of nutrients each year. Soil nutrients constitute both an internal flow – an interaction between the agricultural sector, the natural resource base and the non-agricultural sector – and an output from the regional system. While it is theoretically possible to distinguish between the export of soil nutrients (output) and the internal flows of nutrients removed from fields, but not necessarily exported outside the regional system (because consumed locally), this is practically impossible.
The following estimates are therefore based on total production figures and do not take into account the proportion marketed outside the region. The loss of nutrients occurs through the removal of harvestable parts and immobilization in leaves and stems. Cassava leaves are removed in great quantities for human consumption and even stems may be used as firewood, so they are not available for local recycling. Furthermore, frequent burning of fields leads to further losses, especially of N. The return of plant nutrients to the soil after decomposition of the remaining leaves and stems is subject to leaching, in particular of N and K. While disregarding the immobilization of plant nutrients, a conservative estimate of the amount of nutrients removed through harvesting can be made on the basis of average values on nutrient composition of storage organs of the three major crops: cassava, groundnuts and maize. These figures are presented in table 5.9. They are necessarily limited. Most of the studies quoted have been carried out at much higher yield levels than prevailing in the Kwango-Kwilu. It may be assumed that the efficiency of nutrient use is greater at these levels than at lower yield levels. Other studies refer only to nutrient removal per hectare of sole crops and cannot be applied to the Kwango-Kwilu.

Taking into account these reservations, it can be suggested that an estimated 7,425 tons of N, 3,674 tons of P and 33,024 tons of K may be removed annualy from the Kwilu alone. Inputs of fertilizer are negligeable. Of the 200-300 tons of fertilizer imported by the regional branch of the national fertilizer program (PNE) in 1983, significant quantities had to be returned to Kinshasa for want of buyers. Although fertilizer consumption is expected to increase in the Kwango-Kwilu, it is far from balancing the considerable exports of soil nutrients.

Money

In contrast to soil nutrients and agricultural commodities, money is at the same time an input and an output of the regional system. Money flows in countercurrent to (is paid for) agricultural commodities and (is spent on) manufactured goods, that are respectively outputs of and inputs into the system. Furthermore, money is paid in taxes to the government by farmers. This last flow is not counterbalanced by access to credit. The agricultural sector depends also on remittances from the non-agricultural sector and from the capital. These remittances are nearly exclusively used for consumptive purposes.

Migration

Migration or, in other words, a 'flow' of humans between the agricultural and non-agricultural sectors is an important feature of the agricultural economy of the Kwango-Kwilu. Migration constitutes both an internal flow between regional system components as well as an output of the system. Although the migratory patterns are circular to some extent, implying a return of migrants from Kinshasa to the region, the outflow of migrants far surpasses the inflow. It is estimated that approximately 225,000 people, the majority of them males, will have migrated from the Bandundu region to Kinshasa during the 1975-85 period. The effects of male migration on agricultural productivity will be discussed later.

Information

Information also constitutes an input into as well as an output of the regional system. Information inputs into the regional system obviously take many forms, such as government decrees, information on urban food prices and so on. Technical information inputs through extension or agricultural research are virtually absent. It is noteworthy that radio broadcasts and newspapers are hardly accessible to the inhabitants of the Kwango-Kwilu. Two thirds of the farm households interviewed during the household survey report that their only sources of outside information are travellers. Information outputs are more difficult to describe as they are mainly comprised in the flows of materials. The flow of agricultural commodities, for example, also contains information on the state of agriculture in the region.

Regional system structure and function

The structure of the regional system is determined by the quantitative and qualitative characteristics of its components and their interactions. While the traditional farm sector is relatively homogeneous with respect to farm size and crops, spatial distribution patterns of natural and human resources are heterogeneous. The interaction of climate, soils and vegetation has resulted in a landscape with two main elements: valleys and table lands. To a superficial observer noting the scarcity of settlements and fields, this landscape may seem natural. Yet it has been profoundly modified by human intervention. Woodlands and vast stretches of forest have disappeared. Frequent cultivation of slopes has caused the sliding of Kalahari sand downwards towards the valley bottoms, where it covers the more fertile Karroo soils. If maps 2, 3 and 4 (soils, vegetation and population density) are superimposed, two broad *agro-ecological zones* emerge. An agro-ecological zone is defined in this context as an area of similar soil, vegetation and population density characteristics, resulting in a similar (sub)type of cropping system. Because temperature and rainfall do not vary significantly throughout the region, climate is not included as a variable in this definition. The two zones that can be distinguished are:

a the Karroo valleys of the central and northern Kwilu, with typical population densities over 40/km². In recent years there has been a sharp increase in the population densities in the relative fertile collectivities (Reid 1981). The Karroo valleys are relatively more fertile and better served by roads. The north of the Kwango-Kwilu is relatively uninhabited notwithstanding its relatively fertile soils. This must be attributed to *trypanosomiasis* (sleeping sickness) which spread from the Congo Basin southwards in the middle of the nineteenth century (Nicolai 1963);

b the Kalahari table lands (or plateaus) and the U-shaped valleys of the Kwango and the remainder of the Kwilu, with an average population density around 10/km². The table lands are relatively sparsely populated, in contrast

Discussion

The objective of this chapter has been to use the existing secondary data base to analyse the regional system with a view to identifying regional level constraints on system performance and agricultural production in particular. In chapter 3, a distinction has been made between suprasystem constraints and subsystem limitations. This view on constraints differs from the approach taken by IRRI (De Datta et al. 1978, Flinn 1982). IRRI's constraints' analysis assumes that new technology (i.e. varieties and improved management) has already been adopted by farmers; it does not examine those causes for low yields that lie beyond farmers' control nor does it distinguish between constraints at different levels in the hierarchy.

The regional system as a whole is constrained by the national system. Government control of agricultural production and prices as well as the desastrous economic performance of the country constitute serious constraints on the regional system and all systems below it. Endogenous limitations concern the natural resource component and the non-agricultural sector. Relatively poor soils, a chronic lack of agricultural inputs, unfavourable marketing conditions and inadequate transportation seriously limit agricultural production. Notwithstanding these constraints and limitations, the statistical evidence, however scanty, reported in the section on agricultural production up here, indicates considerable increases in the production of all food crops since the 1950s. Even if one takes a conservative view, it is probable that production has surpassed population growth, estimated at 2.7% annually (République du Zaire/Département du Plan, undated). Aggregate figures for Africa and Zaire show the opposite trend: food production per head of the total population has been declining slowly throughout the last decade.

The key question remains therefore, how production in the Kwango-Kwilu could have increased under relatively unfavourable conditions of soil fertility, government control and market disincentives, and at what costs. This question will be examined in detail in the following chapters.

Notes

1 The typical species in each formation are:

a semi-evergreen forests: *Gilbertiodendron dewevrei, Brachystegia laurentii, Marquesia acuminata*. In riverine forests: *Uapaca spp, Alchornea cordifolia*;

b derived forests: *Trema orientalis, Musanga cecropoides, Elaeis guineensis*;

c savanna grasses: *I. cylindrica, Hyparrhenia diplandra and H. confinis, Andropogon gabonensis*, along with other species such as *Aframomum stipulatum, Pteridium aequilinum*;

d trees in broadleaved woodlands: *Brachystegia longifolia, Julbernardia paniculata, Berlinia giorgii*, in the derived savannas: *Hymenocardia acida*, on Karroo soils *Dialium englerianum, Erythrophleum africanum*, grasses *H. diplandra*. Old village sites grasses: *Digitaria polybotria, Eragrostis congestis*;

e pseudo-steppes: grasses of the drier areas are *Ctenium newtonii, Loudetia simplex, L. demeusii, Aristida vanderysti*. *Rhyncheletrum roseum and R. amethysteum* indicate recent burning; *Pennisetum polystachion* is found in fallows after millet/cassava. Other typical species include *Boophane distycha, Parinari pumela*.

2 The lowest sex ratio is found in Masi-Manimba, the zone closest to the capital. Although it has been suggested that the after-effects of the rebellion of 1963-66 explain the low sex ratio, this has been challenged by Caldwell who points out that the Idiofa and Gungu zones, which were at the centre of the rebellion, show a slightly more favourable ratio (Caldwell 1975:592). Reid (1981) estimated that the sex ratio in the most productive collectivities may be as low as sixty adult males for hundred females.

3 R is commonly defined as the number of years of cultivation multiplied by hundred and divided by the length of the cycle of land utilization, the length of the cycle being the sum of the number of years of cropping plus the number of fallow years (see also note 4, chapter 3). Thus R indicates the proportion of the area under cultivation in relation to total area available for cropping. The calculation of R is complicated by the fact that it is difficult to determine exactly when cultivation ends and fallowing starts, since cassava is left on the fields slowly merging with the surrounding vegetation. It is assumed here that cultivation ends when the last intercrop has been harvested and no more work is done on the fields apart from the harvesting of cassava roots and leaves, i.e. after 18-20 months.

4 In 1970, the modern sector comprised 36 cattle ranches with an average acreage of 530 ha, and about 380 heads of cattle per farm (including small ruminants). These figures have certainly dwindled during the 'Zairization' when most of these farms were expropriated. The modern sector will be disregarded in the remainder of this book.

5 One year later (in May 1983), however, this measure seemed unknown to most of the agricultural staff who continued to apply price control. In part, this may be explained by the lengthy bureaucratic route between Kinshasa and the collectivities. Partly, under the present circumstances, agricultural staff are reluctant to relinquish any control measures (and the inevitable corruption these entail) on which they rely to supplement their meager incomes.

6 FARMING SYSTEMS IN THE KWANGO-KWILU

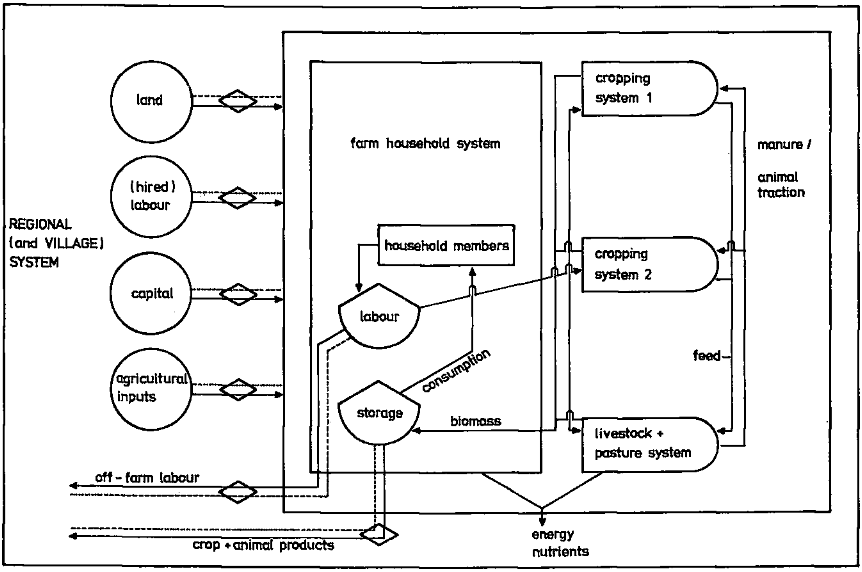
Definition and boundaries

This chapter discusses the farming systems in the Kwango-Kwilu. A farming system is defined as a decision making and land-use unit, consisting of the farm household, cropping and livestock systems, that produces crop and animal products for consumption and sale. The farming system is a subsystem of the agricultural sector, itself a component of the regional system. Other land-use units such as the village or watershed form intermediate system levels between the farming system and the agricultural sector. In turn, the farming system constitutes the suprasystem of lower levels in the hierarchy: the cropping and livestock systems. Like all systems it consists of boundaries, components, interactions between components, inputs and outputs. The main components are the farm household system, the cropping system(s), and the livestock system(s). Figure 6.0 presents a simplified model of the farming system.

The farming system is delineated by *socio-economic* as well as *physical boundaries*. The socio-economic boundaries determine the people who are involved in farming (the farm household) as well as all the resources and inputs, capital and information managed by the farm household. Its physical boundaries are determined by the farm house, the yard and the cropping and livestock systems, i.e. the land used for cropping and grazing. The socio-economic unit of observation corresponding to the farming system is the farm household, while the farm forms the physical unit of observation. In practice, the definition of boundaries as well as the identification of the units of observation meet with some difficulties. It is not always clear who should be included, or what land is actually managed by the farm household. In order to determine the socio-economic and physical boundaries of the farming system, the management unit, the farm household, will be identified first.

In many African societies the farm household system consists of complexly linked subsystems, in which the type of activity and sometimes even the crop

Figure 6.0 The farming system (energy symbols after ODUM 1983 – see annex).



determines membership of subsystems and their spatial boundaries (e.g. Benoit-Cattin & Faye, 1982). Moreover, certain activities may mobilize labour and other resources from larger units such as the clan or village. In many cases, therefore, analysing the farm household system is not possible without an understanding of these wider structures or intrahousehold processes that affect agricultural production.

In the Kwango-Kwilu, however, the structure of the farm household system appears relatively simple. Residential units are easily distinguished and for most purposes they constitute both consumption and production units. Because of matrilinear descent and virilocal residence patterns, women farmers in the same village have little contact and do not commonly share resources, so larger social units seem relatively unimportant to agricultural production. While the composition of residential units may vary, it seems justified to equate the household with the residential unit, and disregard intra- and interhousehold linkages. Some ambiguity arises, however, with respect to male household members who have temporarily migrated to Kikwit or Kinshasa. While the household cannot dispose freely of their labour, it benefits from the remittances – however limited and irregular – they send home from the city. Many of these migrants return home frequently for prolonged periods. Although absent, they clear continue to be part of the farm household system.

The identification of the physical boundaries and unit of observation, the farm, poses a different problem. Although land in the Kwango-Kwilu is never fenced (with the exception of gardens), the fields cultivated by the farm household are easily identified. The compulsory cultivation regulations lead to unequivocal demarcation of fields, at least in principle. Officially, at least, there seem to be few differences in farm sizes in the region (see also table 5.3). The boundaries of the farming system with respect to cultivated land can thus be clearly defined. This is not so, however, for land lying fallow. In the Kwango-Kwilu, fallows are considered common land, that is used by all households according to needs for firewood, wild plants, grazing by goats and so on. Farmers usually cannot claim fallows that they have previously cultivated. Fallows are also often burnt by groups of young men for hunting. While the fallow is an essential component of the cropping system – and therefore of the farming system – it cannot always be located spatially.

Farming system components

The farm household system

The farm household system is the single most important component of the farming system. The farm household is defined as a group of usually related people who, individually or jointly, provide management, labour, capital, land and other inputs for the production of crops and livestock, and who consume at least part of the farm produce. Farm household characteristics, such as the composition by age and gender, which in turn determine labour availability and consumption needs, influence many facets of agricultural production. Farm household objectives define how the agro-ecological potential of a given farming system will be utilized. The farm household allocates its resources to various activities on- and off-farm in accordance to the needs of its members. Characteristics of farm households in the Kwango-Kwilu are discussed below.

Farm household composition

Of the farm households in the survey 69% consisted of a nuclear family, while 11% of the farm households were polygamous. In 20% of the cases the farm household was headed by a woman. A typical farm household comprises five to six people. Typically, women have to look after two to three children, while the older ones may be sent to relatives in town. As discussed, de facto male absenteeism occurs frequently. At the time of the survey, the average sex ratio was 72 men for 100 women.

Farm household objectives

Direct information on the objectives and goals of the farm household is difficult to obtain. Two questions were thought to have an immediate bearing on agricultural production. Firstly, it was supposed that the degree to which farmers saw agriculture as a desirable way of life for themselves and their children, would give some indication of their willingness to change agricultural practices if required. 86% of the adults interviewed during the farm household survey considered themselves as farmers. For women alone, this figure increased to 96%. Only 4% of the men mentioned a regular source of income, generally as traders or artisans, and none of the women did so. Nearly without exception, young men quoted the lack of services (stores, clinics), the isolation of village life and the lack of income-earning opportunities, as reasons for migration. Young women, whose outlooks on a future outside agriculture are very limited, referred to the lack of freedom resulting from the compulsory cultivation regulations and family obligations as reasons for wanting to leave the rural areas. Earning a cash income seemed to be one of the ways to relieve the drudgery of farm life, because it allowed the purchase of additional 'luxuries' such as meat or fish, or new clothes. Farming was a difficult way of life, according to all interviewees, with little scope for change. As one woman put it: *'Nothing will change, my granddaughters will still grow cassava and soak it in the river'*.
Secondly, an indirect indication of farm household objectives was obtained through a question about the main problems experienced by farmers. In reply, women farmers mentioned the shortage of cash income (38%), agricultural prices (36%), the lack of manufactured products (22%), low yields (18%), compulsory cultivation and taxes (16%) and difficulties in marketing (14%). These answers suggest that women are not exclusively oriented towards subsistence production. Although the results must be interpreted with care, they may seem indicative of a potential market orientation. While securing food for the family remains their primary objective, women farmers seem eager to earn a cash income and will go through great efforts to find a market for their products.

Farm household consumption

Throughout the region, cassava provides the mainstay of the diet. It is consumed daily as *luku* (porridge) providing an estimated 60-70 % of the total caloric intake. It is sometimes mixed with small quantities of maize or millet flour. Maize is otherwise only consumed on the cob. Various data from the household survey and case studies suggest that annual cassava consumption per head averages 180 kg of dried *cossettes*, or about 540 kg of fresh roots. An

Table 6.1 Estimated average annual farm household cash expenditures (1980-1981) (in Zaires, exchange rate US$ 1.00 = Z 2.92)

	Kalahari zone		Karroo zone	
	Zaires	% of total	Zaires	% of total
1. Agricultural inputs (seeds, tools, labour, feed)	8.50	1.6	69	7.6
2. Food: rice	1		13	
cooking oil	10		11	
salt	37.50		47	
sugar	3.50		25	
meat	30.50		54	
bread	3		12	
Miscellaneous (beans, vegetables, chillies, biscuits, beer)	94		151	
Total food	179.5	35.0	313	34.2
3. Clothing	96		220	
4. Domestic reproduction expenses (kerosine, soap, matches, etc.)	122		157	
5. Medical costs	31		49	
6. School fees	51.5		67	
7. Taxes	13		17	
8. Social obligations (gifts, festivities, debts, travel)	13		22	
Subtotal	326.5	63.4	532	58.2
TOTAL CASH EXPENDITURE Z	514.5		914	

Table 6.2 Estimated average annual farm household cash income (1980-1981) (in Zaires: US$ 1.00 = Z 2.92).

Source/sale of	Kalahari zone		Karroo zone	
	Zaires	% of total	Zaires	% of total
1. Food crops total	299.5	43%	618.5	65%
– cassava	265.5	37	457	48
– maize	13.5		15	
– groundnuts	10		76.5	
– prepared foods	1.5		61	
various (vegetables, fruits, millet, *voandzou*, squash)	9		9	
2. Livestock and fish ponds	3.5		55.5	
3. Wages/remittances	161		110.5	
4. Crafts	139.5		107	
5. Other (fishing, hunting, palm wine)	108.5		60	
TOTAL CASH INCOME Z	712		951.5	

average household of five people requires about 1,100 kg of cassava annually, including losses. Due to its low protein content, cassava consumption only satisfies about 20% of protein requirements; a substantial part provided by cassava leaves. The overall diet lacks variety and is deficient in protein. Hunting has lost its importance and fish is caught very infrequently. Most fish available in the Kwango-Kwilu has been traded from the Zaire river. The gathering of insects and wild plants is mainly a female task which takes place during the late dry season and early wet season. Caterpillars are a relished source of food and income.

Farm household budgets

Women and men have different obligations with respect to the farm household budget. Women are supposed to surrender the major part of their cash incomes to their husbands. In practice they may not do so, especially if their husbands are absent. In return, men buy additional food and provide for the education and clothing of the children. Tables 6.1 and 6.2 summarize average estimated cash expenditures and cash income of households in Kalahari and Karroo zones. Notwithstanding doubts about the value of the figures and the discrepancy between average income and expenditure, some indications of the household economy are obtained. Most significant is the relatively high percentage spent on food purchases in both zones (around 35%). No cash is spent on cassava, however. This is consistent with the fact that 97% of the farm households interviewed reported that they produced all the cassava required for subsistence. Overall average cash expenditures per head seem very low (Ƶ 100 and Ƶ 170 respectively), but cash expenditure appears about 80% higher in the Karroo zone.

The most noticeable difference in income between the two agro-ecological zones is the importance of the sale of agricultural products, in particular of cassava. In the Karroo zone, the income from the sale of food crops is double that of the Kalahari zone. In the Kalahari zone, other sources of income such as remittances from family members in town, are relatively important.

These figures seem to point to significant differences between the Karroo valleys and the Kalahari plateau. In the Karroo valleys, cash expenditures and income are considerably higher than on the plateau.[1] This may be explained by two mutually reinforcing factors: the production of a relatively high surplus and the presence of traders who sell manufactured goods. In both zones, however, farm household survival depends essentially on cassava as a subsistence and cash crop.

Table 6.3 Domestic work: division of labour by gender (in percentages, N = 187 farm households).

Tasks	MF[1]	Fm	Mf	mG
Pounding	9	4	21	6.5
Cooking	11.5	2	16	1.5
Cleaning	8	3	17.5	4.5
Laundry	9	2	13	3
Fetching water	9.5	3.5	19	7.5
Collecting firewood	9	1	16	1.5
Child minding	5.5	–	3	1
Mending clothes etc.	4	–	–	–
Processing of agric. produce for subsistence (making palm oil, drying cassava, etc.)	7	1	4	–

Note	Adult woman	Girl	Adult male	Boy
1 Code: main responsibility	M*	F	H	G
assistance from	m	f	h	g

* MM: polygamous wives.

Table 6.4 Estimated time spent on domestic work (in percentages, N = 187 farm households).

Task	Average time spent (minutes)	Frequency (% of households)		
		Daily	Weekly	Monthly
Pounding	45′	96	4	–
Cooking	45′	100	–	–
Cleaning	60′	94	6	–
Laundry	120′	10	89	1
Fetching water	60-120′	97	3	–
Collecting firewood	90′	14	85	1

Domestic and agricultural labour

It is considered a woman's task to provide food for her family. For this purpose she cultivates fields attributed to her by her husband's clan. Meanwhile, she retains obligations towards her own clan and rights to land (Ciparisse 1978). Women thus carry most of the responsibility for domestic work and agricultural production. Table 6.3 shows that even while women receive some assistance from young girls, they have to carry out most of the work alone, without help. Domestic work requires an average of 3.5 to 4 hours daily (table 6.4). Food preparation, in particular cassava processing, is the most time-consuming task. Tools and equipment for this work are rudimentary:

MMf	MM	M	F	G	Mh	H	A woman partially or entirely responsible
1	4	52.5	1	1	–	–	99
1	4	62	2	–	–	–	100
1	3	50	10	1	1	1	98
1	6.5	57	7.5	0.5	0.5	–	99.5
1	5	42	9.5	3	–	–	97
1	4	64	2.5	0.5	0.5	–	99.5
–	1.5	24	31	21	9	3	75
–	–	68	8	2	2	16	82
–	5	67	1	–	2	13	87

wooden mortars and pestles for pounding, brooms of palm fronds, gourds for storage.

The division of agricultural labour according to gender varies only slightly within the region. In the Kalahari agro-ecological zone all work including land preparation is done by women and girls, with occasional assistance of male children. In the Karroo zone, men clear the forest, but all other work is left to women, with the exception of upland rice production. Rice is mainly grown by non-traditional farmers in the Idiofa and Bulungu administrative zones.[2]

In table 6.5 quantitative estimates of the division of agricultural labour are provided, based on the interviews conducted during the farm household survey.

Decisions on cultural practices are predominantly made by women, certainly with respect to intercropping and crop varieties, weeding and plant densities. In the Karroo valleys, where men assist in clearing the forest, field sizes and, to a lesser extent also planting dates, are determined jointly by women and men, within the limitations of the compulsory cultivation regulations, of course.

Livestock and cropping systems

The livestock and the cropping systems are also components of the farming system. Farming systems may comprise several cropping and livestock systems, that can be linked in intricate ways. This is not the case in the Kwango-Kwilu, where livestock play a very minor role, and are mainly kept by non-traditional farmers. In the rare cases that small farmers possess a few heads of cattle, these are kept in joint herds, and serve a subsistence purpose. Small ruminants, especially sheep and goats, and fowl, are present at each

Table 6.5 The division of agricultural work by gender (in percentages, N = 187 farm households).

Agricultural tasks	MF[1]	Mf	mF	MMf
Forest clearing	–	–	1	–
and preparation	8.5	6.5	0.5	0.5
Planting	8.5	6.5	0.5	0.5
Weeding	8.5	6.5	0.5	0.5
Harvesting	9	9	–	0.5
Note	Adult woman	Girl	Adult male	Boy
1 Code: main responsibility	M*	F	H	G
assistance from	m	f	h	g

* MM: polygamous wives.

farm, but rarely receive any care (although children may be required to carry some water to the animals during the dry season). These backyard animals are usually owned by men (in 77% of the households). As no feed is grown for livestock and no manure is applied to the fields, there is hardly any interaction – whether competitive or complementary – between the livestock and cropping systems. Occasionally, in the dry season, goats may damage cassava fields. No differences between the Karroo and Kalahari agro-ecological zones have been observed with respect to livestock, although livestock may be more numerous in the Karroo zone.

Cropping systems will be discussed in detail in the next chapter.

Flows in the farming system

Flows in the farming system involve interactions between components as well as inputs into and outputs from the farming system. In final instance, all flows consist of materials, money, energy and information. Some aspects of flows in the farming system are highlighted briefly below.

The outputs of the cropping and livestock systems, crop and animal products, are inputs into the farm household system, that either consumes or sells them. By far the most important output are cassava roots and leaves. The proportion sold depends on farm household subsistence needs and on the marketing opportunities. In the Karroo valleys, more food is produced and also sold, than on the Kalahari plateau.

The farm household provides labour and management inputs into the cropping and livestock systems. Labour inputs vary with household composition. In the Kalahari zone, nearly all labour inputs are provided by

MM	F	M	Mh	G	H	Others	% of cases in which a woman is entirely or partially responsible
–	–	–	–	7	81	11	01.0
2	3.5	77	1	0.5	–	–	99.5
2	3.5	77	1	0.5	–	–	99.5
2	3.5	77	1	0.5	–	–	99.5
2.5	0.5	75	1	0.5	–	2	97.5

women, while in the Karroo valleys men assist women in land preparation.
Money is an input as well as an output of the farming system. Money is obtained through the sale of agricultural products, and through remittances from household members who have access to off-farm income. The latter source is more important in the Kalahari zone, while in the Karroo valleys the sale of food crops constitutes the main source of income. In general, however, money flows are very modest in volume. Very few opportunities exist for non-agricultural employment outside the village.

In the Kwango-Kwilu, externally purchased agricultural inputs are hardly used: planting materials and seeds are taken from the harvest (or occasionally bartered with neighbours); labour is provided by the farm household; tools are obtained occasionally from the village blacksmiths. According to the average farm household budget data, more money is spent on agricultural inputs in the Karroo zone than in the Kalahari.

Many items for household consumption are gathered or produced by the household, instead of purchased: insects for food, firewood, thatch and building materials, baskets and so on.

Information flows from the subsystems and between the farming system and its suprasystem. The farm household uses information from the cropping system to determine the fitness of the land for certain crops, the quality of seeds, to judge the appropriate planting time and so on. External information on prices and on general developments in the world outside the village is received irregularly from the local authorities and travellers.

Structure and function of farming systems in the Kwango-Kwilu

Farming system structure and function are determined respectively by the characteristics of the components and by the way inputs are processed into outputs. A case study from Lobo collectivity in the Kalahari zone may illustrate this.

The farm household consists of one woman farmer, her husband who is absent for most of the agricultural year and three dependent children, the eldest of whom, a girl, assists her mother. In the current year (1982) two new fields are cleared, one on the plateau and one on the slope. The crops grown in association are cassava, groundnuts, *voandzou* and squash on the slope, and cassava and *voandzou* in low densities on the plateau. Some maize is planted near the homestead for subsistence needs. A few goats and chickens are kept, but labour inputs into the livestock system are negligeable. *Voandzou* and groundnuts together yield about 0.4 tons, while squash production is disregarded because of the low quantities involved. Cassava production is estimated at 1.8 tons of dried *cossettes*, of which 0.55 tons are produced on the plateau field, 0.3 tons on the slope field, most of which will be harvested from nine months onwards throughout the subsequent year. Subsistence needs are mainly met through the production of two cassava fields established during the previous year, yielding an estimated 0.95 tons of dried *cossettes*. The household consumes an estimated 0.7 tons of *cossettes*, including processing and postharvest handling losses. Cassava leaf production amounts to approximately 300 kg (fresh weight) of which 150 kg are sold. Some 0.4 tons of *cossettes* are given away to relatives for various purposes, and the remainder, 0.7 tons, is sold. Estimated cash income from cassava roots and leaves totals 450 Zaires, while income from other crops is limited to about 70 Ƶ. Income from remittances from the husband, sale of insects during the dry season and other sources is estimated at less than 200 Ƶ; leading to a total cash income of a little over 700 Ƶ.
The general structure and function of farming systems in the Kwango-Kwilu can now be outlined. Throughout the region, farm households are small and relatively uniform. Women play a major role in food production and processing. Cropping systems based on cassava and shifting cultivation dominate, and livestock is unimportant. Although agricultural production is by definition a seasonal process, in the Kwango-Kwilu output fluctuations are somewhat stabilized by the harvesting of cassava throughout the year.
The main difference between farming systems in the Karroo and Kalahari agro-ecological zones is the degree of market integration. Farmers in the Karroo valleys produce a higher surplus, have a higher cash income and are able to spend more money. Off-farm income plays a relatively more important role on the Kalahari plateau. As a result of these differences, it seems justified to speak of *two types of farming systems*, the Kalahari farming system and the Karroo farming system. In this definition of types of farming systems broad agro-ecological characteristics are coupled with socio-economic variables. At this level of analysis, cropping system qualities, such as types of fields cultivated, are not taken into consideration.
The *Karroo farming system* is situated in the Karroo agro-ecological zone, and

characterized by a higher degree of market integration than the Kalahari farming system. Relatively low levels of food crop production and sale, as well as the increased importance of off-farm sources of income, are particular to the *Kalahari farming system*, located on the Kalahari table lands. The differences are of course relative rather than absolute.

Furthermore, three types of intermediate cases can be found. Firstly, a number of farming systems is situated in the zone intermediate between the Karroo and Kalahari agro-ecological zones. Depending on the presence of other factors, such as infrastructure, they may or may not display some degree of market integration. Secondly, a number of farming systems is found in the Karroo agro-ecological zone, but does not have adequate access to markets, which results in low levels of cash income and surplus production. In this respect, therefore, they are more similar to the Kalahari farming systems. This type of farming systems is mainly found in the Bagata zone. Conversely, there is also a third group of farming systems in the Kalahari zone, that benefits from a relatively favourable position with respect to markets and roads and produces a considerable surplus. This applies to farming systems in the Masi-Manimba zone and the western Bulungu zone.

Discussion

The discussion of the regional system in the preceding chapter raised the issue of the growth of food production in the Kwango-Kwilu. How is it possible that, notwithstanding serious constraints at regional and national levels, such as price disincentives, male migration, government control and inadequate marketing structures, food production in the Kwango-Kwilu has increased considerably since the 1950s ?

As no detailed data on farms and farm households in the pre-Independence period are found, it is impossible to trace any longer term changes in the farming system structure. Nevertheless, the analysis in this chapter suggests that the main reason for the continued production growth is the remarkable *flexibility* of present farming systems in the face of marketing opportunities. This flexibility has three elements. Firstly, cassava serves as a cash as well as a food crop. The implication is that subsistence consumption can be made to fit cash requirements and marketing opportunities. Whenever the opportunity presents itself, cassava production can be expanded rapidly, or additional cassava which would otherwise be left in the ground can be harvested. Because of its flexibility in planting and harvesting times, low field clearing requirements and the continuous presence of planting material, cassava fits the regional system constraints very well.

Secondly, land does not yet seem a major constraint in most areas. Only a small proportion of the total land area is presently cultivated. As shall be discussed in detail, shifting cultivation allows a certain degree of flexibility through the shortening of fallows. If need arises, new fields can be cultivated. It will be argued, however, that the flexibility through the expansion of cultivation to new lands causes many problems at other system levels. Thusfar, however, an increase in area has not led to apparent inequalities in land distribution.

Thirdly, the Kwango-Kwilu may be considered an area of '*female farming*' (Boserup 1970), where agricultural field work is done almost exclusively by women. As a result, male migration hardly affects labour inputs into agriculture. On the contrary, remittances from male household members are an important contribution to the household budget. On the Kalahari plateau, male labour is not even required for land clearing, so additional areas can be cultivated whenever necessary. Female farming systems are conditioned by fluctuations in women's labour inputs because of their multiple household tasks and pregnancies. Cassava, a crop that allows shifts in cultural practices without severe yield reduction, enables women to cope with the double burden of household and agricultural work.

Even if the flexibility of farming systems in the Kwango-Kwilu made a growth in food production possible, this does not necessarily explain why farmers did actually produce a surplus. It would seem that the growth of food production must also be explained by the worsening terms of trade between agricultural products and consumer goods, coupled with political pressures such as increased taxation. As a result, farmers have been forced to produce an ever growing surplus. This was possible because of a reliance on female labour and cassava and because no fundamental changes in the structure and function of the farming system were necessary.

At the same time, however, this intrinsic flexibility of the farming system has its limitations. The same components that allow for great flexibility are also sources of endogenous limitations on farming system performance. This becomes apparent, when the future of agriculture in the Kwango-Kwilu is considered. Low male labour inputs in agriculture prohibit any labour-demanding intensification. Heavy dependence on cassava has its own risks, as shall be demonstrated, and cassava processing may increasingly become a bottleneck. The lack of cash income prohibits the use of external inputs. The shortening of fallows in order to accomodate the need to increase the area under annual cultivation, can have disastrous effects on soil fertility. Since fallows are not managed by the farming system, but by higher level units such as the village, the restoration of soil fertility through fallowing is not controlled by the farming household. As a result, there is no incentive at farming system level to preserve the land.

The following chapter will examine the cropping systems of the Kwango-Kwilu, and in particular their evolution over the last forty years, with a view to gaining a further understanding of how a substantial growth in food production was actually realized and with what effects.

Notes

1 At hypothetical prices (cf. table 5.8) the equivalent annual quantities sold by the average farm household would be 530 and 1,072 kg respectively. Assuming an average farm household size of five people this would add to a total marketed volume of 237,000 tons of cassava in the Kwilu alone, much lower than the figure of 985,000 tons calculated from the official statistics. It is impossible to justify this vast discrepancy, other than through serious doubts about the official regional production and population estimates. Regional sources have some grounds for inflating production and population figures, because of the way regional budget allocations are made from the capital. Furthermore, it seems reasonable to suppose that farmers have not reported the total volume of cassava sold, because the women may have wanted to keep some of the undeclared revenue to themselves, and because they feared taxation. Finally, some of the cassava may not have been sold for cash but may have been bartered.

2 This sexual division of labour is consistent with observations by Boserup (1970). Although ploughing of permanent fields is thusfar unknown in the Kwango-Kwilu, men are becoming more actively involved in the more densely populated areas of Idiofa and Bulungu zones, where rice is grown on semi-permanent valley bottom fields. Although the total number of active males is possibly declining (Reid 1981), the remaining men are perhaps more actively involved in agriculture.

7 CROPPING SYSTEMS BASED ON SHIFTING CULTIVATION

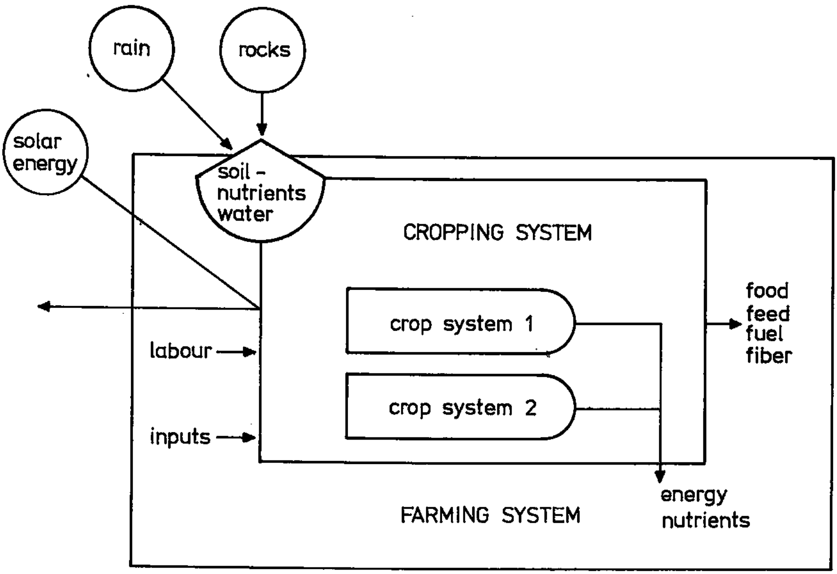
Definition and boundaries

This chapter discusses cropping systems in the Kwango-Kwilu. A cropping system is defined as a land-use unit comprising soils, crop, weed, pathogen and insect subsystems that transforms solar energy, water, nutrients, labour and other agricultural inputs into food, feed, fuel and fiber. The cropping system is a subsystem of the farming system as well as the suprasystem of various biological and physical systems that form its components. The main components of the cropping system are: soils, crops, fallows, weeds, pests and diseases. The most important inputs are labour and management; one of the features distinguishing cropping systems from natural ecosystems. Figure 7.0 presents a simplified model of the cropping system.

The unit of observation corresponding to the cropping system is the field. The boundaries of the cropping system coincide with those of the field on which the crops are grown. When on two separate plots of a single farm the same crops are grown on a similar soil type with the same type of management, resulting in similar weed, pest and disease incidence, these plots may be considered as belonging to the same cropping system.

With the exception of river and homestead gardens, all cropping systems in the Kwango-Kwilu are originally derived from shifting cultivation systems. Shifting cultivation stands for an extensive type of cropping system, with many variations (e.g. Miracle 1967). In the Kwango-Kwilu, the majority of the cropping systems based on shifting cultivation belongs to one subtype, referred to by Miracle as 'classic long fallow' (see below). Within this subtype, however, systematic differences between fields can be observed. These differences are reflected in the term *field type*, which refers to a form of cropping system within a subtype. The field type is defined as the location-specific combination of cropping system components in a given agro-ecological and socio-economic environment. The field type is therefore much more narrowly defined than a shifting cultivation system, or even a subtype of

Figure 7.0 The cropping system with two crop systems (energy symbols after ODUM 1983 – see annex).



it; such as the classic long fallow system, which still covers a broad range of crops, soils and management methods. The field types described here are specific to the Kwango-Kwilu, classic long fallow systems occur throughout the Congo Basin, and shifting cultivation can be found worldwide.[1]
This chapter is particularly concerned with the analysis of changes in shifting cultivation systems, although reference will also be made to other types of cropping systems which are not based on shifting cultivation. While reports on agriculture in the Kwango-Kwilu during the 1940s and 1950s exist, it is not possible to address the traditional pre-1960 systems in the same systematic manner as present cropping systems.

Shifting cultivation in the Kwango-Kwilu before 1960

The traditional agriculture in the Kwango-Kwilu has been described by various scientists working with INEAC, mainly Adriaens (1951), Drachoussoff (1954), Devred & Hardy (1957), and Rassel (1958, 1960), as well as by a few others such as Nicolai (1963) and Renier (1955, 1957). Unfortunately, their descriptions of crops and cultural practices during the 1940s and 1950s are sometimes contradictory. On the basis of their work, Miracle, in his detailed review of agriculture in the Congo Basin (1967), classifies the Kwango-Kwilu as a 'classic long fallow system'. In this type of shifting cultivation, little or no effort is made to maintain or renew soil fertility in the main fields apart from fallowing. Within the class of classic long fallow systems, Miracle considers the Kwango-Kwilu a unique case, *'burn, hoe and cut, plant'*, because of the unusual reversal of the burning and hoeing operations.

In the pre-Independence period, cassava and millet were the major starchy staples in the region; minor crops being yams, taro, sweet potato, many different vegetables and condiments. There is no record of rice as a small farmer crop in the Kwango-Kwilu before 1960. Maize and Congo jute, the only cash crops, were limited to certain areas only, mainly the central valleys. Table 7.1 lists the most important crops in the Kwango-Kwilu during the 1940s and 1950s.

The pre-Independence literature refers to two types of fields: savanna fields and forest fields, and suggests that savanna fields are only encountered in the southern Kwango-Kwilu, at least not in the central part of the region. There are hardly any records from the pre-1976 period on field sizes. Reports from the colonial administration give figures on the total area under compulsory cultivation, but none on average area per field or farm.

In the savanna, cassava-millet was the dominant sequence, sometimes intercropped with *voandzou*.[2] Sorghum had originally figured in the sequence during the 1930s, but was already replaced by millet by the 1950s (Renier 1955, Rassel 1958). Normally, cassava was planted first, immediately after clearing, closely followed by *voandzou*. After the harvest of cassava (from 18 to 24 months after planting), millet was broadcast, i.e. in the second rainy season (February-March). Jurion & Henry (1967:41) deplore the fact that soil preparation and sowing were usually delayed until after the first rains. Weeding was carried out only once and the soil was hoed before the sowing of the millet. The millet harvest was followed by 'a long fallow' which is not defined. Renier (1955, 1957) provides detailed information on fallow vegetation, but does not specify fallow length. From his observations, it would seem that savanna fallows dominated on the Kalahari plateau, with the exception of areas that were frequently burnt. The effects of fires on fallow vegetation and therefore on soil fertility restoration on the plateau was a source of concern to colonial agronomists (Jurion & Henry 1967:41).

In the forest, the main association was cassava + maize + groundnuts + gourds, usually followed by a second crop of cassava. Groundnuts were also grown in monocropping, in small patches. Rassel (1958) suggests that after maize + Congo jute + *voandzou*, fields were fallowed for two to four years.[3] Maize and Congo jute were also grown without groundnuts, in which case the field was cultivated *'until it was abandoned'*. No further details are given on fallow length in the forest, but accounts by farmers suggest that forest fallows exceeding 15 years were common.

The literature is confusing with respect to the construction of mounds or

Table 7.1 Crops in the long fallow shifting cultivation systems in the Kwilu during 1940s and 1950s (sources: ADRIAENS (1951), DEVRED AND HARDY (1957), NICOLAI (1963), MIRACLE (1967).

	Savanna/Plateau (Kalahari)	Forest/Valleys (Karroo)
Staple crops	cassava, *P. typhoides*	cassava, maize
Cash crops	groundnut	Maize, *U. lobata*, oil palm
Minor crops[1]	*voandzou*, sweet potato, over 21 kinds of vegetables	yam, taro, sweet potato, vegetables
Main association	cassava-millet-*voandzou*	maize-groundnuts-cassava

Note
1 Surprisingly, gourds or squashes are not mentioned here.

ridges and manuring. While Miracle himself emphasizes the fact that fallowing was the main way to restore soil fertility, he also suggests that in the savanna all crops were grown on mounds or ridges in which manure was incorporated. After burning the new fields during the dry season, the remaining refuse was dug into large heaps of a height of about 0.35 m (Miracle 1967:75). Hilton (1985) mentions that in land-scarce areas of the Kingdom of Kongo, which extended into the western Kwango, mounds were manured as early as the sixteenth century. There are also several references to the Pende tribe (in the south-east), who practiced a version of a compost-dependent system, whereby vegetation, sometimes after burning, was buried on savanna fields (Miracle 1967:137). Furthermore, Nicolai (1963:239) speaks about the use of a goat manure and water mixture on groundnuts on the Kalahari plateau, but this seems to have been exceptional. Interviews with farmers suggest that mounds and ridges with incorporated plant debris were common practice in the savanna, but were rarely if ever found in the forest.

It may be concluded tentatively that two types of cropping systems existed before 1960, a savanna system and a forest system, each with its specific combination of crops and cultural practices. Besides cropping systems based on shifting cultivation, there is little reference in the literature to gardens. Only Rassel (1960) speaks of *voandzou* gardens. On the basis of interviews conducted with farmers today, it seems likely that homestead gardens, although small, were tended by every household.

Current cropping systems based on shifting cultivation

At present, the same two basic types of cropping systems based on shifting cultivation, the *savanna system* and the *forest system*, are found in the Kwango-Kwilu. These parallel the two agro-ecological zones, the Kalahari plateaus and the Karroo valleys. All farmers distinguish between *nseke* and *mfinda*, terms which are usually translated with savanna and forest respectively, but which indicate a combination of soil and vegetation. *Mfinda*, for example, refers to the Karroo valleys, even if the original forest vegetation has been replaced by low bushes. Two basic field types, *savanna and forest fields*, correspond to the savanna and forest cropping systems respectively. These can be further subdivided according to toposequence, hill to valley sequences of soil types determined by topography (Ahn 1974:128). The characteristics of components of savanna and forest cropping systems will be discussed below.

Field types

Savanna field types

In the savanna cropping system, on the Kalahari plateau, the main field type is the *nseke* (savanna) field with three toposequential variations: on top of the plateau, along the slope, and at the bottom of the slope or in the valley. These will be referred to as Sp, Ss and Sv respectively. Not all farmers have access to slopes and valleys. Slope (Ss) and valley (Sv) fields are preferred for their higher soil fertility, although ridging, a usual practice on savanna fields, is considered a burden on slopes.
Although no cadastral data can be obtained, circumstantial evidence suggests that, in the savanna, more fields are opened on top of the plateau (Sp) than before. This evidence is threefold. Farmers' statements point to an increase in Sp fields that are situated at a considerable distance from the homestead leading to long travelling times to these fields. Sources on agriculture during the colonial period do not mention fields on top of the plateau at all. While these may have escaped the attention of the observers, their number cannot have been very great. Furthermore, the extension agents involved in the compulsory cultivation regulations show a clear preference for plateau fields, because they are easier to measure and supervise than valley or slope fields.

Forest field types

In the Karroo zone, in the forest cropping system, the main field is the *mfinda* (forest) field, located in the forest or in previously forested valleys, again with toposequence variations: slope and valley bottom (Fs and Fv). Outside the valleys, on the plateau, fields are also cultivated. These fields are classified as savanna fields on the plateau (Sp). The Sp fields are usually located at a considerable distance from the homestead and serve to secure a small supply of cassava and other crops when need arises.

The colonial literature makes no mention whatsoever of savanna fields in the central Kwango-Kwilu. Sp fields are clearly a recent phenomenon in this area. On plateaus adjacent to the Karroo valleys, Sp fields are commonly found, and farmers report that they have started cultivating these fields, *'because* mfinda *fields do not yield enough now'*.[4]

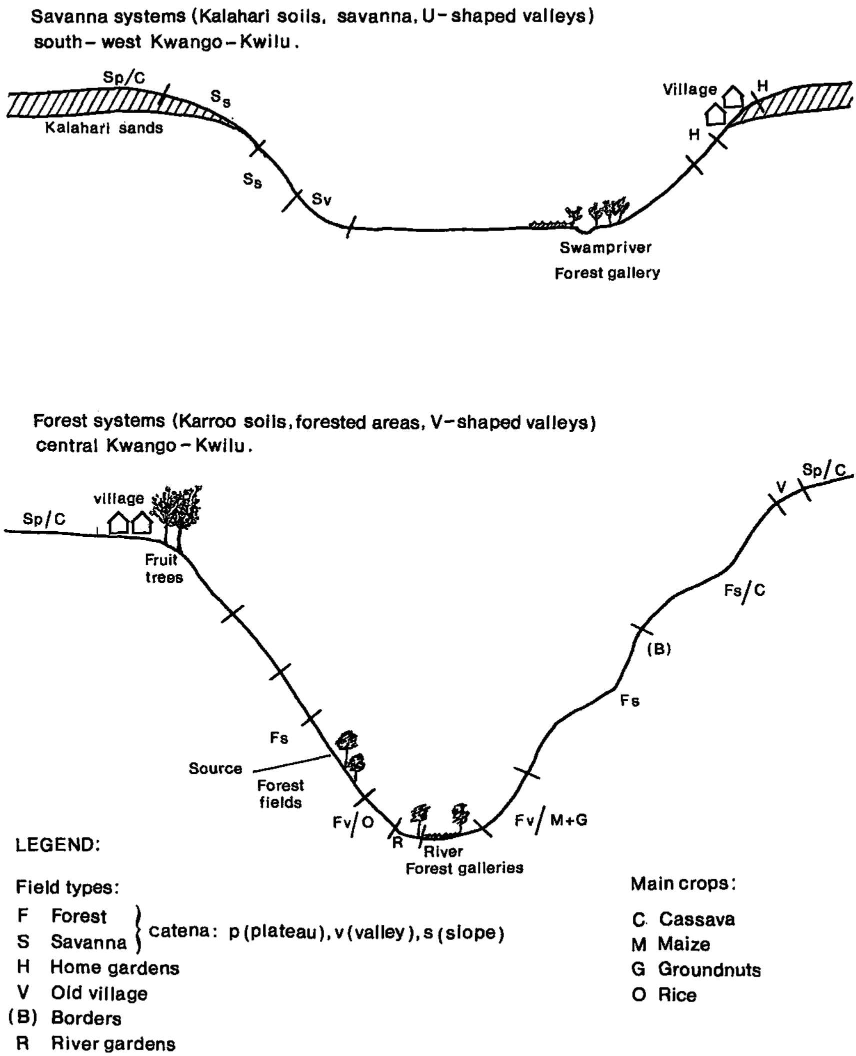
Other field types

Field borders of savanna and forest fields are often treated as separate entities and cultivated in a different manner from the remainder of the field. Field borders comprise a wide range of useful wild plants that are not cultivated but just protected (e.g. *Talinum triangulare*). In some cases fertility in field borders is enhanced through the use of compost or ashes to accomodate crops like onions. Besides field borders, farmers also distinguish small ecological niches on fields that may be occupied by specific plant mixtures, e.g. ginger, eggplant and Congo jute. Patches and borders together can be considered a separate field type (B).The location of different field types, including river gardens, home gardens and old village sites, which will be discussed below, is presented schematically in figure 7.1.

Field sizes and number of fields

The estimation of field sizes is fraught with difficulties. Recent official data refer only to total area under cultivation and consider each crop separately without mentioning intercropping. Consequently, even dividing these data by the number of farmers does not yield any meaningful results. The results of the agricultural census (table 5.3) suggest that well over 80% of the farms is smaller than two ha. The policy on compulsory cultivation has interfered with field size and location from 1976 onwards. It is unclear, however, to what degree farmers really comply to formal requirements and whether they cultivate fields outside those officially controlled by the extension service. The subject is very sensitive and interviews have not revealed any definite trends on field sizes. With one exception: women consistently complain that their fields are larger than those of their (grand)mothers. This is confirmed by the figures on area requirements during the colonial period and the present cumpulsory cultivation regulations (see chapter 5).
Visual estimates during the farm household and the field surveys resulted in a mean of 0.55 ha for savanna fields (Kalahari zone), ranging from 0.2 to 0.9 ha. Forest fields are generally smaller than savanna fields, averaging 0.4 ha (range 0.1 to 0.6 ha). Plateau (Sp) fields are generally larger than slope and valley fields. Important factors influencing field size are: the degree of control of the

Figure 7.1 The location of field types in savanna and forest systems.



extension staff, the age and physical fitness of the farmer and household composition, i.e. the extent to which she may expect help from female children.

Women cultivate at least two fields of the dominant type (S or F), one from the preceding year which only yields cassava, and one of the current year on which the entire range of crops is grown. This leads to an estimated average area annually cultivated by a typical household of 0.9 ha in the forest cropping system (Karroo valleys), and 1.1 ha in the savanna cropping system (Kalahari plateau). This excludes fields from previous years that still yield cassava.

Soils: fallows, clearing and soil preparation

The factors affecting the soil component are fallowing, clearing and land preparation. No details are available on the chemical properties of any fields. The results of the only soil samples taken in the Kwango-Kwilu in recent years have been reported in chapter 5 (PNE/FAO 1981). Only qualitative observations on fallowing, clearing and land preparation are therefore discussed in this section.

Fallows

In the Kwango-Kwilu, three types of fallow are found today: bush, savanna and grass fallow, according to the type of vegetation (FAO 1974). The exact length of the fallow is difficult to determine empirically, unless one witnesses the entire fallow period (cf. Nye & Greenland 1960). Because the boundaries of new plots do not necessarily coincide with the old, clearing patterns are irregular and crop and fallow periods seem to merge, which is reinforced by the presence of cassava as a last crop in the cycle. Although it appears that fallow periods increase with distance from the homestead, there is no fixed pattern to this in the Kwango-Kwilu, in contrast to what has been observed by Pelissier (1966) in Senegal. Fallow lengths can vary considerably even among fields within the same type of shifting cultivation system.

On the Kalahari plateau, the savanna fallow is increasingly replaced by grass fallows dominating vast stretches of the southern table lands. Savanna and grass fallows average three to four years.

Bush fallow is still frequently found in the Karroo valleys, but no true forest fallow with a closed canopy has been observed, with the exception perhaps of a few isolated valleys in the north of the region. Bush fallows vary in length. They average an estimated seven years but range from a maximum of 15 years in the less densely populated valleys of the central Kwilu to only one or two years around Kikwit. In the latter case, the fallow vegetation is dominated by tall grasses, mainly *Hyperrhenia spp*, and some bushes. If the fallow period is reduced to less than three years, old cassava plants are still standing in the field when it is cleared again.

With respect to the savanna as well as the forest cropping system, circumstantial evidence suggests that fallow lengths are declining in comparison to the pre-1960 period. This circumstantial evidence is based on three factors. Firstly, the increasing population densities, reported in chapter 5, suggest strongly that in the more densely populated collectivities, inframarginal land scarcities are emerging. This trend may be reinforced by the compulsory cultivation regulations which through increasing field sizes and restricting locations lead to a limitation of the area available for cropping. Secondly, soil is too hard, resulting in delayed sowing. On savanna fields, low ridges or mounds are usually constructed, but this is not always the case. Ashes or debris from grasses are covered with soil. The preference for ridges or mounds does not seem to follow a fixed pattern. Mounds vary in size or shape, but are not higher than 0.25 m. The ridges are approximately 0.60 m wide, 0.20 m high and they are 1.0-1.5 m apart. Nearly without exception, ridges follow the slopes and do not survive for more than two rainy seasons. By that time, however, cassava is well established and ridges are not considered necessary by farmers. On plateau fields (Sp), ridging and weeding seem minimal.

The traditional practice of making ridges following the slopes seems to encourage erosion. Nevertheless, cursory observation suggests that ridges along the slopes, even if enhancing run-off, allow a large volume of water to penetrate the soil. In contrast to ridges following the contours, they do not rupture in case of heavy rainfall, which could otherwise lead to the loss of plants.

It is uncertain if ridges and mounds occur less frequently today in the savanna than before 1960, because pre-Independence sources are unclear on this particular point. Nevertheless, there are indications that ridging or mounding are not as common as before, and where they are still practiced, little or no plant debris is incorporated. There seem to be two reasons for the omission of plant debris. Firstly, the repeated burning of fields during the dry season reduces the amount of vegetation available for incorporation at the beginning of the rains. Secondly, women mention their heavy work loads as a reason for not making the traditional ridges or mounds with incorporated plant debris. Instead, they still make ridges or mounds, but in a hasty manner. It is also observed by older farmers that ridges and mounds '*do not last as long*' as in the past.

Crops: associations and sequences

On each field type, crop associations and sequences are dominated by cassava, although F fields generally display more complex spatial arrangements of crops than S fields. On all fields, one finds a combination of intercropping and sequential cropping, sometimes also with relay intercropping, if a new crop is planted after one of the intercrops has flowered. Cassava remains on the field and is intercropped with a sequence of other crops, which are specific for that particular field type. On ridges, some form of row intercropping occurs, with cassava on top of the ridges, and *voandzou* and a few plants of squash to the sides. On flat fields mixed intercropping is the rule, although there usually is some regularity in the pattern.

In the savanna cropping system the main association is cassava + *voandzou*,

Table 7.3 Intercropping[1] in the Kwango-Kwilu.

Mixed intercropping arrangements (and variations)	Density range: plants per hectare (x 1000)	Preferred field type (F = forest S = savanna)	Spatial arrangements
1. Cassava+maize (+ *voandzou*)	cassava 3-18 maize 3-5 *voandzou* 50-100	F sometimes S_v	maize in more fertile patches, cassava and *voandzou* seemingly at random
2. Cassava+groundnut (+ maize) (+ *voandzou*)	cassava 3-6 groundnut 100-150 *voandzou* 50-100	F and S	groundnuts sometimes in 'rows', *voandzou* mixed with maize in patches
3. Cassava + millet (+ squash)[2]	cassava 5-10 millet 10-15 squash 1-2 sesame 1-2	S	cassava sometimes on ridges, millet broadcast or in small holes several meters apart; squash on cassava ridges, sesame broadcast in patches.

Notes

1 Not including crops on field borders; only referring tot F and S fields during the first year of cultivation.

2 Sometimes sequential, i.e. planted at various moments during the cassava cycle.

followed by millet + squash planted in February, after the harvest of the *voandzou*. Sometimes millet is planted at the same time as cassava. In both cases, cassava remains in the field after the harvest of the intercrops. *Voandzou* is placed at the higher steps of the catena (Sp), while other crops may be inserted in patches at the lower steps (Sv).

In the forest, cassava + maize + groundnuts dominate the cropping cycle, with patches of *voandzou*, *Hibiscus spp*, yams and sweet potato along the borders. After the groundnut harvest in December, squash is sown, sometimes in intercropping with a few new cassava plants, while some of the maize is left to dry in the field. Cassava is frequently observed as a first crop on F fields.

Table 7.3 gives details on the three most important intercropping patterns, cassava + maize, cassava + groundnut and cassava + millet, plus minor crops. These three associations account for an estimated 80% of all intercropping in the Kwango-Kwilu. Observations on intercropping are complicated by staggered harvesting and planting of most crops. Furthermore, unplanned arrangements occur through the spilling of seeds, seeds from unharvested crops of a previous season or because of the eating of wild fruits in the fields. Crop associations in the Kwango-Kwilu are characterized by very low numbers of the minor crops in the association. For example, squashes, vegetables, but also sometimes *voandzou* and maize, may be found in densities of around 100 plants/ha. The total number of crop associations, if defined simply as the absence or presence of a crop in a certain combination, probably exceeds forty. Oil palm has not been included in the table, although it is found on all F (forest) fields and may be considered an element in intercropping (Ferwerda 1984). Intercropping patterns frequently involve also a varietal mixture of the main crops, cassava, groundnuts and, sometimes, maize.

The spatial arrangement of crops varies according to the location of the field. On slope fields (Fs and Ss) it is common to find small patches of different crops, not just along the borders but unevenly spread throughout the field. Farmers say that this helps to control erosion. They seem to plant more demanding crops such as yam in ecological niches where ashes have accumulated during burning.

Crop sequences are presented schematically in table 7.4. It may be noted that all sequences end with cassava as the last crop in pure stand. There is also no clear distinction between crop sequences for the two field types, apart from the first crops in the sequence, and the fact that millet does not occur on forest fields. A comparison with tables 7.1 and 7.3 shows that taro and yam are less important today. Congo jute has completely disappeared (i.e. it is only tended as a wild crop and harvested occasionally for subsistence needs). While cassava featured predominantly in past crop associations and sequences, it is now nearly universally grown as a first crop immediately after opening the field, in the forest and the savanna. Farmers appear well aware of this change and motivate it by saying: *'Without cassava there is nothing, no food, no money.'*

Rice constitutes a recent introduction in the Karroo zone, where it is found on Fv (valley) fields and in river gardens. It is the only crop which is grown in pure stands. If rice is grown in river gardens, it tends to be grown for several consecutive seasons. More commonly, however, men, usually *fermiers* (non-traditional farmers), grow upland rice as a cash crop during the first rainy season on Fv fields. Following the rice harvest, the field is turned over to women who usually continue with a cassava + squash association and treat it like a forest field. The implication is, however, that women lose one season out of their traditional cropping calendar and have to find alternative ways to provide a groundnut + maize + cassava crop. They may do so by:

a continuing cultivation of a Fs or Fv field for an additional season;

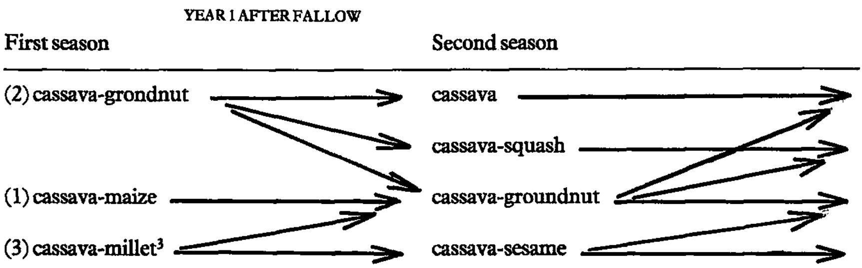
b opening up an additional F field;

c foregoing the maize crop and growing a cassava + groundnut association on a Sp field.

The first two solutions ultimately lead to a further decline in fallow length. The third solution is often preferred, because it entails a relatively low labour input and no assistance from men.

Details of individual crops will be discussed in chapter 8.

Table 7.4 Main crop sequences in the Kwilu[1].



Notes

1 The numbers correspond to the associations mentioned in table 7.3 and refer only to F and S fields.

Table 7.5 The agricultural calendar of the Kwango-Kwilu.

	May	June	July	August	Sept.
Rainfall[1]	100	(50)	(50)	50	150
Clearing		forest	savanna		
Burning		savanna	forest	(sav)[4]	
Cassava[2]			prep. cutting	plant	plant
Maize[3]	sel. seed				plant
Groundnuts	sel. seed			plant	(plant)
Upland rice					plant
Voandzou				plant	
Roots/tubers[5]					
Squash	harvest				plant
Sesame	harvest				
Millet		harvest			

Notes

1 Rainfall figures: rounded averages to the nearest 50 mm (INEAC/INERA). Rainfall for June and July combined is about 50 mm.

2 Cassava harvesting not indicated because it is not tied to a particular month.

3 Maize is rarely planted in the second season (Febr.-May).

4 Entrances placed in brackets indicate options of individual farmers rather than general trends.

5 Roots/tubers other than cassava: yam, taro, sweet potato, irish potato.

Labour and management

The agricultural calendar

The agricultural year starts at the beginning of the dry season (late May) when new fields are selected for cultivation. Land preparation takes place from June through early August. Planting depends on the onset of the rains, starting usually during the second half of August and extending well into September and sometimes even early October. Farmers in forest areas may

YEAR 2 AFTER FALLOW First season	Second season	FALLOW
cassava[2] ——————————	——————	
cassava[2]-squash ——————————	——————	fallow[4] with cassava
cassava[2]-millet ——————————	——————	
cassava[2] ——————————	——————	

2 Cassava remains on the field while intercropped with other crops and is also harvested occasionally throughout the fallow.
3 Renier (1957) suggests that millet is sometimes planted before cassava as a first crop after fallow.
4 Whether cassava will still be harvested after the second year depends on the cultivar, the cash and food needs of the household and the distance to the field.

Oct.	November	December	January	February	March	April
200	200	150	150 for-sav.	150	150	100
				savanna		
weed		weed		plant	weed	
weed		harvest	harvest	harvest		
weed	1st harvest	harvest	plant	weed		harvest
weed	(2nd weed)	harvest				
		harvest				
plant			1st harvest	harvest		
			harvest	plant		
plant	weed		harvest	plant	weed	
				plant	weed	

begin dry seeding of groundnuts as early as late July or the first week of August. Although risky, this practice enables women to harvest a groundnut crop in November at the height of 'the hungry season'. Cassava planting is not limited to a fixed period of the year. This practice, staggered planting, implies that plants that have been planted earlier can be weeded at the same time as new cuttings are planted. In any case, weeding is done haphazardly, usually no more than once after planting has been completed. Cassava may occasionally be weeded a second time at the harvest of the intercrops.

While agricultural activity is intense from September through January, work during the second season is less clearly structured. On fields where cassava remains, very little maintenance is required and the planting of a new intercrop requires only a cursory hoeing. If new fields are cleared in January-February, the turn-around time between the December harvest and the start of the second season is likely to cause delays in planting.

Table 7.5 presents an overview of cropping activities during the agricultural year in the Kwango-Kwilu.

Table 7.6 Estimated number of working days on forest and savanna fields during the 1980-81 agricultural season (in 5-hours working days).

Tasks	Per hectare		Division of labour[1]
	(forest)	(savanna)	
Burning & clearing			
– secondary forest	100	–	M
– soil preparation savanna	–	70	F
– planting	40	60	F
– weeding[2]	30	30	F
– harvesting & carrying produce[3]	60	50	F
	230	210	

Notes
1 M = male, F = female.
2 Very dependent on weed population; only one weeding included.
3 Harvesting: including cassava harvesting which occurs throughout the year, but excluding crop processing, and excluding rice harvesting.

Table 7.7 Comparing INEAC labour input-values with field observations for the three major crops (INEAC source: various studies reported in the *Normes de Main d'Oeuvre 1958*).

Tasks	Working days/hectare[1]	
	INEAC (men)	Djimba field observations (women)
Planting groundnuts	50	16
Planting maize	10	5
Prepare cuttings and planting cassava	17	12
Single weeding (all crops)	10	16
Harvesting groundnuts	30	10
Harvesting maize (without husking)	10	5
Harvesting cassava roots	25	15
	152	79

Note
1 Working days INEAC: eight hours, field observations: five hours.

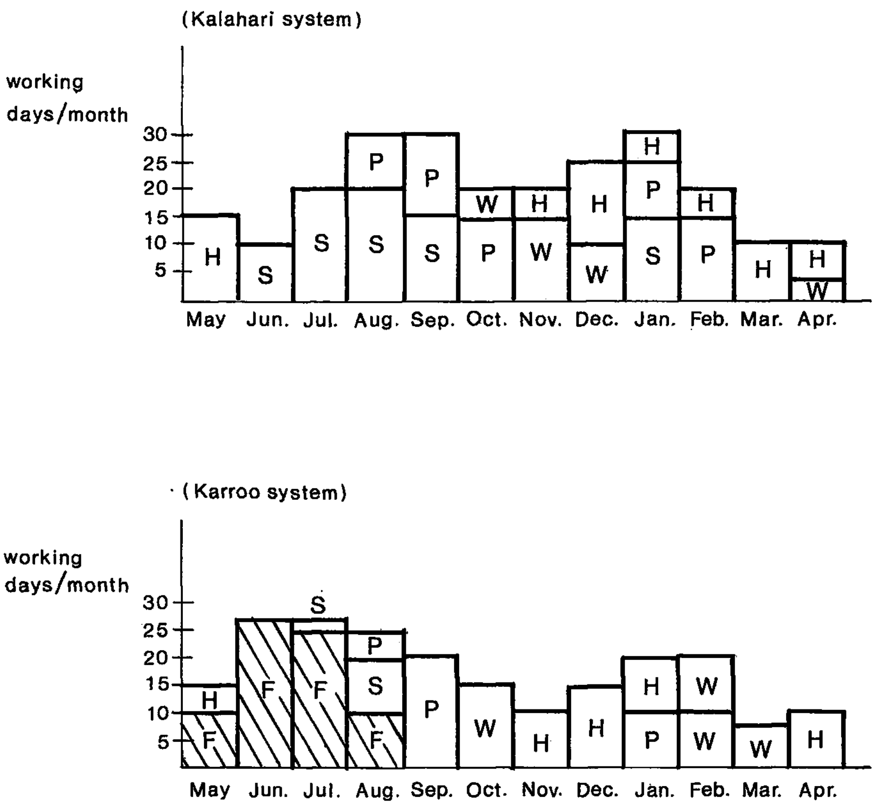
Labour inputs

Exact data on labour inputs in traditional agriculture are notoriously difficult to obtain. The following trends have been distilled from the farm household survey, the field survey and interviews.

Outside peak periods, women work an average of five days or even less each week (Sunday and one other day are usually kept free from agricultural work). Of the remaining 22 days each month, only 15 to 20 days seem to be actually used for agriculture, because social obligations or illnesses in the family keep women from going to the fields. However, in the peak months of September and December/January, agricultural work takes up more than 25 days monthly. Women work an average of about five hours in the field each day, although they may spent up to seven hours if necessary. The time needed to walk to and from the fields (thirty to sixty minutes each way) brings the total working day to about eight hours, since there is some overlap between domestic and agricultural work (e.g. women collect firewood and water on the return trip from the fields). On F (forest) fields, male labour for clearing and burning is limited to about three months each year. It is unusual for men to assist their wives in agriculture at any other time during the year. Young girls are supposed to assist their mothers, but they are not strictly supervised and their labour inputs vary considerably. Table 7.6 shows estimated labour inputs according to field type and gender, but does not differentiate between crops since crop-specific activities on intercropped fields cannot be distinguished. There is some need to complement these figures by crop-specific observations. During the field survey in 1982, women were observed at repeated intervals in order to estimate labour inputs for the major crops. In table 7.7 these are compared with average figures from various INEAC studies. The latter seem to refer exclusively to male agricultural labourers, so not too much value can be attached to the comparison. Nevertheless, it is interesting to note that, with the exception of weeding, all observations from the field survey yield lower data than the INEAC figures. On the one hand, this may be explained by the lower planting densities for single crops in farmers' fields in comparison to the sole stands on INEAC fields. On the other hand, the differences could also be attributed to the difference in the quality of the work. It could be hypothesized that the quality of agricultural work leaves more desired today than it did in the past. This is confirmed by comments from older-generation farmers, and younger farmers' complaints about lack of time. During interviews, several older women observed: '*Young girls are lazy and do not know how to cultivate properly anymore*'. The fact that higher labour inputs in weeding were observed is noteworthy, in view of farmers' statements on the need to weed more than in the past. There is some reason to think that the higher labour inputs into weeding could be interpreted as an indication of increased weed incidence resulting from shortening fallows.

Figure 7.2 illustrates the monthly distribution of labour. Total estimated labour inputs per hectare appear lower on S fields, because the clearing of savanna is less time-consuming than of the forest. However, total labour inputs per household seem higher in the Kalahari system than in the Karroo system as a result of the slightly larger fields. Farming in the savanna is further characterized by higher female work loads and more pronounced seasonal bottlenecks.

Figure 7.2 Estimated monthly distribution of labour in agriculture, by farming system (in 5-hours days).



F = forest clearing
S = soil preparation savanna
P = planting
W = weeding
H = harvesting & carrying produce (reourrent cassava harvesting not shown)

male labour only

female and child labour

Tools

The tools used by agriculturalists in the Kwango-Kwilu are simple: hoes of varying sizes and shapes (smaller ones for weeding), bush knives – both manufactured by village blacksmiths – and occasionally axes in the forest areas. Nicolai (1963) has provided a detailed description of various hoe shapes, most of which can still be found today.

The management of fields

Farmer management varies, among other things, according to field type. In the Karroo valleys, forest fields are rather carefully tended, in contrast to savanna fields on the plateau (Sp) that are visited only occasionally when need arises to harvest cassava or squash. In the Kalahari zone, Sp fields are also accorded a lower priority than the slope and valley fields (Ss and Sv), but there seems to be no marked difference between the latter two. In general, observations by the author suggest that Sp fields are managed in a more extensive way than other fields. This results in lower labour inputs in weeding, delays in planting, absence or poor quality of ridges, frequent burning of vegetation during the dry season, and a reduction in the number of intercrops.

Two examples of how farmer management and decision making affect cropping systems are provided here. The first case concerns a widowed farmer with three children in Feshi, in the Kalahari agro-ecological zone. She was cultivating two fields, a plateau field (Sp) and a valley field (Sv). Because two of the children were too young to assist her, and the eldest, a boy, attended school, she decided not to grow millet on either field. Millet is usually grown in mixed or relay intercropping with cassava, and requires considerable labour to scare away the birds, normally a children's task. Instead, she planted a cassava + maize + *voandzou* crop on the Sv field, soon after it was burnt and cleared. The crops were planted directly in the ashes, without hoeing, because she had no time to make ridges and the ashes '*were sufficient*'. Although the maize germinated poorly, she carefully weeded the field and harvested about 150 kg of green maize in December, from a 0.4 ha field. In this way she was able to bridge the rainy months of November and December, when cassava processing and drying are difficult. In terms of crops, cultural practices and management (but not in terms of yields!), her Sv field became similar to a forest (Fv) field. On the slope field (Sp), she decided to grow mainly cassava, intercropped with patches of squash. When the cassava produced a poor harvest or roots and leaves, she intercropped it with a few sweet potato plants.

The second case study is situated in Lobo, also on the Kalahari table lands. The farmer concerned had initially established two fields that year, one on the slope (Ss) and one on the top of the plateau (Sp), as well as a small homestead garden. After four months, it appeared that the cassava on the plateau field was heavily infested with bacterial blight and cassava mealybug. As she expected almost no return from that field, she then decided not to do any weeding and limited her work to the harvesting of *voandzou* and a few minor crops. Instead, she concentrated work on the slope field, where she repaired the ridges that had been damaged by a rain storm. Cassava leaves were not harvested from the slope field, because, as she said: *'The roots have to grow first'*, but only from the plateau field, where leaf production was very limited, and from the garden, where she planted additional cassava cuttings of a leafy variety. Thus, decisions concerning one field led to changes in management in two other fields (the slope field and the garden).

Weeds, pests, diseases, predators and other subsystems

Weeds, pests, diseases, predators and herbivores constitute complex subsystems by themselves. Apart from biological and physical factors, the cropping system, i.e. the combination of crops, soils and management also determines the specific set of weeds. Pests and diseases of the most important crops are briefly mentioned in the review of individual crops in chapter 8. Common weeds were collected from a large number of fields and have been identified as *I. cylindrica, Cyperus rotundus, Pteridium aequilinum, Eragrostis ciliaris, Pennisetum polystachyon, Paspalum conjugatum, Hyparrhenia spp and Afromomum stipulatum* on forest fields, and *Loudetia demeusii, L. simplex and L. vandereystii, Landolphia lanceolata, Indigofera congesta and Parinari pumela* on savanna fields.

The garden cropping system

Although all farmers in the Kwango-Kwilu practice a long fallow type of shifting cultivation, it is not the only form of land utilization.[5] Apart from savanna and forest fields, farmers in the Kwango-Kwilu distinguish several types of gardens. These are, however, of minor importance in terms of subsistence production. These gardens correspond to a separate cropping system, the garden cropping system, with different subtypes or field types. The garden cropping system is not based on shifting cultivation and fallowing, but on other ways of soil fertility restoration, mainly through household refuse and green manure. Gardens are much more permanent than shifting fields, but they may be shifted from time to time. The three field types distinguished in the garden cropping system are discussed below. Their locations have been shown schematically in figure 7.1.

On former village sites, crops are cultivated that require a high fertility level such as yam or tobacco (for local consumption). Oil palm and other useful trees on villages sites are also tended. When weeds become a problem, the fields may be hoed or burnt. This field type (V) does not consist of a clearly defined association or sequence. The village site is cultivated in small patches for many years, with cassava as the final crop. Only farmers whose villages have moved in, say, the last ten years cultivate village gardens. As villages move less frequently today, this field type is bound to lose its importance.

Homestead gardens constitute another field type. Near the homestead, small plots are fenced in to protect them against backyard animals (field type H). In the entire region homestead gardens are very small (4-10 m^2) and very few crops are grown: typically one finds a few leafy vegetables (*Amaranthus spp, Hibiscus spp*) around a single banana tree, preferably on top of a refuse heap. Because cassava leaves provide the bulk of the vegetables in the diet, home gardens receive little attention and are never watered. Household refuse and compost are sparsely applied to gardens. Sometimes a few 'sweet' cassava plants are grown for easy access during the heavy rains in November when women are unable to harvest and process cassava from their main fields.

Some tribal groups also establish semi-permanent river gardens (field type R) along the streams, where taro, yam, vegetables and other minor crops are grown to provide food during the dry season. Occasionally, these river gardens also serve for rice cultivation.

Cropping systems as components of farming systems in the Kwango-Kwilu

In the preceding chapter, two main types of farming systems were distinguished that corresponded roughly to the two agro-ecological zones, the Karroo farming system in the valleys and the Kalahari system on the table lands. It was also concluded that several intermediary groups of farming systems existed, depending on agro-ecological zone and the degree of market integration. It was shown that these types of farming systems differ mainly in their input-output (ecological and economic) environments, in particular the degree of market integration which is much more marked in the Karroo zone. In contrast, the characteristics of the farm household component do not seem to vary greatly between the farming systems.

It is now clear, from the analysis of the cropping system, that the farming systems also display differences with respect to field types. In all cropping systems, and corresponding field types, cassava dominates the cropping component. The original classification of types of farming systems in chapter 6 can thus be refined. On the basis of dominant field types, three types of farming systems can be distinguished:

a Kalahari farming systems, with savanna (S) fields, a growing proportion of them on the plateau (Sp), and gardens, mainly old village sites (V fields) and less frequently river gardens (R);

b Karroo farming systems, with slope (Fs) and valley (Fv) fields only;

c Intermediate farming systems, originally derived from Karroo systems, with F fields and Sp fields outside the valleys.

Discussion

In this chapter an attempt has been made, as far as data would allow, to analyse the changes in cropping systems in the Kwango-Kwilu since the 1940s. These changes are summarized and discussed in this final section.

Shifting cultivation

Shifting cultivation has remained the nearly exclusive mode of land utilization in the region. Land-use intensity, however, seems to have increased in most areas, in particular in the central Kwango-Kwilu. The available statistics do not permit a calculation of R (the land-use intensity factor), but there can be no doubt that R values far exceeding 33 are found in many collectivities. The circumstantial evidence consists of shortening fallows, relative land scarcity resulting from the compulsory cultivation regulations, and farmers' statements.

Firstly, there are strong indications that fallows have shortened throughout the entire Kwango-Kwilu; most dramatically so in the central valleys. This is evidenced by changes in fallow vegetation, in particular the fact that bush fallows are increasingly replaced by savanna and grass fallows.

Secondly, several factors, discussed in this and previous chapters, suggest that the compulsory cultivation regulations seem to have increased the area under cultivation by increasing the individual field size.

Thirdly, many of the discussions with farmers point to increased land-use intensities. Nearly without exception, they complain about the travelling distances to fields. There are repeated mentions of the disappearance of

forests, trees and the occurrence of grass fallows. *'Trees will not grow, only grasses, but the soil is not good enough for maize after the grasses are cleared.'*
In combination with the growth of the agricultural population in the Kwango-Kwilu, the evidence points to an increase in land-use intensity and the emergence of inframarginal land scarcities, especially in the central valleys. *Inframarginal land scarcity* is defined here as a degree of land-use intensity resulting in a shortage of land for soil fertility restoration through fallowing at village system level. In other words, although average population densities in the regional system suggest that land is still plentiful, shortages may occur at village level. These shortages should not be taken to mean that the land supply is not adequate for annual cultivation. The key issue here is the maintenance of fallow lengths. Inframarginal land scarcity, therefore, also results from the permanency of settlements in comparison with the past. While the problem seems most acute in the Karroo valleys, it can also be found in the Kalahari zone near small urban centres, such as Gungu or Feshi. If land-use intensity factor, R, exceeds 33, Ruthenberg (1980) suggests that fallow systems replace shifting systems with corresponding changes in cultural practices. The R value, however, may be an inadequate measure to record rapid changes in land use. In the Kwango-Kwilu, increasing R values in densely populated areas do not necessarily imply a land-use pattern and cultural practices that differ from areas with lower R values. Even in the densely populated Karroo valleys, with population densities exceeding 45 persons/km^2, clearly defined holdings and permanent field divisions are not found. The only adjustment to increasing inframarginal land scarcity in the Karroo zone is the opening of savanna fields on the plateau outside the valleys and the increasing reliance on cassava.

Field types

While the distinction between savanna and forest fields still prevails, a new field type, plateau fields in the savanna, Sp, seems to emerge. It appears that this field type was unknown, or at least uncommon before 1960. The reasons for the emergence of Sp fields differ. In the Karroo zone, this field type results from an increase in land-use intensity, leading to the expansion of cultivation to more marginal areas. In the Kalahari zone, the reasons are less clear. Land scarcity is not always a determining factor, although land availability is certainly limited to the distance women are able to travel from their homesteads to the fields. In the savanna, Sp fields may have resulted from the need to bring more land under cultivation in order to offset possible yield declines.
In both agro-ecological zones, other factors have also played a role in the

emergence of Sp fields. A modification in field types has been reinforced by the *cultures en bloc* policy, the grouping of fields. These measures were first introduced by the colonial government to reduce the risk of bush fires and to facilitate the regrowth of natural vegetation, and later reinforced by the compulsory cultivation regulations. Under this regulation, which is not always applied, women are required to open up adjoining fields on slopes, rather than separate plots protected by anti-erosive strips of grasses. A high proportion of fields is now located on the table lands close to roads rather than in the valley bottoms, so that they can be easily inspected by extension agents. Finally, the opening of new Sp fields does not only result from land shortage or land allocation policies, but may also have been triggered by farmers' reactions to changes in the environment. In one instance, in southern Masi-Manimba, farmers had become aware that the deforestation of the upper level of the catena in the Karroo valleys promotes the downward movement of Kalahari sands from the plateau onto the lower levels of the catena. They decided as a group to cultivate new fields on the table lands rather than at the top of the slope, although it would have been possible to open additional Ss fields.

No distinction between the two farming systems has been found with respect to Sp fields: in the Karroo and Kalahari zone Sp fields are managed in similar ways.

With respect to field types, it would seem that the distinction between forest and savanna fields is less clear today than in the past. With the exception of Fv fields, with their higher soil fertility and potential for upland rice, savanna and forest fields do not differ fundamentally in cultural practices, fallows and cropping patterns. It could be suggested that Fs, Ss and Sv fields tend towards a common field type that combines the cropping sequences of the savanna with the cultural practices of the forest on poor soils after grass or savanna fallow.

Field sizes

Compulsory cultivation regulations, although recently repealed, have not only affected the location of fields, but probably also their sizes. Official requirements on field sizes under the compulsory cultivation regulations were higher than in the past (before 1960). One would expect therefore, depending on the degree of effective control, that field sizes have increased. Women's consistent complaints about the large areas they have to work, and older women's comments about the poor execution of cultural practices seem to point in this direction. On the other hand, in areas of acute land scarcity, for example around Kikwit, decreasing field sizes would be expected, but this is

not mentioned by farmers. The only statistical evidence is provided by the average data from the agricultural census, showing that the average area per farm has declined very slightly in the 1970-1980 period. This may contradict the previous statements, but as cadastral data cannot be obtained, the evidence remains inconclusive.
There is some circumstantial evidence that farmers may have reacted to declining yields by increasing field sizes as well as the number of fields. The compulsory cultivation regulations may have enhanced the trend towards expansion onto the marginal table lands. Certainly, many new fields are opened in February, at the start of the second rains, a phenomenon that was not common in the past.

Crops

Changes in field sizes, in fallow lengths and field types have also affected cropping patterns. While cassava was always an important crop in the savanna, it is also increasingly grown as a first crop in the forest, partly in reaction to the growing urban demand for cassava. Crop sequences and associations do not differ clearly anymore between forest and savanna fields, with the exception of the first association immediately after opening the field. As shall be discussed in detail, the number of intercrops with cassava is also reduced. On all field types, irrespective of soil type and location, cassava is the first and most important crop, associated with a small number of minor crops. On the other hand, intraregional differences in crop production may have been accentuated. In the Bulungu and Idiofa zones, upland rice has been introduced as a male cash crop (the crop is still mainly grown by non-traditional *fermiers*). Maize production has also gained importance in the Karroo valleys. On the other hand, millet has lost its central role on the southern table lands, so that past differences between savanna and forest fields have been reduced. Subspontaneous oil palm forests, typical of the valleys, are being destroyed on a large scale to grow annual crops.

Soil fertility restoration

Miracle (1967) observes that people who have access to both forest and savanna areas tend to use techniques that are more complex and labour-intensive in their savanna fields. In the Kwango-Kwilu this appears to apply only to farmers with a long standing tradition of savanna cultivation, e.g. the Bunda in southern Idiofa and northern Gungu. However, farmers who have recently started cultivation in the savanna, hardly make use of any labour-in-

tensive techniques such as mulching, composting or ridging. Their savanna fields are cultivated much in the same manner as forest fields.
In general, then, other methods to restore soil fertility than through fallowing have not yet evolved. Where they existed previously in the savanna, e.g. the incorporation of plant debris, they have often been abandoned because farmers consider them too labour-intensive to be applied to large surfaces. The decline of ridging and mulching is particularly serious because their positive effects on physical soil properties cannot easily be restored through other means. Burning for clearing during the cropping cycle is practized more frequently than in the past, and ridging and mulching seem to be disappearing from many savanna fields.

Labour inputs

There is too little evidence to draw any conclusions on changes in labour inputs. Nevertheless, circumstantial evidence seems to indicate labour shortages. Delays in weeding and planting, insufficient ridging and mounding, and the increased reliance on cassava seem to suggest this. Regional data from the agricultural census show that the labour force per farm has declined with about 20%. The regular absence of men from their villages explains some of the labour shortages, but not all, since women have always borne the brunt of agricultural work. One can only speculate that the apparent shortages are either a result of women's lack of motivation for agricultural work, or of increases in field sizes. Both reasons are mentioned by the older generation of farmers.
The reasons why farmers abandon fields at the end of the cropping cycle may also be related to labour problems. In the forest, weed infestation, rather than just yield decline seems an important reason. The preference for opening up new fields instead of increasing labour inputs in weeding is undoubtedly related to the division of labour within the farm houseold. In the Karroo zone, men carry out most of the clearing work, while women are exclusively responsible for weeding. Additional weeding would mean an even greater burden on women. A possible way for women to decrease their work loads could be to convince their husbands to open up new fields, using the 'excuse' that yields are declining. Some of the comments by women farmers seem to point in this direction, e.g. *'if a man wants to be nice to his wife, he opens up a new field for her'*, *'it is easier to open a new field than to continue working the old, even if it yields as much'*.
This could suggest that the shortening of fallows is not just caused by increased population densities and land shortages, but may also be a result of labour shortages. This confirms other observations in Africa (Tiffin 1982).

Conclusions

Recapitulating, the main changes in cropping systems over the last thirty years are increased land-use intensity leading to the expansion of cropping into more marginal areas of the Kalahari plateau and increased presence of cassava in all field types.

These changes in cropping systems explain why farmers in the Kwango-Kwilu have been able to produce considerable surpluses of food crops, notwithstanding regional level constraints. In the preceding chapter, at the farming systems level, it was shown that a reliance on female labour, land availability and cassava explained much of this flexibility. At the cropping systems level this insight can now be elaborated upon. The emergence of a new field type and the increasing presence of cassava on all types of fields (including as a first crop in the forest), demonstrate how the shifting cultivation system has adapted to increasing land shortages. The reduction of the male labour force has coincided with the reduction of the forest area. Where forests disappeared, male labour inputs into agriculture, which had traditionally mainly been limited to forest clearing, also declined. The absence of men from agriculture may therefore have been promoted by 'push' as well as 'pull' factors. With the disappearance of forest fallows, they had no legitimate role in the traditional division of labour. Meanwhile, this fact allowed them to leave the rural areas to the more attractive urban centres, without disrupting the shifting cultivation system.

However, the reduction of the fallow length seems to have increased the burden of weeding. An increase in the frequency of burning provides a partial, and temporary, solution for weed problems, and facilitates the clearing after grass fallow, which is now increasingly common. To offset declining fertility, farmers have sometimes resorted to increased field sizes and, without exception, to cassava, which can be grown on depleted soils with low field-labour inputs and allows the production of a considerable surplus for sale.

At the same time, however, it is clear that increased output from the cropping system has serious consequences for the sustainability of agriculture in the region. The feedback loops that normally regulate natural ecosystems have been interrupted: fields are opened although fallow length has been insufficient, and cassava is repeated after cassava. This is the principal endogenous limitation of the cropping system. The decline of soil fertility associated with the expansion of arable cropping, the destruction of forests and the large-scale removal of nutrients through crop exports are not compensated by any adjustments in cultural practices.

The main exogenous constraint on cropping system performance is the overall lack of support to the development of the traditional agricultural sector, as witnessed by disadvantageous price relations, the unavailability of agricultural inputs, and the absence of extension and research services.

The two cropping systems are differentially affected by these limitations and constraints. In the relatively land abundant Kalahari zone declining yields can theoretically be offset by increasing field size and the number of fields. However, female labour bottlenecks and travelling time to the fields limit this option, although the cropping system allows some flexibility in the quantity and timing of labour inputs. With present labour input levels and the absence of fertilizer the scope for improving and even maintaining yields seems very limited. Present low population densities render investments in infrastructure and marketing and the regular delivery of inputs unlikely in the near future.

In the Karroo valleys, future expansion of arable cropping in space is problematic. Expansion in time occurs continuously through the reduction of fallows, leading to permanent land occupation in the peri-urban areas. The introduction of upland rice provides perhaps a solution to some problems (but not the fertility decline) in the valleys, because it allows for a certain diversification and involves male labour. The Karroo agro-ecological zone is relatively well endowed with respect to infrastructure, and theoretically the supply of agricultural inputs should not pose unsurmountable problems. At present, however, the existence of roads and traders only means that agricultural products, and therefore also soil nutrients, are more easily channeled into Kinshasa than from the Kalahari zone.

The flexibility of the present shifting cultivation system of the Kwango-Kwilu appears to reach its limits. Limitations such as low soil fertility and low labour inputs are unlikely to be solved within the system alone. The African crisis manifests itself in the Kwango-Kwilu in a specific form. Rather than a crisis of food production or distribution per se, it is *the crisis of shifting cultivation* as the dominant mode of land use. The next chapter will examine the key role of cassava in all field types with a view to understanding the effects of changes in cropping systems on the cassava crop system.

Notes

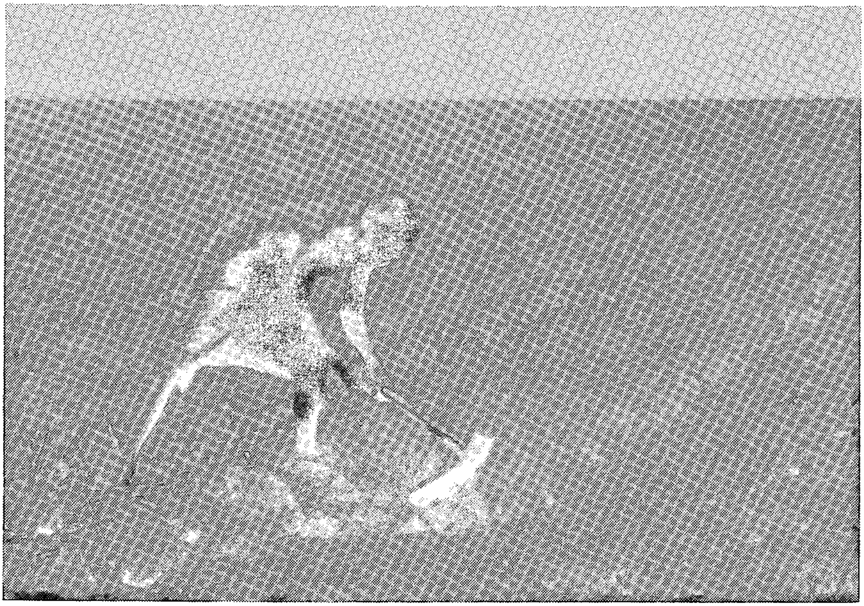
1 The concept of field type has originally been developed for the analysis of shifting cultivation (de Schlippe 1956 a,b). It is applicable to other types of cropping systems as well, as shown by Timmer's work on different types of paddy fields (Timmer 1947).

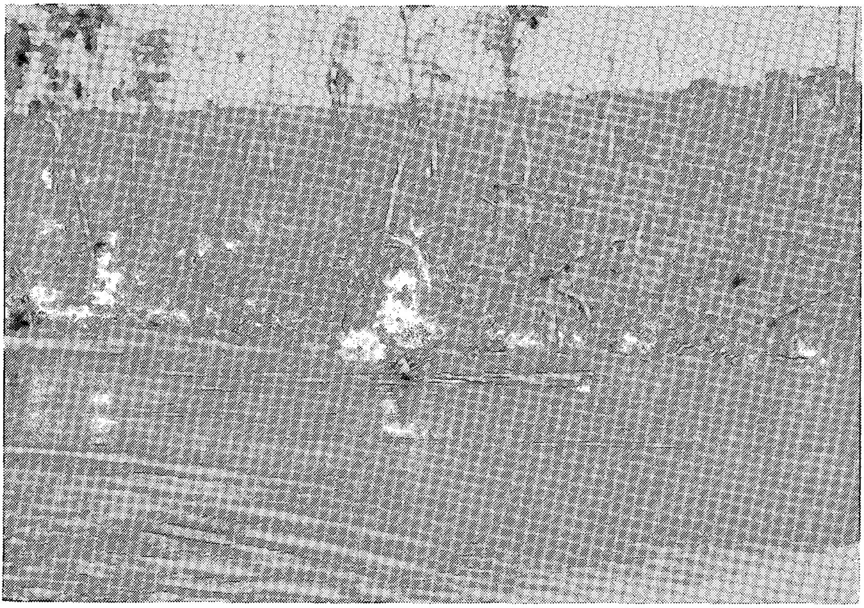
2 The notation introduced by Gomez & Gomez (1983) has been followed, i.e. + for intercropping and – for sequential cropping (see glossary for definitions).

3 This statement is confusing since *voandzou* was a typical savanna crop (sometimes also grown in pure stands in gardens), while maize was nearly always limited to the valleys and Congo jute was certainly so. If the association occurred in the forest, as Rassel (1958) and Miracle (1967) suggest, a fallow length of two to four years is very short. Because of the crops involved, this association seems unlikely even for the savanna, although the fallow length suggests a grass fallow.

4 An exception may be the Ngongo tribe in the Lukula valley who are said to cultivate fields on the table lands traditionally.

5 Although not mentioned by Miracle (1967) with respect to the Kwango-Kwilu, an ash-dependent shifting cultivation system is also practised in some isolated villages of the Kalahari plateau (Feshi zone). In this so-called '*mafuku*' system, grasses are collected from a large area and heaped on the borders of the field and incinerated. Onions and irish potato are planted directly in the ashes without further hoeing.

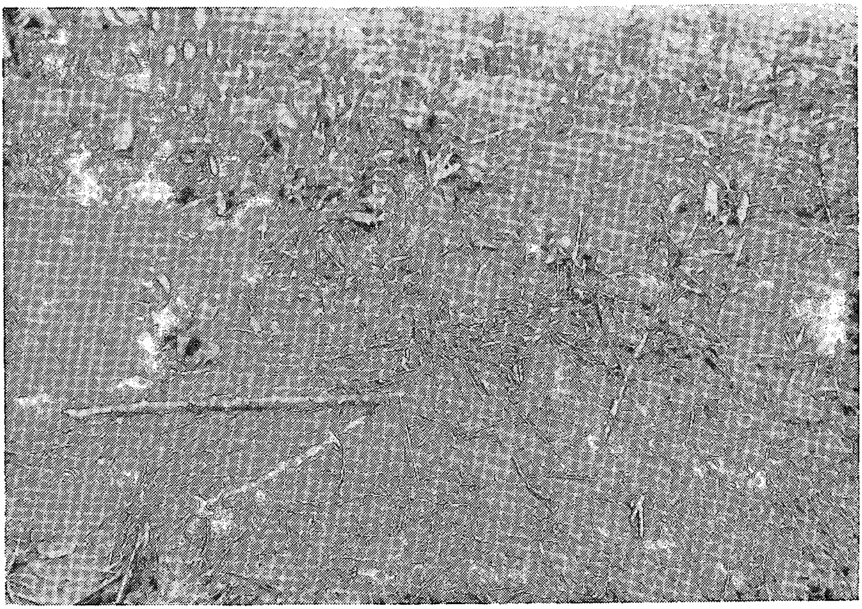
1 

2 

1 Soil preparation and ridging in the savanna after grass fallow on a plateau field (Sp). Frequent burning has limited the volume of grasses for incorporation.

2 Slope fields in the Kwilu valley (Fs), new clearances on the right and cassava merging with fallow vegetation on the right.

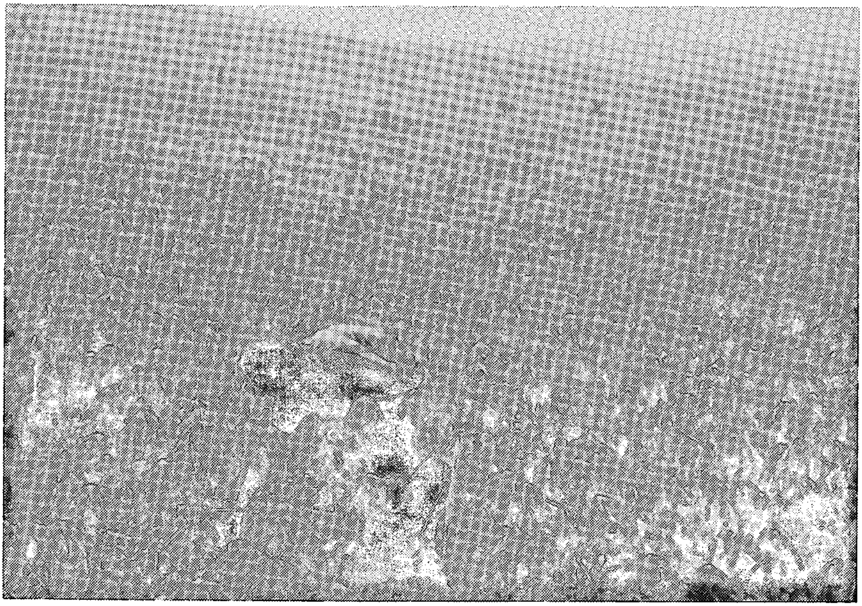
3 

4 

3 Farmers – grandmother and granddaughter – with cassava cuttings of two local varieties. About 5 cm will be cut off each end before planting.

4 Emergence of stems from two cuttings, planted horizontally on a mound on a Sp field without intercrops. All stems are heavily attacked by bacterial blight.

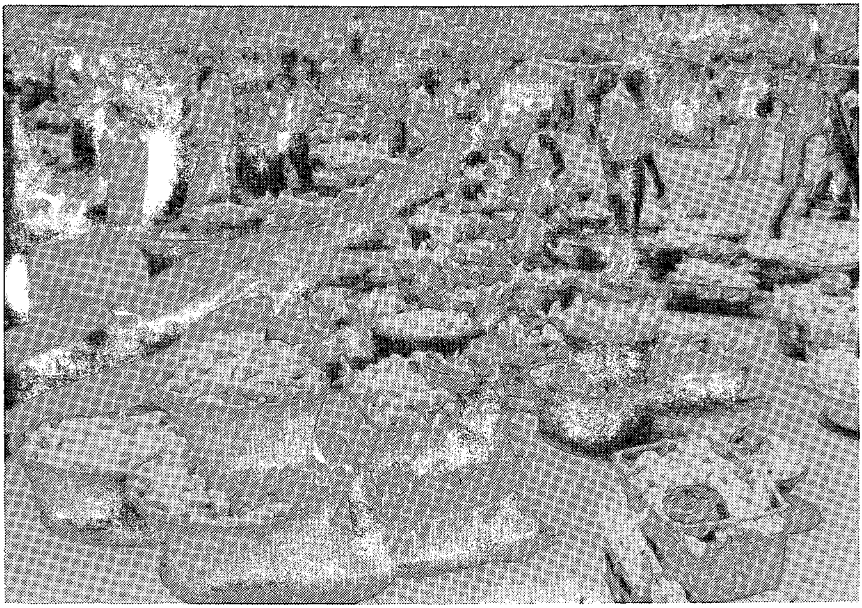
5 

6 

5 Cassava field at the bottom of a slope (Sv) with heavy weed infestation and low cassava densities.

6 Individual farmers' plots joined into large fields grown with cassava in monoculture, Sv field.

7



8

7 Cassava – squash – sweet potato association on a slope field (Ss) with low ridges cutting across the contours.

8 Cassava *cossettes* (dried and processed roots) at a local market in baskets of various shapes.

8 FACTORS AFFECTING THE CASSAVA CROP SYSTEM

Definition and boundaries

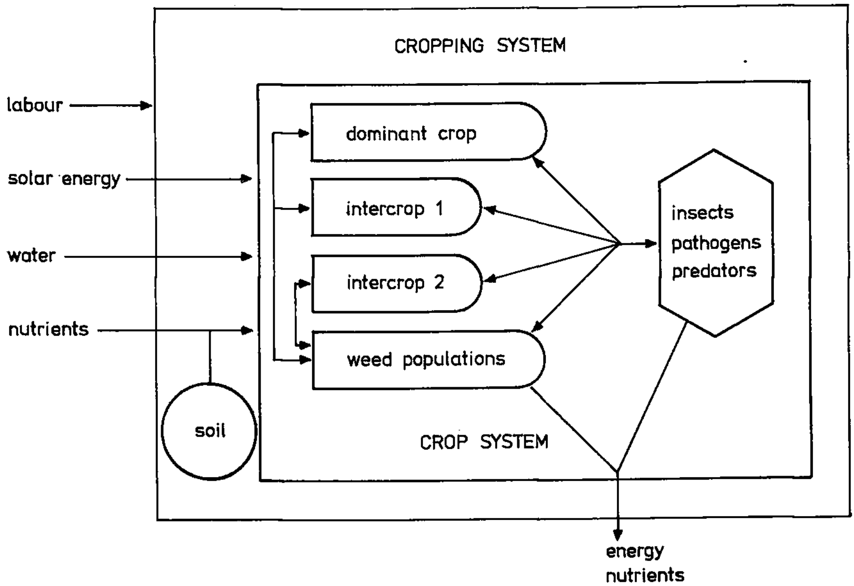
The focus in this chapter is on the crop system, the arrangement of crop populations that transform solar energy, water, nutrients and other inputs into biomass. The crop system is a subsystem of the cropping system. It is important to distinguish clearly between the two. The cropping system constitutes an ecosystem, involving besides crops also components like soils, weeds, pathogens, and inputs such as labour and management. In contrast, the crop system involves only crop populations, in sole or mixed stands. It goes without saying that the crop system cannot be studied in isolation from the cropping system. This chapter discusses how the cassava crop system is affected by changes at cropping and farming systems levels. A simplified model of the crop system is presented in figure 8.0.

The boundaries of the crop system coincide with those of the crop populations studied. The unit of observation is therefore the crop, not the field. In shifting cultivation, crop populations often involve a combination of different species as well as a combination of different varieties of the same species.

The analysis of farming and cropping systems in the Kwango-Kwilu has shown that one of the most noticeable changes over the past thirty years is the increased importance of cassava. Cassava now figures in all crop associations and crop sequences (with the exception of upland rice). The term *cassava crop system* will be used here to indicate that cassava constitutes the dominant crop population in time and/or in space. The most important characteristic of the cassava crop system, cassava varieties, is reviewed at length. Furthermore, two essential factors affecting the cassava crop system, cultural practices and pests and diseases, are discussed with a view to gaining more insight into the flexibility of cassava-based shifting cultivation. Where possible, data on cassava production in the pre-Independence period will be included.

The discussion is preceded by a brief introduction on cassava in African shifting cultivation systems.

Figure 8.0 The crop system (as a component of the cropping system) (energy symbols after ODUM 1983 – see annex).



Cassava in African shifting cultivation systems

The dependence on cassava as food and cash crop is not unique to the Kwango-Kwilu. In the Kwilu alone, cassava accounts for an estimated two thirds of the total volume and value of agricultural production in the region, and for about three quarters of the volume and value of the marketed production. The sale of cassava supplies approximately 40% of the average farm household income. Cassava provides 60-70% of daily calorie requirements of the Kwango-Kwilu population.

In Zaire as a whole, cassava supplies over an estimated 4,620 kJ/person.day or 55% of dietary energy (over 300 kg/person.year). Zaire is the largest cassava producer in Africa and is responsible for some 10% of the world production of cassava. Cassava roots supply more than 50% of daily caloric requirements of 200 million Africans. Africa is expected to experience the largest annual increase in demand for cassava, while Zaire's demand growth rate may be as high as 3% annually (Phillips 1983). Cassava is grown on ten million ha in Africa (IITA 1984), a major portion of which is situated on acidic, low fertility soils.

The introduction of cassava into Central Africa constitutes a clear example of the adaptability of African farming and cropping systems. Within less than three centuries, the crop has become the main staple as well as the dominant component of nearly all crop associations and sequences. Cassava does not grow wild. Rather than arising by natural selection, supposedly hybrids between wild species were once domesticated and maintained through vegetative reproduction (Nassar 1978). As a result, the large variation of cultivars makes it difficult to designate definite characteristics to the species *M. esculenta* (Nassar 1978). It has been suggested that the original centre of domestication of cassava lies in northeastern South America, from where the crop was introduced to Middle America (Heiser 1973: 145). However, Renvoize (1973) argues that little evidence exists to confirm a Brazilean domestication.

Whatever the case, cassava has been introduced independently into West and East Africa and Madagascar. Ross (1975) describes how the Portuguese, having learnt the art of cultivating and processing cassava from the Tupinamba Indians, introduced the crop into their West African settlements. From there, it became diffused throughout tropical Africa. According to Jones (1957), by the end of the eighteenth century cassava was widely grown in the Congo Basin, but it remained a crop of local importance. Hilton (1985) reports about the Kingdom of Kongo that millets (*Eleusine coracana, Pennisetum typhoides*) and sorghum were the staple crops throughout the fifteenth century. By the end of the sixteenth century, however, maize was already known in the savanna area and in the seventeenth century it was said to be the most common crop. Cassava, introduced in the seventeenth century into the Kingdom of Kongo, apparently met with reluctance from the population, but was nevertheless quickly adopted in the more humid areas. Probably the first reference to cassava in this area was by a Capuchin friar who resided in the Songo area (Bas Zaire) from 1683 to 1688. Untill the early seventeenth century there is hardly any reference to the cultivation of cassava in Central Africa, although cassava products were already known (Ross 1954:66). Linguistic evidence indicates that often the local names of the cassava plant are derived from the Portuguese language. This is also the case in the Kwango-Kwilu, where cassava is called *manioko*.

Although most of the agricultural practices were introduced from South America at the same time as the crop itself, it was not until the late nineteenth century that the *farinha* processing techniques became known in West Africa with the return of freed slaves. This way of processing, called *gari* in West Africa, has never reached the Kwango-Kwilu, nor most of Central Africa: in the climatic conditions of the Congo Basin, cassava is most easily kept as dried and processed roots (*cossettes* and *batons* or *chikwangue*) (Gietema-Groenendijk 1970)[1]. According to Jones (1957) the frequent consumption of cassava leaves is a typical African invention.

Apparently, cassava has competed succesfully with other moisture rich starchy staples of the African lowland tropics such as yam, taro, and plantain which are easier to process but more labour demanding in production. Throughout the colonial period in Africa, however, cassava was considered an unsuitable staple crop, although it was promoted by some colonial administrations as an anti-locust emergency crop. Untill the publication of Jones's *Manioc in Africa* in 1959, cassava was thought to cause soil depletion and erosion as well as malnutrition. Moreover, it was feared that its ease of cultivation would encourage laziness. Jones demonstrated that only an excessive reliance on cassava may cause nutritional problems, and that these are by no means associated with cassava alone, but occur with most starchy staples. He was of the opinion that the soil fertility problems could be easily solved by the introduction of appropriate cultural practices, while the low labour requirements can only be considered an asset of the crop. In his view, cassava toxicity could be overcome by applying suitable processing methods. The advantages of cassava explain its widespread adoption as a staple in nearly all of tropical Africa:

- it is adapted to a wide range of climatic and edaphic conditions, and it is drought tolerant;
- it is very tolerant of low soil fertility and poor soil structure;
- it requires little care during growth, with the exception of weeding during the first few months; cassava has the lowest field (not total) labour input requirements of all tropical staple crops and is also relatively tolerant of neglect or delays during cultivation;
- while cassava loses its labour input advantage if postharvest handling is taken into account, it is less tightly constrained by seasonality than other crops;
- it is not damaged by locusts;
- it may be harvested any time between 6-8 and about 36 months (depending on variety);
- if processed into dry products, it can be relatively easily stored;
- it is a high producer of calories and protein (if the aerial parts are included) per unit of land and labour (de Vries 1978);
- its economically valuable parts are not needed for reproduction, which takes place through cuttings.

As a result, cassava occupies a special position in African shifting cultivation systems: it fits nearly all types of crop sequences and intercropping arrangements, and can be grown in extremely diverse patterns. It allows great flexibility in total and seasonal labour inputs and in resource allocation in general. This makes cassava very well adapted to the risk aversion strategies of African farmers who, in cropping systems characterized by low field labour inputs, have to deal with low fertility soils and highly uncertain climatic, economic and political conditions. It could be suggested that cassava's greatest comparative advantage is situated on poor soils under edaphic, climatic and socio-economic conditions rather similar to those of Kwango-Kwilu farmers.

Components of the cassava crop system: crops associated with cassava

The main components of the cassava crop system are cassava itself and the crops grown in intercropping or in sequence with cassava.
Information on the range of food crops associated with cassava before 1960 is scanty. Crops and crop associations of that time have been summarized in table 7.1. As discussed, rice was not found before 1960. Farmers report that they are growing more maize than in the past and less millet. Minor crops such as *Ocimum spp* (basil), also mentioned by Renier (1957), and *Sphenostylis stenocarpa* have nearly disappeared. Pre-Independence observations on crop-specific cultural practices, in contrast to general information on cropping which has been discussed in the preceding chapter, have hardly been found, and are mostly lacking in detail. It seems, however, that the main food crops were not always intercropped with cassava. Groundnuts, *voandzou*, maize, and millet were also encountered in pure stands or intercropped with other crops than cassava.
Today, the cassava crop system involves nearly all food crops, since cassava occurs on each field type. Table 8.1 summarizes the characteristics – varieties, planting material, cultural practices, yield and introduction – of traditional and recently introduced crops in the Kwango-Kwilu. Coffee, the only cash crop, is excluded because it is not grown by traditional farmers (*paysans*), although young coffee may occasionally be intercropped with cassava.
Tobacco, although not a food crop, has been mentioned in the table because it is grown for subsistence in some areas. Little information is available of postharvest handling practices and losses, but it has been found that farmers are aware of storage losses: in 1981 all but 2% of the farmers reported losses due to humidity, pests and predators (FAO 1983).
Leafy vegetables, spices and fruit trees are not included in the table. Of these crops, no details of yields are given, since the number of plants is small and harvesting takes place intermittently according to needs. The overall variety in vegetables and fruit trees is quite considerable[2], although most households grow but a narrow range of these crops. A limited number of useful plants is not actually cultivated in gardens, but protected and sometimes planted along pathways: *Tephrosia vogelii* (fish poison), *Triumfetta cordifolia, U. lobata* (fibers), *Landolphia lanceolata* (traditional medicine), *Cymbopogon citratus*

(lemon grass), pineapple, *Ricinus communis* (castor). Oil and raphia palms are also protected and sometimes planted near the homestead for multiple uses (wine, building material, shade, fibers and, in the case of oil palm, oil).
With the exception of the main food crops, cassava, maize, millet, groundnuts, and rice, most crops are grown in small numbers, often arranged in small patches in the fields. In all field types (excluding only gardens (R and H)), cassava dominates with respect to number of plants, labour requirements, volume and value of production, and importance in the diet. Rice is the only crop exclusively grown in pure stands. The presence of cassava is so much a matter of course, that it is often not mentioned when farmers are interviewed on their crops, even when they are standing in the middle of a cassava field. When questioned about this omission, they reply: '*Why should I talk about cassava? How can a woman survive without cassava?*'
While cassava will be discussed in detail below, current practices relating to the three other major food crops in the Kwango-Kwilu, as they have been observed during the various surveys, are briefly outlined here.
Maize (*Zea mays*) is mainly grown on forest (F) fields, often intercropped with cassava and groundnuts. Maize is rarely planted in the second rainy season. Very little if any cultivation is carried out before planting. In each hole three to four seeds are placed at a depth of 10 cm. Spacing depends on intercropping arrangements. In row intercropping 120-150 cm are left between each maize stand. In many cases, maize is grown in patches among other crops, resulting in very low densities (often no more than 20-100 plants on a 0.5 ha field). Maize is not weeded separately. Streak virus seems to occur occasionally. The period from planting to harvesting is usually 120 days, but the cobs may be left drying on the stalks during the short dry season. Early harvesting of young maize (after 95 days) for subsistence consumption is common. The cobs are stored with or without husks in the kitchen. Considerable postharvest losses have been observed due to rats and moisture. 100 kg of cobs yield about 60 kg of flour.
Groundnuts (*Arachis hypogea*) are sown after superficial hoeing and sometimes ridging, at an average density of 20,000 plants per ha in intercropping (two to three seeds per planting hole). Low germination of local varieties leads to high seed rates. The low densities seem to have encouraged the occurrence of *Rosette* virus in the northern Kwango-Kwilu. *Cercospora* leaf spot is common. Nodulation is inadequate and most nodules are not active. The growth cycle of local varieties is about 105 days, but groundnuts are often harvested earlier. The plants are pulled up and left on the fields to dry. Losses occur at this point due to early sprouting and, possibly, *Aspergillus flavus*. The high number of empty pods may be attributed to low calcium levels. Groundnuts are stored in the shell. The shelling percentage is 70%.
Bulrush millet (*Pennisetum typhoides*) is found exclusively among tribal groups

Table 8.1 Traditional and recently introduced food crops in the Kwango-Kwilu.

Crop	Number of locally distinguished varietes[1]	Field type[2]	Estimated quantity of planting material used by farmers
Cassava (*Manihot esculenta Crantz*)	at least 30	S,F, rarely H,V; never R	2500 m/ha depending on density and stake length
Maize (*Zea mays*)	at least 3, 2 with white and 1 with yellow seeds	$F_{s,v}$ sometimes H or V, rare in S_v	40-60 kg/ha
Groundnut (*Arachis hypogea*)	2 main cvs: 3-4 large seeds per pod; or 2 small brown seeds per pod (most common) (spreading)	F, S rarely H or V	80-150 kg/ha
Millet (*Penrisetum typhoides* Burm.)	1 observed,**) 2 more reported by farmers one of which may be *Sorghum bicolor.*	only S	15 kg/ha
Rice (*Oryza sativa*)	various, incl. R66 and little Y3	$F_{s,v}$	80-100 kg/ha
Bambara nut or *Voandzou* (*Vigna subterranea*)	commonly 1 cv with one seed/pod; also a cv with 2 seeds	mainly S and F_s often B	40 kg/ha unshelled

Growth cycle[3]	Specific cultural practices in traditional cropping	Yield range. ha^{-1} [4]	Introduction[5]	Production constraints
1st leaf harvest after 3 months; roots from 8 months onwards; last leaf & root harvest at appr. 36 months	Ss fields often on ridges; S_v fields on mounds	leaves 0.1-0.5 t; roots 2-20 t fresh weight, per cycle. INEAC 3-9 t on Kalahari*	probably widespread from 1800 onwards; depending on variety	low soil fertility, K deficiency; high pest & disease incidence, esp. CMV, CBB, CM, CGM, CAD.
green maize harvested from 90 days onwards left in fields up to 150 days	3-5 seeds in each hole; no thinning, rare in pure stand	300-800 kg grains. INEAC 300-500 kg on Kalahari*	unclear; large diffusion in Central Kwilu only since 1940, white variety from Kasai, 1970s	low incidence of streak virus (2d season); low densities; weeding
early harvest of fresh seeds after 75 days	mixed with other crops or in sole stand in patches; usually flat.	forest 800 kg plateau less than 500 kg. Renier (1957): after late burning on Kalahari	as late as 1900-1920s in some areas	low germination rates; some incidence of *rosette* virus; some brown spot. P deficiency; very low nodulation rates; considerable post. harvest and storage losses
mostly 2d season; 4 months	rarely in sole stand	500-700 kg INEAC 400-500 kg*)	traditional crop of Pende & Yaka tribes	no disease, but heavy losses to birds
appr. 120 days	always monocropped; seed broadcast upland rice only	500-800 kg; Renier: 1200 kg	hardly any upland rice before 1970; irrigated rice being introduced by Chinese (Y3 introduced in 1949) but mostly lost; spectacular spread through Central Kwilu since 1970s	low pH, lack of inputs esp. fertilizer; labour bottlenecks in weeding and harvesting; inadequate processing facilities
6 months	very low labour requirements	500-700 kg dry seed	unknown, certainly before 1850	none in particular; very good storage characteristics

Crop	Number of locally distinguished varietes[1]	Field type[2]	Estimated quantity of planting material used by farmers
Various legumes:			
– *Glycine max*	several	F, S_v	40 kg/ha
– *Cajanus cajan* (*Pois d'Angole*)	unknown	S, B	50 kg/ha
– *Phaseolus lunatus* *P. vulgaris*	unknown; *P. vulgaris* at least 4	S, B, H	50 kg/ha
– *Sphenostylis stenocarpa* (*mfuyu*)	unknown	S	unknown
Various roots & tubers			
– sweet potato (*Ipomoea batatas*)	at least 2	all field types	terminal cuttings, 30 cm
– Irish potato (*Solanum spp*)	various cvs	B, S	seed potatoes appr. 40 gr
– Taro (*Colocasia esculenta*)	only 1 observed	B, R, V	tuber cuttings 100 gr each
– Yam (*Dioscorea spp*)	no information on cvs; species include *D. rotundata*, *D. cayenensis*, *D. dumetorum*	F, B (often oil palm used as support)	tuber cuttings 200 gr each
Squash (*Cucurbitaceae*)	various species probably *Bennica hispida*, *Cucumis sativa* *C. maxima*	B, H	plants established individually
Sesame (*S. indicum*)	at least 2	mainly S also H, V	10 kg/ha
Sugarcane (*Saccharum spp*)	unknown	B, H, R	individual cuttings
Tobacco (*N. tabacum*)	several	B, H	50 gr/ha

Growth cycle[3]	Specific cultural practices in traditional cropping	Yield range. ha^{-1} [4]	Introduction[5]	Production constraints
70-90 days	no traditional techniques	up to 1 t with manure; with compost & ridging 500 kg	very recent, through RC missions	inoculation; nodulation deficient; photosensitivity
6 months	staggered planting & harvesting; ratooning	300-500 kg	from Angola	germination; rarely used as feed
4-6 months	mounds or ridges	400-600 kg	from Bas Zaire since 1900s	none observed
6-7 months; progressive harvest during dry season	on ridges with ashes	500 kg	unclear probably 19th century	no seeds available, has nearly disappeared
3-5 months progressive harvest of leaves & tubers	sometimes on small mounds	1-3 t tubers	through early missionairies around 1910	lack of vigorous cuttings for planting after dry season
4-6 months	always on ashes planted shortly before dry season	variable	1930-1940s by colonial administration	storage of seed-potato difficult
5-6 months	household refuse manure on H fields	up to 6 t	from Central Congo Basin	none in particular
progressive harvest after 3 months	only in long rainy season, sometimes on mounds	3-8 t fresh weight	from Central Congo Basin	soil fertility; no tradition of making mounds in forest
3-5 months	no special practices; seeds left drying in the fields	appr. 100 gr. of seeds/plant	unknown	none in particular good storage qualities
harvest after 3 months	seed broadcast, some thinning	200-300 kg	possibly from Eastern Zaire	germination; labour bottlenecks in harvest
over 1st harvest after 6 months	some composting	up to 30 m of cane/plant	from Angola***)	only grown for subsistence
first leaf harvest after 80 days	with compost or manure; well weeded	unknown	from Angola or Bas Zaire, 19th century	only for subsistence; only grown by men

Notes

1 Estimates based on an inventory of locally known and grown varieties as identified by different names and characteristics. No botanical analysis has been made.
2 Field type codes:
S = savanna; F = forest; B = field border; H = home garden; R = river garden;
V = old village site; p = plateau; s = slope; v = valley (catena).
3 Gives an indication of the variability of growth cycle (planting till harvesting) depending on varieties, cultural practices and food habits.
4 Average yields likely to be obtained by small farmers with traditional techniques depending on field type and variety in prevailing cropping patterns.
5 Introduction into traditional field types; not first appearance in the Kwilu.

* An unpublished undated INEAC report on improvements on Kalahari soils gives these fields for the three major crops, probably in the early 1950s. No equivalent figures are known for Karroo soils, only average data for the Kwilu (Nicolai, 1963).
** Renier (1957) mentions four or five varieties of millet, with different grain size and ear shape and 20 'hybrids'.
*** See Van den Abeele and Vandenput 1951: 150.

of the southern Kwango-Kwilu. It is sometimes grown in sole stands, but more frequently intercropped with cassava or *voandzou*. Seeds are broadcast or sometimes a pinch of seed is deposited in a shallow hole. Thinning is uncommon. No pests and diseases are recorded, but losses to birds and rats can be considerable. Millet is the only crop which is stored in traditional granaries.

Cassava

Cassava varieties

Cassava varieties in Africa

There is general agreement that the number of morphologically distinct varieties of cassava in Africa is very high. Beck (1982), who collected over 450 varieties in Nigeria, relates this to the highly heterozygous nature of the original importations and the way the crop is grown in shifting cultivation. Cassava's ability to grow on depleted soils makes it a suitable last crop before fallowing. It remains unattended in the field, where it produces new seedlings. Farmers will select some of these seedlings as new planting material, leading to the emergence of new varieties.
Rogers & Fleming (1973) have proposed a taxonomy of cassava based on botanical characteristics. Their survey of a great number of cassava collections shows that the genus *M. esculenta* may be subdivided into four main classes with rough or smooth root surfaces, and obovate or linear lobed leaves. Other

properties of leaves and stem (in particular stem color, distance between leaf scars, branching) may also be distinguished but do not alter the main subdivisions.

The distinction between 'bitter' and 'sweet' varieties has been the subject of many studies. Although bitter varieties generally have higher HCN values than sweet varieties, the division is inexact, and overlapping between the two classes exists (Coursey 1973). De Bruijn (1971), who defines bitter varieties as containing > 200 mg HCN per kg (fresh root weight), has demonstrated how environmental factors such as manuring with N, or low K levels increase the glucoside concentration. It is commonly known that some varieties change from sweet to bitter when planted in a different environment. Adriaens (1946:32) reports that when sweet cassava is repeated on the same field from the same cuttings, it yields bitter roots. These varieties will be referred to as 'intermediate' or 'variable'.

Throughout Africa, bitter varieties are much more common than sweet ones, notwithstanding the fact that sweet varieties have been promoted by some colonial administrations out of concern with the toxicity of bitter varieties. There is no satisfactory explanation for the predominance of bitter varieties, although IITA studies have shown that low HCN content is regulated by a recessive minor gene complex (IITA 1973). Jones (1959:134) suggests that perhaps only the bitter kind has been introduced initially into Africa, or that African climate and soils tend to either favour bitter varieties and tend to *'make them all bitter'*, or that African farmers have preferred bitter varieties. He mentions higher yield as a major reason for farmers to select bitter varieties. Cock confirms that this may have been correct, although in new lines bitter varieties are not higher yielding than sweet ones (Cock 1985:83). De Schlippe (1956a:66) had already observed that bitter cassava can remain unguarded for years, away from a homestead that may already have moved.

Cassava varieties in the Kwango-Kwilu

It is exceptional to find reports mentioning individual cassava varieties in Zaire (cf. Adriaens 1957). Drachoussoff (1947), in one of the few studies of crop varieties, in the Inkisi and Bangu sectors in Bas Zaire, reports a total of 14 and 12 cassava varieties respectively. However, only 3 of these varieties are common to both sectors, implying that there are at least 23 different varieties.

No information has been found on the diffusion of varieties in the Kwango-Kwilu before 1950. In the course of the 1950s, mainly as a result of INEAC's selection work in Yangambi, a few new varieties were introduced in the region, in particular the variety *N'tolili*. Their number cannot have been very

Table 8.2 A classification of local cassava varieties[1] commonly grown in the Kwango-Kwilu.

Local name(s)	Field type[2]	Growth cycle[3]
1. Dinkondo	S	12
2. Fululuka	S, F	?
3. Kandumba	Fs	12-24
4. Katebo, Mutebo	Fs, Sv	24-36
5. Kikatula, Musangala	Fs, Sv	8-15
6. Kisela, possibly Kasele	Fs, S	?
7. Kivudi	Sp, Ss	?
8. Kivula	Sp, Ss	?
9. Lengi	B, Fs, S	12
10. Madioko, Matuluku, Mundioko	Fs, Ss	12-18
11. Manga	F, S	12-24
12. Manianga	S	15-36
13. Manzungila	S	15-34
14. Mbala mundele	Fs, S	12-24
15. Muboma bwaki, M. ndombe, Kikoloko	S	18-30
16. Muboma mpembe, M. fuluka	S	12-24
17. Mufuma	Sp	?
18. Mwanza	Fs, Sv	?
19. Sakaria	F, S	?
20. Sedi	S	?
21. Tadi, Mukwa kivulu	S	12-24
22. Tsala	S	12-24
23. Vuoti, Voti, Marimenina	S	12-18

Notes

1 Because they are not commonly grown or because sufficient information was not available, the following varieties are mentioned here by name: Mubulu, Kibwatuba, Madinga, Kalando, Mupe, Kavunji, Muka, Kwengo, Kabenya, Kikonde, Kawaya, Mandefu, Kisanga, Mufoto, Longulongu, Malonda, Malwadi, Muledila, Melela, Muboma kapindi, Munika, Musamba, Kikemfu. This brings the total number of varieties recorded to 46. Moreover, 17 varieties have been recorded that refer to the name of the individual who first introduced it, nearly always a woman (e.g. Ngudi Kapindi, Ngudi Astrid). It is assumed that these do not concern 'new' varieties and they are therefore ommitted. Of another 6 names it has been impossible to ascertain whether they refer indeed to separate varieties.

great and most people today do not recall their introduction. During the 1960-1966 period, agricultural production in the region was severely disrupted by the rebellion. Many villagers had to flee and cassava was only planted occasionally. It could have happened that some local varieties have been lost during this period.

From the late 1970s onwards, there has been an increased exchange of varieties within the region, in first instance as a result of the spread of bacterial blight (CBB) and other pests and diseases. Farmers and local authorities remember the serious shortages that occurred throughout the southern Kwango-Kwilu

Sweet/bitter var.[4]	Pest/disease susceptibility[5]	Root yield[6]	Occurrence[7]	Remarks
sweet	?	medium	F, B, M	2 subvarieties
var.	?	?	M, F	–
var.	root rot	high	F, G	high farmer rating
sweet	CGM, CM	high	F, M, G	no root rot
var.	root rot	high	M, G	high farmer rating
sweet	?	medium	M, B	–
bitter	CBB	?	M	uncommon
bitter	CBB	low	M	–
var.	?	high	B, M	in patches
var.	?	high	B, F, M	in patches
bitter	various	medium	F	–
bitter	CBB, CAD	low	F, M	disappearing
bitter	?	low	F, M	slow growing
bitter	?	high	B, M, G, F	high leaf yield
bitter	CBB, CM, CAD	low	F, G, M	very common
bitter	CBB	high	G. F, M	very common
bitter	?	medium	F	disappearing
sweet	CBB	medium	M	uncommon
var.	?	high	M	introduced from Kasai
bitter	?	medium	B, F, M	–
bitter	CGM, CAD	medium	F, G	no CBB observed
bitter	CGM, CBB, CM	medium	F, M	common
var.	CM, CBB	medium	F, M, B, G	very common

2 Field types: S: savanna, F: forest fields, s: slope, v: valley, p: plateau.
3 Length of growth cycle: roots usually harvested after or between months indicated.
4 Sweet, bitter and variable (see text).
5 Susceptibility to pests and diseases: CMV has been omitted because all local varieties are susceptible; CGM is probably underrepresented because most of the observations have been carried out before 1982 (when CGM was not yet widespread in the area) and mainly during the rainy season (when the mite population is reduced). For abbreviations see glossary.
6 Root yield: high, medium or low as rated by farmers; leaf yields do not seem to vary as much as root yields and are therefore not recorded.
7 Occurrence: the zones are indicated by initial (Bulungu, Feshi, Gungu, Masi-Manimba).

during the 1970-1971 season (when CBB was first observed) and reports from missionaries at that time even mention a famine in the Feshi zone.[3] In 1977-78, the chief of the collectivity of Mukoso (Feshi zone), one of the areas most affected by blight and mealybug, successfully organized the introduction of new varieties (in particular *Voti* and *Tadi*) from other parts of Feshi and from the Gungu zone.

Today, farmers in the Kwango-Kwilu recognize by name numerous rather ill-defined varieties grown in their fields. Nearly without exception, fields carry more than one, and often several varieties of cassava. In the field survey

Tabel 8.3 Farmer evaluation of desirable qualities in local cassava varieties in the Kwango-Kwilu.

Characteristic	Desirable qualities.
Root yield	high number (7-8) of medium sized roots of regular shape, allowing partial harvesting. Mainly bitter varieties that produce 'solid roots'.
Leaf yield	dense canopies and rapid canopy formation to ensure early leaf harvest (from 3 months onwards). 'Dwarf' varieties (maximum height 1.75 m) to allow easy harvesting of young leaves. In some areas late flowering is preferred, since leaves are not usually harvested after flowering.
Crop architecture	suitability for mixed or row intercropping. Short and sturdy branches that reduce wind damage.
Adaptability	tolerance of delayed planting and poor sandy soils. Varieties that do not suffer from 'too many diseases'.

(see table 8.4) the average number of varieties per field was 3.6, but some fields carried more than five varieties. The sweet varieties are commonly grown in small patches along the borders or in gardens and may be planted later than the bitter ones. In general, each variety is limited to one or two field types. Women are always keen to obtain new varieties and exchanges of cuttings occur frequently. Knowledge of cassava varieties is mostly confined to women.

Farmers in the Kwango-Kwilu are explicit about their reasons for preferring bitter varieties: '*because they contain more starch, give a better quality finished product* (luku or chikwangue) *and because the* cossettes *can be more easily stored*'. Adriaens (1951) reports already that in the Kwango sweet varieties were considered inferior, and '*children are laughed at if they eat sweet cassava*'.

The number of cassava varieties observed by the author in the Kwango-Kwilu is at least 35, and may be as high as 45. This is considerably higher than the number reported by Drachoussoff (1947), whose study, however, relates only to a very small area in comparison to the Kwango-Kwilu. The cassava varieties in Drachoussoff's study as well as in the Kwango-Kwilu far exceed the number of varieties of any other crop species.

Although the Kikongo names of some of the most common varieties are known in the entire region, most varieties have various names in each tribal language. Jones (1959:99) writes that the names given to cassava varieties are based not only on physical characteristics of the plant but may also refer to the place from which it was obtained or to incidents in village life. In contrast to, for example, the traditional potato naming system in the Andes (Brush 1980:37), only a small part of the cassava nomenclature in the Kwango-Kwilu is organized in a binomial fashion, i.e. with noun and qualifying adjective for each variety. The following names may serve as an illustration: *Dinkondo* ('banana'), *Manga* ('mango'), both referring to yellow root flesh, *Mubulu* ('holes'), *Mbala mundele* ('white man's root' – not a sweet variety sometimes

consumed by Europeans, but possibly an early INEAC introduction), *Mufuma* ('root of the ancestors'), *Muboma fuluka* ('root that fills the stomach').
The *classification* of cassava varieties by farmers in the Kwango-Kwilu appears to be based on a distinction of plant properties (names relating to stem colour, leafiness, plant height), root characteristics (names relating to root skin and flesh colour, root shape), provenance (names relating to villages or people), agronomic characteristics (e.g. late or early maturing varieties) and taste. The distinction between bitter, sweet and variable varieties is not reflected in local names. It is noteworthy that farmers do not distinguish any of characteristics on which the four botanical classes proposed by Rogers & Fleming (1973) are based.
Table 8.2 summarizes the classification and characteristics of local cassava varieties commonly grown in the Kwango-Kwilu.

Farmer preference of cassava varieties

The farmers participating in the field survey and group interviews have been asked what they consider desirable traits in existing varieties, and why they prefer some varieties to others. The results are reported in table 8.3. There seems to be general agreement among farmers that they prefer a relatively large number of medium sized roots, because small roots require more work in processing, in particular peeling, while very large roots are difficult to handle and may break during harvesting. There was no clear preference for erect or spreading plant types. Farmers unanimously emphasized the need for a mixture of late and early maturing varieties.

Cassava cultural practices

This section reviews changes in cassava cultural practices, resulting from changes in cropping and farming systems, and their effects on the cassava crop system. Cassava cultural practices will be addressed under the following headings: fallowing and field selection; planting dates; planting techniques; plant densities; weeding; green manuring and ridging; crop associations and crop sequences; crop production and harvesting strategies. Some of the data relating to this section are summarized in table 8.4.

Fallowing

No quantitative data are available on past or present fallow lengths. Aggregate figures on the estimated area under cultivation in the Kwango-Kwilu point to

Tabel 8.4 Cultural practices and management of cassava fields, by field type.

Field type 1	Sp (n=6)	(%)
Field size (average, ha)	0.5	
Planting dates: before 15/9	4	(66)
15/9-15/1	1	(17)
after 15/2	1	(17)
Average number of cassava varieties/field	3 (max 6)	
Other crops on the field with cassava (no of cases/field)		
Voandzou	3	
Maize	1	
Squash	6	
Vegetables (*Hibiscus spp* etc.)	1	
Groundnuts	4	
Other root crops (sweet potato mainly)	3	
Number of fields with no other crop besides cassava in association/sequence	–	
Number of fields weeded in first 3 MAP [2]	4	(66)
Ridging or mounding	–	
Cassava population (average) per ha	9600 (max 12500)	
Average start of leaf harvest (MAP)	3	
Average start of root harvest (MAP)	12.5	
Range of start (MAP)	9-15	
Average end of root harvest (MAP)	24 (max 36)	
Average frequency of root harvesting and processing (per week)	1	

Notes

1 Field types Sp: savanna, Kalahari plateau; Ss: slopes, Kalahari; Fs Karroo zone degraded forest, slopes.

2 MAP = month after planting.

an increase from less than 2 to over 5% of the total area (chapter 5). Evidence on fallow lengths suggests a considerable decline and a replacement of bush by savanna fallow, and savanna by grass fallows in the Karroo and Kalahari agro-ecological zones respectively (chapter 6). The increased land-use intensity is corroborated by farmers' statements. Older farmers in the Karroo zone remember that they had to '*wait until the bushes* (i.e. the undergrowth) *were twice their height*' before there husbands would clear the forest, '*but now only the cassava and weeds need to be burnt*'. Consequently, in areas of population pressure, around Idiofa and Kikwit for example, the fallow is practically eliminated, since three year old cassava plants are still standing in the field when it is cleared again for a new cassava crop.

As reviewed in chapter 7, there are three reasons for the overall decrease in fallow lengths:

Ss (n=18)	%	Fs (n=9)	%
0.3		0.4	
14	(77)	6	(66)
3	(17)	2	(22)
1	(6)	1	(1)
4 (max 8)		3 (max 7)	
14		–	
5		3	
3		–	
7		4	
4		1	
4		–	
1		3	
15	(83)	3	(33)
8		–	
1200 (max 15600)		9800 (max 18000)	
3.7		3.5	
11		10	
8-15		7-15	
23 (max 34)		31 (max 41)	
2.2		2	

1 the rising population density in the central valleys and around small townships leading to the emergence of inframarginal land scarcity, in particular in the Karroo system;
2 pressures from government officials such as the *moniteurs agricoles* to control field size and agricultural production in general, leading to field locations that can easily be supervised (for example on watersheds) thereby limiting the choice of possible fields;
3 women's preference of fields that may be easily cleared, in other words, fields that have not been under long fallow and where woody vegetation has not yet regenerated.

The shortening of the fallow period is aggravated by the increased use of burning for clearing; itself partly a result of labour bottlenecks, and partly because of the spread of uncontrolled bush fires. The fact that cassava has become increasingly important in the various cropping patterns may in itself cause a further decline in fallow length, because cassava in the last shift of a sequence does not favour the development of trees by shading out grasses, but delays the regeneration of bush and forest (de Schlippe 1956a).

Field selection

In the past, fields were attributed to farmers by the *chef de terre*, who was supposed to make sure that land was equally distributed, in terms of area and quality, among households, according to needs (Nicolai 1963). Although the literature is not very explicit about this, it seems that each woman had access to several plots situated at various steps of the catena.

Today, the selection of field locations is governed by several principles: the supervision required by the compulsory cultivation rules, land availability and distance. Inframarginal land scarcities have lead to the opening of fields that are increasingly removed from the homestead. Farmers mention the distance to their fields as one of the most important problems in time allocation. In areas of land scarcity, e.g. around Kikwit or Gungu, women may have to walk as much as three hours to reach their fields.

Increased distance to fields leads inevitably to poor weeding, delays in planting, and indirectly to a limitation of intercropping to those associations that require low labour inputs (cassava-squash rather than cassava-maize or groundnuts), because women try to visit these fields as little as possible.

Planting dates

In the past, planting occurred mainly from early October (with a peak in that month) to the middle of February, although planting before October was not exceptional (e.g. Renier 1957). At present, a clear trend towards an extension of plant data at both ends of the traditional period has been observed. Early planting (before September 15) and to a lesser extent also late planting (from February to April) are more common. Table 8.4 shows that 24 out of 33 fields are planted before September 15, and 3 fields are planted after mid-February. Early planting is the rule for Ss (slope) fields in the savanna (14 out of 18 fields).

Several factors explain the shift in planting dates. Firstly, the relative decline of cassava versus other commodity prices implies that more cassava must be harvested in order to retain the equivalent purchasing power. At present inflation levels, farmers must probably sell more cassava than ever. Thus, seasonal scarcities are enhanced, leading to a vicious circle in which cassava is harvested ever earlier and is therefore planted earlier as well (or later in the season, which constitutes just another way of planting earlier by 'jumping' the dry season).

Secondly, the shift in planting dates may be related to yield declines which are discussed in chapter 9. In those cases where cassava yields less than in the past, farmers tend to solve seasonal scarcities through early harvesting. This implies that new cassava fields have to be established in order to provide a continuous flow of produce. Farmers in Lobo, for instance, were planting new cassava fields in April, just before the end of the rainy season, because they expected to exhaust their current cassava fields by the beginning of the following rainy season. When questioned about the reasons, they mentioned that '*there is not enough cassava anymore to last us through the entire year*'.

Thirdly, labour shortages may intervene in two ways. If insufficient labour is available to clear the field in time, planting has to be delayed to a time when the new field is completely cleared. This is a particular problem in the savanna system, where the clearing of grass fallows is a very tedious and time-consuming job, in which women do not receive assistance from male family members. If insufficient labour is available to carry out the planting, plant data shift or are extended to a later point in the season. In cases where cassava is planted earlier, competition occurs with the sowing of groundnuts which takes place in August or early September (as happens in some cases also with millet). In fact, in many instances the planting of groundnuts has also shifted to an earlier date, possibly to accomodate the need for timely cassava plantings (in a few cases groundnut sowing has been observed as early as July 25).

There is no reference in the literature to the practice of *staggered planting*. Today, this seems to be a common phenomenon. Labour bottlenecks, unfavourable weather conditions and other factors such as an illness in the family may cause great differences in planting times even within the same field: discrepancies in planting time of over three months between both sides of a 0.5 ha field are not uncommon. Furthermore, yield losses caused by pests and diseases encourage farmers to replace individual plants in unprecedented numbers, and often require the replanting of entire plots, up to five months after planting. Seasonal contingencies and expected failures in other crops are also solved by planting new cassava plants. In general, staggered planting appears to increase as (perceived) yield security decreases.

In the past, flexibility in planting times was not a problem because nearly all varieties were long cycle varieties, i.e. harvested from about 18 months onwards. Consequently, the rainfall limitation caused by late planting was offset by a long growth period. Today, rapid harvesting causes sensitivity to the time of planting. The combination of early harvesting and late planting results in yield losses due to a reduction of the growth cycle, and due to

suboptimal use of the available rainfall during the year. In particular cassava that has been planted after February tends to suffer heavy losses because of the erratic rainfall during the later part of the second rainy season. Field observations tend to show that it is this cassava crop that seems especially affected by pests during the dry season (when it is three to five months old). Furthermore, early harvesting leads to yield losses because the plant has insufficient time to accumulate dry matter. Late planting, after October, means that the cassava crop has to forego the positive effects of the 'flush' in mineralization of soil organic matter that takes place at the start of the rainy season, resulting possibly in further yield losses.
If cassava planting dates are shifting, the issue of relative planting dates in intercropping and resulting competition between intercrops becomes critical. Traditionally, the intercrops were planted roughly at the same time as cassava (with the exception of those intercrops planted later in the sequence after the harvest of the first intercrops). This seems no longer the general rule, especially if losses are high and many plants have to be replaced throughout the season.
Finally, the presence of great numbers of cassava plants in various developmental stages in the same or adjacent fields is likely to favour pest and disease built-up.

Planting techniques

It is not clear whether present planting techniques are different from those of the past, because no reference has been found to cassava planting in the pre-Independence literature. Planting techniques in the Kwango-Kwilu are characterized by the use of very long cassava cuttings (from about 80 to over 130 cm). Usually, two to four cuttings are planted crossways at the same spot. Cuttings may be planted at an angle of about 30° to the soil, but horizontal planting is more common. In both cases cuttings are planted at an average depth of five to seven cm. Some younger women appear to be unfamiliar with the geotrophical polarity of cassava and have been seen to plant the cuttings upside down. On the sandy soils of the Kwango-Kwilu, shallow planting almost inevitably results in poor anchoring, especially if no ridging has been carried out, and cuttings may suffer heat damage. The use of long cuttings is likely to lead to increasing competition between shoots, while self-shadowing may also be a problem. The availability and selection of plant material will be discussed in the section on pests and diseases below.
The only indication of changes in planting techniques comes from farmers. They agree that planting is carried out in a rather careless way nowadays. *'They just stick the cuttings into ground, without even bothering to cover them. They*

are too much in a hurry', an old farmer said disapprovingly of her granddaughters. It cannot be ascertained to what extent this reflects labour shortages or other factors.

Plant densities

Renier (1957) and other sources speak of densities below 5,000/ha that were apparently common throughout the Kwango-Kwilu before 1960, but do not distinguish between savanna or forest fields. At present, however, densities of 12,000 plants/ha are commonly observed. Table 8.4 shows that average cassava populations range from 9,600 to 12,000, but occasionally much higher densities have been noticed. Intrafield variations in density are common, which makes it difficult to generalize about densities.

Cassava densities vary according to field type. In the Karroo zone, relatively high densities are found on slope fields (Fs), and lower densities in the valleys (Fv) where other crops such as maize may compete with cassava. Medium densities are found on plateau fields. In the savanna, the reverse trend is observed. Highest densities are found on the more fertile slope and valley (Ss and Sv) fields, where there is a lower number of intercrops than in the forest. On fields that are considered very poor and are managed extensively, (field type Sp), densities tend to be low; around 6,000 plants/ha. Information supplied by farmers on this subject is somewhat inconclusive. Some speak of higher densities, but others deny this, although all women seem aware of the reduction of the number and range of intercrops. With some reservations, therefore, it may be concluded that higher cassava densities are found today than in the past, in particular on the Kalahari plateau.

Several assumptions may be made about the factors explaining current high plant densities as compared to the 1940s and 1950s. One can suppose that farmers expect to offset the future losses and poor yields per plant by planting a higher number of plants. Another reason could be that higher crop densities compensate for the effects of weed competition when weed control is not sufficient. Because plants remain smaller as a result of poor soil fertility, farmers may plant higher numbers of cuttings. Also, an increased dependence on cassava leads to lower densities of the various intercrops and results in higher cassava densities. Finally, the disappearance of ridging and mounding on some fields implies that less space is lost and that densities are therefore higher than in the past. Nicolai estimated that with ridging and mounding only 36-40% of the real area is used (Nicolai 1963:249).

Weeding

There is hardly any reference to weeding in the pre-Independence literature. According to older farmers, cassava was weeded at the same time as groundnuts, i.e. four to six weeks after the planting of both crops, and weeded once again at the harvest of the groundnuts. According to colonial rules, farmers were also supposed to weed at the end of the rains, in order to reduce the damage of bush fires in the dry season when the dry weeds would provide an additional source of fuel to the fires. There is no evidence of this practice today.

At present, weeding seems to occur only once, usually after eight to twelve weeks after planting. Only two thirds of the fields surveyed in Lobo were weeded within thirteen weeks (table 8.4). Farmers unanimously complain about the burden of weeding, and older farmers emphasize that they find more weeds in the fields than before.

Two issues are involved here: increased weed incidence and labour shortages (perhaps leading farmers to notice the weeds more than before). The possible increase in weed incidence may be explained by a number of factors. Firstly, it is likely that weeds increasingly become a problem when fallows shorten, and when field clearing is insufficient. Where farmers rely on burning, the stolons of most grasses are not destroyed. Secondly, if canopy formation in cassava is delayed because of poor plant development due to soil fertility and diseases, one may expect more weed problems. Shifting plant data, in particular if planting is delayed until after the onset of the rains, and the reduction of the number of intercrops are further factors contributing to increased weed incidence. The reduction of intercrops can in itself also be a result of increased weed incidence, although it is definitely related to the increased importance of cassava.

Quite apart from weed incidence, labour shortages and time allocation are also likely to influence the frequency and the quality of weeding. Farmers generally recognize that delays in weeding lead to a need for additional labour inputs into weeding later in the season. This seems to apply in particular to plateau fields where great travelling distances are involved.

It may be tentatively concluded that the need for weeding may be greater today than in the past, while labour constraints are perhaps more severe. However, there is no way to assess the overall impact on yields. Increased weed problems can have other consequences as well. The fact that weed competition tends to be greater at the beginning of the rainy season than later in the year may be an additional reason why women prefer late plantings. Late planting then provides an opportunity to weed the field simultaneously. Weeding may also be intentionally neglected, because certain weeds constitute an alternative source of leafy vegetables that complements cassava leaves, in particular if cassava leaf yields are low. This is supported by the observation that vegetables such as *Hibiscus esculenta* are sometimes intercropped with cassava, be it at low densities; a practice which seemed unknown in the past (when vegetables were mainly grown along field borders or in gardens).

Manuring, mounding and ridging

As discussed before, there is some confusion in the literature about the ubiquitousness of ridging and mounding in the pre-1960 period. Two variants seem to have existed traditionally:

a organic matter was put on heaps at the end of the rains and left to dry, then set on fire, and mounds were constructed by adding more top soil (BaPende tribe, mainly Gungu zone);

b grasses were burnt at the start of the dry season, and the remaining ashes and debris were covered with soil at the start of the rains (most other tribal groups). According to farmers, there have also been locations where cassava was always planted on flat soil, without any ridging or mounding but where some form of mulching or manuring was common (usually at the lowest step of the catena, Sv and Fv fields).

Table 8.4 shows that ridges or mounds are found on only one quarter of the fields, all field type Ss. Further observations suggest that these practices are disappearing fast all throughout the Kwango-Kwilu, although superficial mounding and ridging without the incorporation of organic matter are still common. Older women and women with sick children say that they are unable to carry out the ridging for lack of help. Apart from labour bottlenecks the main reason seems to be the sheer lack of plant debris due to frequent burning and insufficient fallowing.

Intercropping

The pre-Independence literature emphasizes the association of cassava with other crops (e.g. Nicolai 1963, Miracle 1967), and mentions the practice of crop rotations (although it is not always clear what crops and in what order were involved). In the savanna at least, cassava was grown as a first crop, immediately after clearing, as well as the last crop. In contrast to other sources, Renier (1957) suggests that millet always preceded cassava. In the past, sole cropping of cassava was exceptional and occurred only on very poor soils (Drachoussoff 1965: 147).

Although the cassava crop system still involves several other crops besides cassava, there seem to be important changes from the past with respect to the number, densities and sequences of intercrops. Of the fields surveyed in Lobo, only four do not carry any other crop but cassava throughout the cropping cycle (table 8.4). However, the range of intercrops is limited, mainly involving *voandzou* (particularly common on Ss fields), squash and various vegetables. No millet has been observed on any of the fields. The nature of most intercrops (vegetables, *voandzou*, squashes and sweet potato) shows that these are not grown in great numbers. Densities, although not recorded separately for intercrops, seem to be generally low, in particular for maize. Circumstantial evidence suggests the emergence of what could be named the 'monocropping' of cassava. *Monocropping* is used here to refer to a cassava crop system in which the populations of other crops, associated with cassava in relay, sequential and/or intercropping, are greatly reduced. In other words, cassava dominates the total cropping cycle, both in time (cassava followed by cassava, sometimes after only a very brief fallow period) and in space (cassava dominating the field while other crops are planted at very low densities). The reduction of the number and densities of intercrops may be assumed to affect cassava yields positively through the reduction of competition, as well as negatively because the positive effects of intercropping on ground cover and on the control of weeds and pests and diseases are foregone.

Cassava production and harvesting strategies

Pre-Independence sources make little mention of farmers' production and harvesting strategies, i.e. the way in which farmers apply resources to satisfy cassava needs. Only some general comments about farmer behaviour have been found. Hardy (undated, probably 1955) speaks of the *'indifference towards any issue involving cultural practices'* which he thought the result of the poverty and fatalism of the population. Drachoussoff (1965), however, suggests that a system of *'dual management'* was in place, whereby compulsory fields (i.e. fields cultivated under the compulsory cultivation rules) were considered by farmers as government fields, where improved practices were applied, in contrast to traditional fields.

The oldest farmers interviewed in 1982-83 do not seem to recall a distinction between the management of different types of fields in the past, with the exception of differences related to vegetation and soils. They indicate that they used to harvest cassava roots and leaves about once a week from forest and savanna fields alike. Root harvesting started about 15 to 18 months after planting, with the exception of a few early maturing or sweet varieties that were grown in gardens (field type R or H) and used for special purposes.

Today, differences with respect to management and cultural practices are clearly related to field type. Table 8.4 shows that root harvesting starts within the first year after planting, although variations occur between individual fields. Fs fields in the forest seem to be harvested from a slightly earlier stage onwards. Root harvesting continues until two years or more after planting, and may end only after 41 months. Leaf harvesting starts after the third month after planting. There are considerable differences between field types with respect to the frequency of root harvesting which takes place twice or even more frequently each week on Fs and Ss fields respectively, and only once weekly on Sp fields. The volume of roots harvested each time varies little; women say they '*always harvest one basket*'. Although basket shapes vary greatly, extensive weighing shows that they usually contain a standard volume of 18-20 kg. Staggered harvesting of roots and leaves is always the rule. Where pest and disease attacks lead to poor yields, fields are exhausted sooner than expected and new ones are planted as soon as this becomes apparent.

A tentative explanation of differences between field types with respect to production and harvesting strategies is based on differences in distance and soil fertility. In general, plateau fields are situated at a greater distance from the homestead and are managed more extensively, as illustrated by the data on weeding. Plateau fields in the savanna (Sp) yield less because of their lower fertility, and they are harvested infrequently. Where farmers have also access to slope and valley fields, the plateau fields are dealt with as a reserve, harvested when other fields do not yield enough. Slope fields in the forest (Fs) are harvested for a longer period, starting earlier and extending later than on other fields, probably because dry matter accumulation in roots is more rapid on these relatively fertile fields and overall yields are higher.

Summarizing, the cassava crop system has been affected by a great number of changes occurring at cropping and farming systems level. This section has analysed the impact of changes in labour, management and other inputs on the cassava crop system. On the basis of mostly circumstantial evidence, it may be tentatively concluded that there has been a considerable shift in cassava cultural practices in the Kwango-Kwilu over the last thirty years. A trend seems to be emerging towards reduced fallows, monocropping of cassava at higher plant densities (with limited numbers of intercrops) while ridging and weeding are more neglected than in the past. Cassava is harvested from an earlier date onwards than before and planting dates are adjusted accordingly. Plateau fields (Sp) are increasingly cultivated but are managed in a less intensive manner than the slope fields. Plateau fields are considered as 'security fields' that are used to provide cassava when the harvests from other fields are insufficient. In short, the increasing dependence on cassava on the one hand and the breakdown of classical shifting cultivation practices on the other, have mutually reinforced one another.

This situation does not appear unique to the Kwango-Kwilu, and has been observed by the author in parts of the Congo and Central African Republic, but there are few references to similar changes in cassava cultural practices in the recent literature. One example is provided by Silvestre & Arraudeau (1983:148) who describe cassava production in south Togo where, as a result of increasing population densities, cassava populations surpassing 15,000 and root harvests after six to eight months are found.

Cassava pests and diseases

Cassava is more tolerant to pests and diseases than most other crops because growth can be stopped at almost any time without destroying the storage roots. Moreover, cassava has abundant chances for recovery after damage. Until quite recently, pests and diseases were not considered a serious problem in cassava, with the exception of mosaic disease. In the last decade, however, cassava pests and diseases have become an issue of great concern, in particular in Africa. This section discusses pests and diseases in cassava crop systems in the Kwango- Kwilu.

Pre-independence publications by INEAC make reference to only two diseases: cassava mosaic disease (CMD) and root rot caused by *Phytophtora spp*. From its establishment in 1947 onwards, the INEAC station at Kiyaka in the Kwango-Kwilu mentions the presence of CMD on farmers' fields, but it is not indicated to what extent yields were affected. Hardy (undated) in his description of agricultural conditions in the region observes '*abnormal attacks of pests and diseases on plants that have been physiologically exhausted*', but does not give any details. It was also reported that the CMD is more severe in the so-called *mikondo* (dry forests) of the southern Kwango-Kwilu, than on the treeless table lands where the winds keep the *Bemisia* populations at low levels (Rassel & Hardy 1954, 1955). Apart from cassava diseases, several insects had been observed in cassava fields (Lefèvre 1944), but there are no reports on pest damage in the Kwango-Kwilu before 1960.

Detailed quantitative and qualitative data on the current incidence and the extent of the losses due to pests and diseases in the region is unfortunately lacking. Farmers point to increased pests and disease incidence as a major source of yield reductions. This is confirmed by other key informants. Visual screening of fields in the Kalahari and Karroo zones suggests that very few fields, if any, are now free from pests and diseases. There is general agreement that the following major diseases and pests are widespread in the Kwango-Kwilu today (IITA annual reports 1980-1983).[4]

Cassava bacterial blight

Cassava bacterial blight (CBB) (causal agent *Xanthomonas manihotis* and perhaps also *X. cassavae*) was first observed in the Kwango-Kwilu in the 1970-71 season (Meyer & Maraite 1975, Singh 1981), and has now become the most widespread disease in the area. Although the disease is reported to be particularly severe during the rainy season (Lozano et al. 1981:16), symptoms of blight and die-back may be seen throughout the entire year. Apart from serious root and leaf losses, CBB also results in the destruction of planting material due to the die-back of the stem.

The review of local cassava cultivars (table 8.2) suggests that all of these may be susceptible. The full range of symptoms caused by *X. manihotis* has not yet been adequately defined (Hahn et al. 1979). CBB is seed transmitted, but infection may also take place through punctures by *Pseudotheraptus devastans* (Meyer & Maraite 1975). Some studies suggest that CBB incidence is directly related to soil fertility and climate, and epidemics may develop under conditions of heavy rainfall (Meyer & Maraite 1975). The authors argue that the following factors explain the sudden increase in CBB in Zaire: the general decline of soil fertility; the appearance of more virulent strains of *X. manihotis*; and, perhaps, a change of climate (Meyer & Maraite 1975). Daniel et al. (1978) report that in the Congo CBB appears during the wet season and stagnates during the drier months. Persley (1978) points out that *X. manihotis* has several sites of survival during the dry season, and that, at the onset of the rains, the disease develops rapidly from the epiphytic leaf population and infected plant debris. Apparently, the pathogen is ecologically more competent to survive after a long dry season in the savanna than in the forest with a short dry spell. This would explain the persistance and severity of CBB on the southern plateaus in the Kwango-Kwilu.

The spread of CBB may be delayed by pruning and burning most of the above ground portion of infected plants. However, this method is most effective with resistant varieties that are only lightly infected (Centre for Overseas Pest Research 1978:116). Terry & McIntyre (1976) suggests that a six months interval between successive cassava crops may be sufficient to prevent the carry-over of the pathogen. However, in the Kwango-Kwilu, CBB infection appears as severe on fields that have previously been fallowed as on fields where cassava crops succeed one another, perhaps because fallows are too brief and cassava plants remain in the field. Tolerance to CBB would be induced by NPK applications at the same level as required for high root yields (Arene & Odurukwe 1979). Butare & Banyangabose (1982) conclude from their experiments in Uganda that an increase in the general level of fertility (in particular by applying P and K) will not prevent infection but retards the development of CBB. The poor soils of the Kwango-Kwilu may be considered particularly conducive to the occurrence and spread of CBB.

Cassava anthracnose disease

It is uncertain when cassava anthracnose disease (CAD) (causal agent *Colletotrichum spp*) was introduced into the Congo Basin. It was first observed by ORSTOM in the Congo in 1975 (Makambila 1978). It is now widespread on all savanna fields in the Kwango-Kwilu, in particular under conditions of low fertility. CAD causes stem cancer and die-back in the green part of the stem. Both root and leaf yield are affected. The tolerance of local varieties seems to be low. Moreno (1979) suggests that since low soil K may be associated with CAD, higher infection levels would be expected if cassava is intercropped with sweet potato and maize which compete for the available K, but there are no indications sofar that cassava intercropped with these crops suffers more from the disease. Both Boher et al. (1978) and Makambila (1978) report that CAD often occurs in association with CBB in the Congo, which, according to cursory observations by the author, may also be the case in the Kwango-Kwilu. Rain is an important factor in CAD development: the incidence of stem lesions increases during the rainy season.

Cassava mosaic disease

The virus causing cassava mosaic disease (CMD) is of African origin. CMD is transmitted through infected cuttings and *Bemisia tabaci* (Nestel 1976, Terry 1981). All African varieties are susceptible (Beck 1982). CMD has been observed in East Africa as early as1894 (Hahn et al. 1980a). CMD has become the most widespread economic disease in Africa with yield losses varying from 20 to 95% (Hahn et al. 1979). CMD also causes reduction of 30 to 50% in fresh leaf weight, even in 'resistant' varieties (Terry & Hahn 1980). Effective control of CMD stems only from the use of resistant varieties. There appears a correlated resistance with CBB (Hahn et al. 1980a & b). No assessment of yield losses due to CMD exist for the Kwango-Kwilu. Farmers do not seem particularly concerned by the presence of CMD, but some of them appear aware of the cumulative effects of CMD in combination with other pests and diseases. In some areas, leaves that show a slight degree of chlorosis (a characteristic CMD symptom) are actually preferred as a vegetable because of *'their juicy taste'*. Leaf harvesting, as currently practiced by farmers, would have the effect of enhancing the symptoms (Verhoyen 1978).[5]

Cassava mealybug

Cassava mealybug (CM) (*Phenacoccus manihotis*) is the most serious pest in the area. It has first been observed in the Kwango-Kwilu in 1972 (Nwanze & Leuschner 1978) or 1973 (Hahn et al. 1979). It is unclear whether it was introduced from the Kasai or Bas Zaire. Before 1980, its incidence was limited, but increased rapidly after that. It is spread in two ways: by transport of infested planting material and by unsettled, often airbone, first instar nymphs. Hahn et al. (1979) attribute the introduction of CM in Africa to infested planting material. As well as a reduction of root yields, CM causes reduction of leaf production by damaging the terminal shoots. Severe symptoms include shoot stunting, shortening of the internodes, reduced leaf growth and die–back. The incidence of mealybug increases with the decline in rainfall, and is particularly severe during the dry season on eroded soils and on soils with moisture stress. Drought stress favours pest build-up, which increases at the end of the dry season when temperatures rise. Widespread infestation by CM seems to occur in the southern Kwango-Kwilu with a dry season of over ninety days. Damage due to CM is most severe during the months of September to November, which coincides with the planting of new cassava fields.

Cassava green mite

Cassava green mite (CGM) (*Mononychellus tanajoa*) is another recent phenomenon in the Kwango-Kwilu, very likely from Bas Zaire. The mite has probably first been introduced into Africa in Uganda through infested cuttings originating in Latin America (Hahn et al. 1979). There is no report on widespread damage in the Kwango-Kwilu before 1981, but serious symptoms and defoliation have been observed on savanna fields in the 1982 and 1983 dry seasons. Highest levels of mite populations are observed during the dry season. IITA estimates that in Africa, CGM is presently expanding at a yearly rate of over 400 km, transmitted by wind and infected cuttings (IITA 1983).

Conclusion on pests and diseases

In view of the lack of detail of the data, general conclusions on pest and disease incidence in the Kwango-Kwilu can only be tentative.
There is no doubt that, in the Kwango-Kwilu, important changes in cassava

pest and disease incidence have taken place in recent years. CMD is no longer the only source of yield losses. During the 1970s, CBB has become the most serious disease, spreading rapidly into the Feshi and Gungu zones. It is likely that CAD also gained importance at that time. From 1980 onwards CM, and even later CGM were introduced. Consequently, in both the forest and savanna cropping systems each of these pests and diseases is present, although to a different degree. Nearly without exception, plateau and slope fields in the savanna (Sp and Ss) are most seriously affected. An important factor in the rapid spread of pests and diseases – in less than a decade – has been the free exchange of planting material and the use of infected material. In general, farmers seem aware of the fact that pests and diseases can be transmitted through cuttings. However, the lack of cuttings may occasionally be very acute, because of the death of a high proportion of cassava plants on the older fields that usually produce cuttings. Under those conditions, any cutting that looks healthy to the superficial observer, even if it originates from a diseased plant, constitutes scarce and valuable planting material. While traditionally cuttings were selected with some care, this is not always possible given the infestation of the majority of cassava fields.

Increased densities, possibly reinforced by increased field sizes, have led to a demand for more planting material, reinforcing the shortage of healthy material. Furthermore, the yield losses due to pests and diseases encourage farmers to experiment with planting material and 'new' varieties from other areas, in the expectation that these may prove less susceptible than their own. The exchange of cuttings throughout the Kwango-Kwilu has probably increased considerably since the end of the 1970s.

Thusfar, only the uncontrolled movement of planting material (cuttings) has been held responsible for the recent introduction of pests and diseases (Singh 1981). With the exception of small quantities introduced by the *Programme National Manioc* (Pronam) and private missions there have been no significant introductions of planting material in the Kwango-Kwilu before 1983. The exchange of cuttings between farmers takes place mainly between villages within the same zone within a radius of perhaps 50 km. Observations by the author suggest that an important vector in the spread of pests and diseases are *cassava leaves*. In high demand in many semi-urban centres, leaves are marketed over distances of several hundreds of kilometers. Each of the four major diseases and pests can potentially be transmitted through terminal shoots or the green part of the stem (some 15–30 cm of the stem is always harvested with the leaves). Consequently, transmission through the marketing of cassava leaves should not be overlooked and may be more important (because happening over larger distances and in much greater quantities) than the movement of planting material.

It is impossible to estimate losses in the Kwango-Kwilu due to cassava pests and diseases. There are no details on the pre-Independence losses to CMD. Figures on Zaire may serve as an indication, however, for present losses. IITA estimates losses in Zaire to cassava mealybug (CM) and green spider mite (CGM) alone at 30% (IITA 1984). Ezumah (1981:34) estimates for Bas Zaire that CM may cause a 50-80% reduction in cassava root yield. IITA/Pronam surveys indicate that anthracnose (CAD) is more severe in Zaire than in Nigeria and more serious in the Bandundu than in Bas Zaire (Ezumah 1981:30), but he does not quantify the effects.

Finally, the extent of the damage by pests and diseases to the cassava crop systems seems to be related to a series of factors at the cropping systems level. The literature suggests that environmental factors, in particular (micro)climate and soil fertility, are conducive to the rapid spread of mealybug, CAD, blight and green spider mite (Maraite & Meyer 1978). The hypothesis is put forward here, that changes in the shifting cultivation system may have favoured environmental factors that contribute to the spread and severity of pests and diseases in the Kwango-Kwilu. Further investigation would be required to analyse whether this applies in the same degree to pests as well as diseases.

The environmental changes resulting from changes in the cropping system that may be thought to affect the spread and severity of cassava pests and diseases are:

a soil fertility;

b planting dates;

c the presence of inoculum in or near the fields.

a Soil fertility in cassava fields is likely to have declined through the reduction of fallow periods. The decrease in manuring and ridging is presumed to have affected soil fertility as well. Meanwhile, increased burning may have positive effects on K levels, which might in turn have suppressed infection with CAD and CBB.

b Delays in planting and in particular the planting of cassava during the second rainy season exposes young plants to drought stress and low temperatures that favour mealybug and, subsequently, with the onset of the rains, the spread of CBB.

c The relative shortage of land close to large villages leads to the establishment of new fields adjacent to old cassava plantations. As a result of the supervision by extension agents, farmers now commonly join individual plots into large units that may extend over several hectares, that may favour the spread of pests and diseases. Changes in cultural practices have further resulted in the increased presence of cassava in the fields. Staggered harvesting and the fact that cassava plants are left to merge with the surrounding fallow vegetation, imply that diseased plants are not immediately eliminated, even if new fields are cleared by burning. These practices all contribute to the presence of a continuous source of inoculum in or near cassava fields. Staggered planting enhances the effects, because plants in all developmental stages may grow closely together on the same field.

Notes

1 In the Kwango-Kwilu cassava is nearly exclusively processed into *cossettes* (dried roots). Immediately after harvesting, the roots are carried to a small stream where they are peeled and then soaked for two to three days, depending on the temperature. After soaking the roots are sliced lengthwise and brought to the village to dry in the sun. If properly dried, the resulting *cossettes* can be stored for several months. They are ground into flour and mixed with boiling water in order to prepare *fufu*, the staple dish in the Kwango-Kwilu. In the region, *bâtons* (*chikwangue*) which are commom in Bas Zaire and many other parts of Central Africa, are only found occasionally along the road side, destined for travellers.

2 Leafy vegetables and spices commonly found are: *Basella alba*, *Amaranthus spp* (nine varieties), *Hibiscus esculentus* (three varieties), *H. sabdariffa* (four varieties) tomato, onion, eggplant, *Capsicum spp* (four varieties), unindentified 'Chinese' cabbage, ginger. Hibiscus and amaranthus are the most common vegetables. Fruit trees: *C. auriantifolia*, *C. limon*, *Dacryodes edulis*, *Cyphromandra betacea*, *Averrhoa carambola*, *Artocarpus incisa*, *Anona muricata*, *A. reticulata*, *Eugenia spp*, *Musa spp*, *Carica papaya*, *Mangifera indica*.

3 It is noteworthy that these shortages are barely, if at all, reflected in the official statistics which only indicate a 4% production decrease in 1971 as compared to 1970.

4 Foliar diseases caused by *Cercospora spp* are common but do not seem to cause much damage. Other pests and diseases may be found in the Kwango-Kwilu but their presence has not been officially confirmed (e.g. *Zonocerus variegatus* and bacterial stem rot caused by *Erwinia sp*). In contrast to some of the pre-1960 literature, little reference is made today to root rot caused by *Phytophtora*. In any case root rot cannot be considered a serious problem because it occurs mainly on poorly drained soils which are very uncommon in the area.

5 This suggests that on-farm varietal trials in which farmers would be allowed to harvest leaves as they usually do, could be an effective way to screen for CMD resistance.

9 CASSAVA YIELDS IN THE KWANGO-KWILU

Methodological issues in measuring cassava yields

The output of the crop system is crop biomass, in the case of cassava, roots and leaves used as food.[1] Production of roots and leaves can be measured as an output per unit of labour or land. There are grounds to argue that both ways of assessing productivity are important in the Kwango-Kwilu. Cassava production, processing and marketing involve high and nearly exclusive female labour inputs. According to the estimates on female labour inputs presented in chapters 6 and 7, women in the Kwango-Kwilu experience serious labour bottlenecks. This is particularly true in the Kalahari agro-ecological zone, where, in any case during certain months, relative labour scarcities may occur. This would suggest that the calculation of output per unit of labour would be more relevant than that per unit of land, assuming that farmers would aim to maximize production per unit of scarce factor. Conversely, in the Karroo valleys, land rather than labour seems to be the scarce factor. Nevertheless, even there labour bottlenecks should not be underestimated.

While the calculation of cassava outputs per unit of land as well as of labour would therefore be desirable, the available data are deficient in both respects, but even more so with respect to labour. Given the problems in obtaining reliable labour input estimates for production and processing, the latter calculation is entirely out of the question. For want of alternative, the following discussion of changes in cassava productivity is therefore based on per hectare yields.

However, even estimating production per unit of land presents considerable problems. Official statistics, as has been discussed in chapter 4, are highly questionable, in particular with respect to production and area. In this chapter, a look will be taken at cassava yield figures, in so far as they are available, in order to determine the overall trends against the background of the total production increase since the 1950s.

Because cassava allows great flexibility in cultural practices and resource allocation, yields vary vastly from one area and farm to another. Low yields cannot be taken to merely reflect the low potential of local varieties or of the agro-ecological environment, nor inadequate cultural practices. For example, rather than a result of poor cultural practices, low cassava yields may very well be a function of prices, processing and marketing opportunities that force farmers to leave an unknown quantity of roots unharvested. In that case, constraints at regional level (prices and marketing), at farm household level (processing) and at cropping system level (harvesting strategies) influence the performance of the crop system. Consequently, the analysis of cassava yields, or the so-called yield gap analysis, cannot be limited exclusively to cultural practices, or the crop and cropping systems levels.

In other words, cassava yields must be related to the entire hierarchy of systems, and can in fact be taken as a proxy for the performance of the agricultural system as a whole. Comparing yields, between farms, or regions, or between farmers and research stations, requires considerable care. Unless specifications are given of the conditions under which cassava is grown, a comparison risks being meaningless. Certainly, without specifications, such a comparison provides little basis for conclusions about yield potential or comparative advantage. Unfortunately, official statistics for the Kwango-Kwilu, as well as for Africa for that matter, are based on averages of very diverse situations.

Before examining actual yields in the Kwango-Kwilu, some of the methodological issues involved in the measurement and comparison of cassava yields are discussed in detail below. They refer in particular to the difficulties involved in interpreting official statistics and agronomic experiments in comparison to farmers' fields.

Length of growing cycle

Because cassava does not have a fixed ripening point, it can be harvested at any time between approximately 8 and 36 months. As shown in table 8.4 farmers in the Kwango-Kwilu may harvest from 7 to an exceptional 41 months, depending also on field type. Official data rarely, if ever, specify after how many months cassava has been harvested and whether annual or total pluri-annual production is referred to. International research centres such as IITA have introduced the standardized practice of harvesting after 12 months, whereas INEAC trials were usually harvested after 20 months. It is unclear how yields obtained after growing periods of differential lengths may be compared, in particular if variations in variety and physical environment also occur.

Moreover, even in the case of a standard period of 12 months, yields are probably also influenced by planting dates. Because starch accumulation is likely to slow down during the dry season, yields from cassava planted late in the rainy season are likely to differ from those of a crop planted at the onset of the rains.

Partial, staggered or sole harvests

Nearly without exception, farmers in the Kwango-Kwilu practice partial harvesting (one or two roots may be harvested while the plant is left standing and continues to grow) as well as staggered harvesting (some plants are harvested entirely, others are left standing in the field), often in combination. Both practices may be assumed to influence total yields, in various ways.
Partial harvesting per se does not influence starch accumulation and may even lead to an increase in total root yield. However, partially harvested plants grown from horizontally planted stakes in sandy soils (and therefore poorly anchored), may suffer wind and erosion damage. Sometimes, these plants are prone to lodging and their roots may become uncovered and damaged, thus leading to yield losses and sometimes even to the loss of the entire plant. Even if population densities are converted to standard figures, yields from a partially harvested field may be lower, therefore, than from standard fields, thus leading one to underestimate the performance of (traditional) varieties in farmers' fields.
Staggered harvesting reduces total plant population. The remaining plants will not suffer more from weed competition since their canopies are likely to be fully developed by the time harvesting starts, and they may even make better use of the available nutrients. The relation of plant population to yields being extremely complex (Toro & Atlee 1980), it is difficult to say how yields are influenced, in comparison to fields with a fixed plant population that is harvested entirely after 12 months. Sole harvests are the rule on research stations, making comparison to farmers' fields dubious at least.

Sole stands or intercropping

In the Kwango-Kwilu, and in many parts of Central Africa, mixed or row intercropping of cassava is the rule, with a variety of intercrops, resulting in great variations in plant population. Official statistics almost never transform yield figures to a standardized level of, say, 10,000 plants/ha and to a standardized unit of time. Neither do they account for varying densities and developmental stages of crops in intercropping. As a result, yield reduction through lowered cassava densities and, to a lesser extent, through intercrop competition, especially shading, is underestimated. Cassava densities in the Kwango-Kwilu may be as low as 3,000 or exceptionally exceed 20,000 plants/ha, depending on field type and intercrops (and perhaps also variety). In case of poor initial establishment, new cuttings are planted when the first intercrop is harvested (usually after three months), leading to even more complex crop densities with varying developmental stages, that ought to be considered when discussing yields.[2]

Leaf and/or root harvest

Farmers in the Kwango-Kwilu always harvest cassava leaves, and these may be as important as a source of food and cash as roots. Leaf harvests are only rarely mentioned in research reports or official statistics. Nevertheless, the practice of frequent leaf harvesting is bound to influence root yield, both directly (through decreased photosynthesis) and indirectly (through an influence on disease and pest incidence). Lutaladio & Ezumah (undated) mention that while bimonthly leaf harvests do not seem to influence root yields, mosaic virus disease (CMD) incidence is increased and anthracnosis (CAD) incidence may be decreased. Yields from farmers' fields where frequent leaf harvesting is common practice are likely to be considerably lower than those from trial fields or from fields where cassava is not grown for both roots and leaves. In the Kwango-Kwilu, farmers may harvest leaves as frequently as twice weekly from the same field.

Total root yield or 'usable' root yield

Farmers in the Kwango-Kwilu tend to assess yields in terms of 'usable' roots, i.e. roots that are large enough to be processed and sold. Because processing, and peeling in particular, are very labour-intensive, only larger roots are usually harvested, while the smallest ones (with a diameter of less than approximately 4 cm) are discarded, except in the case of acute shortages. Roots that are damaged or broken during harvesting or transporting are also eliminated, as well as roots of unusual irregular shapes that are too difficult to peel. The proportion of roots that is considered 'usable' depends on variety and total (expected) yield. Thus, the actual yield/plant may vary considerably. Research reports usually do not indicate whether all roots or only a proportion of the total root yield are included in the final production figures.

Fresh root yield or root dry matter

Although root yield is usually measured as fresh weight, this is by no means always the case, and it is often not mentioned. The most interesting yield figure for farmers is not so much fresh weight but root dry matter or starch content. This tends to be greatest when temperatures are relatively low (Cock 1985:70). In general, seasonal influences on root and starch production are to be reckoned with (Silvestre & Arraudeau 1983:83). In other words, the time of harvesting influences dry matter yield, which is highest in the coolest months, and harvest dates should therefore be mentioned. IITA trials in Zaire are always harvested 12 months after planting, which takes place at the beginning of the rainy season: this implies that the harvest takes place at the end of the dry season when dry matter content is highest. In contrast, farmers spread their root harvests throughout the year, leading to lower total dry matter harvests. Moreover, cassava plants that are not harvested immediately after the end of the dry season will draw upon reserves from the sink for regrowth and are likely to have lower yields than plants grown under IITA experimental conditions. Dry matter content may also depend on variety. Sapin (1958) provides data to suggest that varieties with the highest dry matter content also have the highest dry matter yield/ha, while they do not at all have the highest fresh weight root yields.

Farmers will select varieties in terms of their final use such as *gari* or *chikwangue*. Fresh root or even dry matter yields are not necessarily a reliable indicator of the amount and quality of these products (Ibe & Ezedinma 1981). Thus, in order to adequately assess the yield performance of cassava varieties it is necessary to specify fresh weight root yield, dry matter content and dry matter yield as well as consumer acceptability.[3]

It may be concluded that, unless the conditions under which cassava production and harvesting take place are carefully described, yield figures only provide a poor indication of crop system outputs. The use of average data on farmer yields, e.g. in the World Bank's (1981) assessment of comparative advantages of root and cereal crops, may therefore be misleading. Whenever careful comparisons are required, such as in defining the yield gaps between research station and farmers' fields, a standard procedure is required. Such a procedure might involve the following steps:

a selection of the most suitable unit, yield per unit of area and/or per unit of labour, with the possible inclusion of other scarce factors;

b definition of the unit of yield measurement, e.g. kg of fresh root and/or leaves, dry matter or energy (kJ);

c standardization with respect to time period, e.g. 12 months, and, in case of per hectare yields, with respect to plant population and LER (land equivalent ratio);

d description of relevant cultural practices, e.g. intercropping, and leaf and root harvesting strategies.

The evolution of cassava yields

Cassava yields in sub-Saharan Africa

The only extensive source of cassava production and yield statistics in Africa are the FAO Production Yearbooks. However, in view of the methodological questions discussed above, and because these are based on aggregated statistical data, these should be interpreted with due care.
According to FAO, the production of cassava in sub-Saharan Africa increased at annual rate of 2.2 % over the last twenty years. Nearly 80% of this growth is accounted for by an increase in area. The average annual rate of increase in production fell to 1.48% during the 1975-84 decade. In Central Africa, including in Zaire, yields remained virtually unchanged from the mid-1960s to the mid-1980s, averaging 6.21 tons versus 6.36 (presumably fresh weight).

Pre- and post-Independence cassava yields in the Kwango-Kwilu

The methodological issues involved in measuring and comparing cassava yields are compounded by the lack of validity of agricultural statistics in Zaire. The validity of post-Independence data has been discussed sufficiently above. However, even pre-Independence statistics of cassava present some problems. This fact was recognized to some degree by the authorities themselves. The 1955 annual report from the colonial administration, for example, admits that the cassava production figures are '*purely indicative*' since they are based on the number of '*imposed*' farmers (i.e. who have to cultivate a certain acreage), '*whereas cassava is always produced by women*', whether their husbands are '*imposed*' or not. The former colonial agricultural statistics service primarily intended to report the 'imposed' area and the volume marketed, not to estimate total acreages and production. This is particularly true for the 1945-49 period, for which no total production figures are available, and for which yields can therefore not be derived.
Before 1945 no annual production figures are available at all. The only information on cassava production before 1945 in the Kwango-Kwilu relates to the famines of 1936-1939 and 1941, when, supposedly due to a combination of extreme drought and severe incidence of cassava mosaic disease, farmers were not able to produce enough to cover their subsistence needs. Apparently, under these conditions cassava yielded less than 1.5 t/ha in 1941 (Drachoussoff 1954).
Regrettably, no figures have been found, notwithstanding extensive searches, for the Kwango-Kwilu or the Bandundu referring to the 1959-69 period. For

the period after 1970 figures on annual production, and to some extent also on area, are available. However, area figures become increasingly unreliable with the introduction of the compulsory cultivation regulations from 1976 onwards. As stated, production figures probably reflect more what is considered desirable rather than reality. As the government itself put it: *'The production of the main staple crops, such as cassava (...) is not known'* (République du Zaire/ Département de l'Economie nationale 1984:195). This is aptly demonstrated by the fact that a recent publication on cassava production (Cock 1985) quotes figures on labour inputs and farm sizes in Zaire for 1958 only. A further illustration is provided by a comment made to the author by the chief librarian of the Africa Library of the Ministry of Foreign Affairs in Brussels: *'Before 1960, there is little on cassava. After 1960, there is absolutely nothing...'*

There are considerable discrepancies between production and area figures of cassava from regional and national sources. It is difficult to explain these in view of the fact that figures supplied by the national office are in theory derived from aggregated regional figures, which are in turn based on data supplied by the subregional offices, and ultimately on data collected by the extension staff in the collectivities. As discussed in chapter 4, there are grounds to assume that figures from regional offices are consistently overrated, because of their use by the political authorities in the attribution of national funds.

Table 9.1 presents average cassava yields for the Kwango-Kwilu for the pre-Independence period and for the years after 1960, as far as they are available. In all years, yields in the Kwilu are consistently higher than those in the Kwango. In part, this may be explained by the fact that more fertile soils of the Karroo agro-ecological zone covers mostly the Kwilu, while the Kwango consists nearly entirely of Kalahari soils. Nevertheless, it seems unlikely that the considerable difference between yields in the Kwango and the Kwilu may be attributed to agro-ecological factors alone. Cultural practices and differences between field types are likely to intervene as well, but it is uncertain in what direction. The number of intercrops seems higher on forest fields, and while plant densities vary, the highest densities have been observed on savanna fields. Consequently, both factors would tend to lower cassava yields on forest fields.

Colonial yield figures seem to reflect a clearer trend than those for the post-Independence period. Pre-Independence yields in the Kwango appear to stagnate around 8.5 t/ha, while in the Kwilu yields seem to decrease from 15 to less than 11 t/ha, although this trend cannot be traced over more than a few years. This decline cannot be attributed to exceptional climatic conditions. Only in 1954 the dry season was unusually long and a serious outbreak of mosaic virus was reported. These factors may have affected the yield figures

Tabel 9.1 Estimated[1] yields of cassava, Kwango-Kwilu subregions and Bandundu region, 1952-1979 (fresh weight, t/ha^{-1}).

Year	Kwango	Kwilu	Bandundu
1952	12.7[2]		–[3]
1953	–	–	–
1954	8.5	15.2	–
1955	8.5	13.4	–
1956	8.6	11.0	–
1957	8.5	10.8	–
1958	8.5	10.8	–
1959-1969 not available			
1970	–	–	7.2
1971	–	–	6.9
1972	–	–	6.8
1973	–	–	7.0
1974	–	–	7.2
1975	–	–	7.3
1976	13.2	14.5	7.2
1977	11.8	15.6	7.2
1978	7.9	16.8	–
1979	7.8	14.6	–

Notes

1 Calculated from:
- Service Provincial de l'Agriculture et de la Colonisation, Province de Léopoldville, for the pre-1960 data.
- Regional Statistical Office, Bandundu, for the data on the Kwango and the Kwilu.
- National Statistical Office, for the regional data (Bandundu).

2 Until 1954, the Kwango-Kwilu was administered jointly as the Kwango.

3 – Indicates that data are not available.

for that year and the subsequent year (1955). There is no explanation for the continuing decrease after 1956, however. Moreover, the Kwango was much more affected by the drought and the subsequent famine than the Kwilu. The severe food shortages in the Feshi zone prompted the colonial administration to send several special missions to the Kwango-Kwilu. Nevertheless, the yield figures for the Kwango as a whole do not reflect any decline in these years. Apart from official statistics, there are few other sources on cassava yields during the 1950s and none of these sheds any light on the yield decline in the Kwilu. Nicolai (1963) uses only the official colonial figures, and can be disregarded here. Renier (1957) estimates per hectare yields at 9 tons in the savanna and 12 tons in the forest, which does not contradict official statistics. Other sources report yields of 3-10 t/ha of fresh roots for the Kwango (Jurion & Henry 1967:134; no indication of exact years or growth period). Drachoussoff (1954), in his report on the 1954 drought estimated that *cossette* yields were as low as 2 t/ha, whereas 3.5 t were normal (corresponding to about 6 and 10.5 tons fresh weight).

Therefore, one can only speculate about the pre-Independence yield decline in the Kwilu. From 1956 onwards, the colonial administration expresses its concern over the *'unequal distribution of cassava production in time and space'*, as a result of which local shortages occurred. Moreover, *'farmers near the towns demand to increase their fields in order to produce a surplus'*, but this is considered impossible *'given the availability of land'*. Surplus production would only lead to *'shortened fallows and soil exhaustion'* (Annual Report 1956). The 1957 annual report of the colonial agricultural service mentions that although the area under cultivation increased from the previous years, probably for the first time there was hardly any growth in total output. These comments in combination with the decline in yields seem to suggest that the traditional system of shifting cultivation was already under stress during the mid-1950s. Furthermore, it may also be concluded that the research by INEAC at Kiyaka and the introduction of improved varieties do not seem to have had an impact on cassava yields.

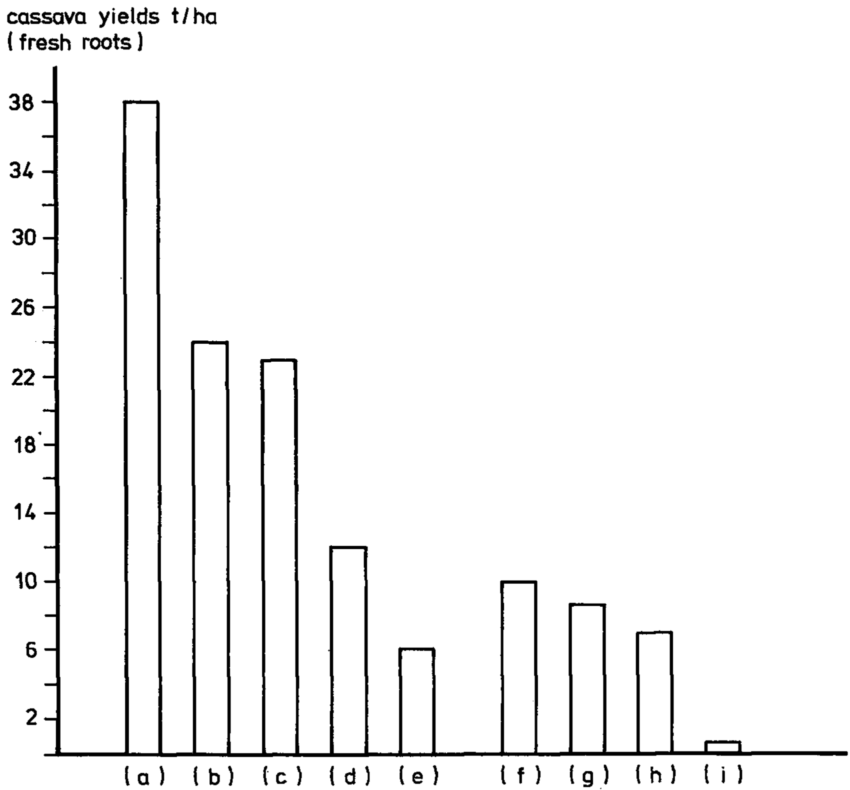
From 1970 onwards, the picture becomes even more confusing. The disaggregated data for the Kwilu and the Kwango would suggest that yields would have increased remarkably after Independence. However, a check with the aggregated regional data reveals that this is most unlikely. Two thirds of the total cassava output in the Bandundu is produced in the Kwilu, so one would expect regional figures to reflect yield trends occurring in the Kwilu. In contrast to the regional data for the Kwilu, national figures for the Bandundu as a whole seem to stagnate around 7 t/ha. This figure is significantly lower than those for the Kwango-Kwilu in the mid-1950s, in particular if one takes into consideration the fact that the Mai Ndombe is included, a sparsely populated forest area where average yields are situated between 14 and 20 t/ha (regional statistics, 1976-1979). Because there seems no reason to assume that cassava productivity in the Kwango-Kwilu is higher than in the remainder of the country, a comparison with aggregated yields for Zaire (around 6.5 tons) confirms that the national figures for the Bandundu are more correct than the regional data.

However flimsy the statistical evidence, it seems to point to a decline in average cassava yields in the Kwango-Kwilu. The yield decline is perhaps already apparent from the mid-1950s, i.e. well before any of the current pests and diseases were introduced in the area. While it is uncertain to what extent they have affected overall yields in the 1980s, the causes of the yield decline before 1980 cannot be attributed to pests and diseases.

Yield gaps in cassava

In order to understand the decline in average cassava yields, more needs to be known about gaps between yields obtained under different environmental and management constraints. The yield gap analysis and constraints

Figure 9.1 Cassava yield gaps, Kalahari zone (savanna).



(a) PNE 1981: improved variety + fertilizer 38 t
(b) INEAC 1959: improved variety 24 t
(c) PNE 1981: local variety + fertilizer 23 t
} on-station trials

(d) Pronam 1982: improved variety 12 t
(e) Pronam 1979: improved variety 6 t
} multilocational trials

(f) best farmer yield: local variety 10 t
(g) average farmer yield before 1960, Kwango 8.5 t
(h) average farmer yield 1979, Kwango 7 t
(i) lowest farmer yield: local variety susceptible to CBB, CM, 0.3 t
} actual farmer yields

methodology has been developed to identify the gaps between maximum (experimental) station yields and actual farmer yields, and to define the contribution of each production factor to the yield gaps (De Datta et al. 1978). It assumes therefore, that new technology already exists, but is underexploited because of constraints that refrain farmers from using the most profitable level of inputs.

There are two, complementary, ways to assess yield gaps. One way would be to use a theoretical model simulating the growth of cassava under various constraints (Veltkamp (1985) provides elements for such a model). The other way is to measure actual yield gaps in farmers' fields while controlling the levels of production factors.

In its original form, this method is unsuitable for the present analysis of yield gaps in cassava in the Kwango-Kwilu. Firstly, because no improved technology is currently available (although some elements, such as improved IITA varieties may be emerging, but have not yet been applied by farmers). Secondly, because the data base is entirely insufficient. Nevertheless, this section attempts to approach yield gaps by presenting the available information on experimental and farmer yields under various conditions. In order to increase the basis for comparison, only data referring explicitly to savanna cropping system (Kalahari agro-ecological zone) have been used (all cases where soil type was not mentioned have been eliminated). Because of a lack of data on the Karroo valleys, no reference can be made to this zone.

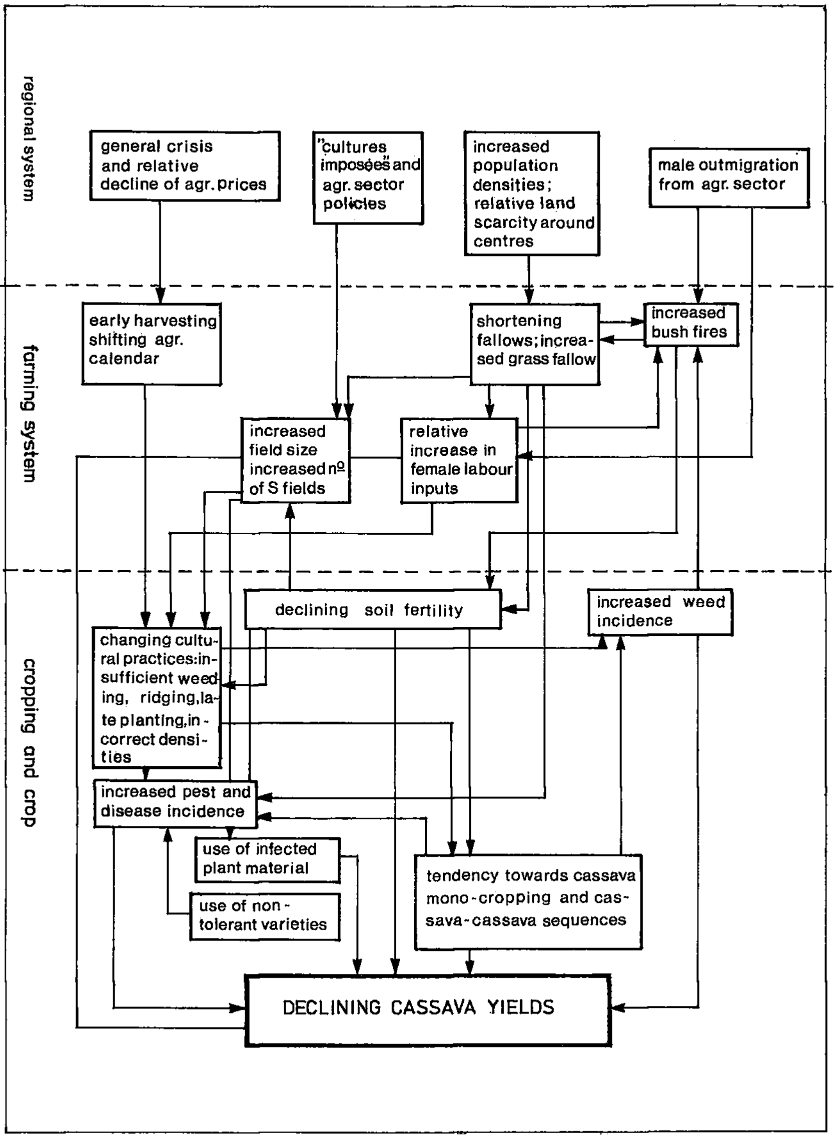
Figure 9.1 presents on-station and on-farm yield data for the Kalahari zone. Only two types of on-station trials have been documented in some detail; those that concern variety and soil nutrients. Pre-Independence trials by INEAC and recent work by Pronam mainly tested improved varieties, whereas the PNE (*Programme National Engrais*) provides some data on cassava yields under fertilized conditions. However, because the PNE does not give any details on trial design, it is difficult to interpret the results.

The highest yields have been obtained by PNE with fertilization and improved varieties: 38 t/ha, while the yield of the local control variety was 23 t/ha. If varieties alone are considered, the highest on-station yields were those of INEAC in 1958 with the hybrid Matuluku 2: 24 t/ha after 20 months, and yields over 15 t/ha after 20 months were certainly not uncommon (INEAC 1959). In 1979, Pronam reports a maximum yield at Kiyaka station of 6 t/ha (variety F113), presumably over a 12 months period (Pronam 1980). In 1982, in an experiment involving fields at several locations, the highest average fresh root yield was 12 t/ha (F100), while the control variety yielded only 4 t/ha (it is not mentioned which local variety was used) (IITA 1983:123).

Farmer yields in the Kalahari zone vary considerably. The best yields that have been measured during the field survey are in the range of 8-10 t/ha (1981-1982 season; fresh roots; southern Masi-Manimba after 15 months, Ss fields, intercropped with *voandzou* and groundnuts; mixtures of several local cultivars).

Average farmer yields for the Kwango are also included here. They were 8.5 tons before 1960. Official statistics, based on the compulsory cultivation requirements, range from 13.2 to 7.8 t/ha, average fresh root yield (1976-79).

Figure 9.2 Factors associated with low cassava yields at different levels of the hierarchy.



These figures, however, do not adequately reflect yields in the savanna on Kalahari soils, because they include also some smaller areas on Karroo soils in the northern Kwango. The lowest yields measured under farmer conditions vary from 0.3 t/ha (in the case of near-complete destruction of the crop by CBB and CM) to 4 t/ha after 24 months (southern Idiofa, 1980).

These figures seem to indicate that fertilizer rather than variety accounts for the greatest yield gap: in PNE trials, the local variety yielded as much as the best INEAC variety without fertilizer, and Pronam trials with improved varieties do not yield more than the best farmer fields. The extent to which pests and diseases cause yield gaps is difficult to assess from these figures, however.

Conclusions: cassava yields as a proxy for the performance of the hierarchy of systems

In the Kwango-Kwilu, cassava is the most important component of the crop system and cassava based crop systems dominate the savanna and forest cropping systems. In turn, the latter produce cassava outputs that are used by the farm household for food and cash. The cassava surpluses sold by farm household systems constitute the main output of the regional system. Cassava constitutes the crucial flow in the hierarchy of systems.

Circumstantial evidence would suggest that average cassava yields in the Kwango-Kwilu have been declining since the mid-1950s. The reasons for this decline can be attributed to factors at all levels in the hierarchy of systems. These have been discussed in detail in previous chapters and are now summarized in figure 9.2. Although the statistical evidence is weak and some degree of speculation cannot be excluded, it is hypothesized here that the following 'scenario' may explain the declining cassava yields in the Kwango-Kwilu since the mid-1950s.

At the regional level, a growing demand for cassava and the relative decline of agricultural prices lead to early harvesting of the crop. Increasing population densities cause fallows to shorten, resulting in changes in fallow vegetation and the increase of grass fallows. At the same time there are some indications that the compulsory cultivation regulations may result in increasing field sizes. At the farming systems level, production has expanded onto the plateaus (Sp fields). Greater demands are put on female labour due to the absence of men from the agricultural sector and possibly due to the increase in area. This may be aggravated by the increase in grass fallows, requiring more female inputs in clearing. At the crop and cropping systems levels, changes in agricultural practices are apparent. They result from the interaction of declining soil fertility, shorter fallows, shifts in the agricultural calendar and women's increased work loads. Increased surplus production has undoubtedly put greater demands on women's time, because of additional postharvest handling (processing and marketing), and may have affected field labor inputs, although this has not been investigated. The overall effect seems to be a tendency towards the monocropping of cassava.

It is unclear to what extent pests and diseases are contributing to the yield decline. Yield data relating to the period before 1980 show already a decline, i.e. before any of the recent introductions of pests and diseases. Furthermore, some sources suggest that pest and disease incidence may be related to environmental factors, such as shortened fallows, declining soil fertility and cassava monocropping as well as to the use of susceptible varieties (see chapter 8).

Thus, declining or stagnating cassava yields must be seen as a symptom of a wider problem, the *breakdown of the shifting cultivation system* in the Kwango-Kwilu. This conclusion allows a return to the assumptions on the nature of the African crisis. In the Kwango-Kwilu, cassava production has increased as a result of the inherent flexibility of the agricultural system, but at the probable cost of a slow decline in yields over the last 25 years.

A number of factors suggest that the production increase cannot be sustained in the future, if conditions remain equal. Declining cassava yields are indeed a symptom of the crisis. The emergence of inframarginal land shortages makes it unlikely that the area under cassava can be substantially increased. At the same time, the recent increases in pest and disease incidence as well as the considerable amounts of nutrients exported from the area raise serious questions about the potential for maintaining yields even at the present low levels.

The African crisis has been attributed only in part to a lack of agricultural technology. Nevertheless, it may be suggested that in the Kwango-Kwilu, improved technology would be one of the factors that could contribute to improving cassava yields. The foregoing analysis indicates strongly that improved cassava technology must take account of environmental factors at all levels in the hierarchy of systems. The next chapter examines to what extent past and present research efforts have managed to deal with cassava as a component of a shifting cultivation system in transition.

Notes

1 On a few occasions farmers on the Kalahari table lands have been observed using cassava stems as fuel, but fuelwood is not considered a usual byproduct of cassava.

2 INEAC has conducted occasional trials with higher than standard 10,000/ha densities, but does not discuss how these yields compare to those from other experiments (INEAC Kiyaka annual report 1952).

3 The following conversion rates of traditional cultivars in the Kwango-Kwilu have been estimated: 100 kg of fresh roots yield 39 kg of *cossettes* yielding 27 kg of flour for *fufu*, while the amount of *fufu* depends on the quantity of water added.

10 STRATEGIC AND ADAPTIVE RESEARCH ON CASSAVA IN SHIFTING CULTIVATION SYSTEMS

This chapter offers a selective review of strategic and adaptive research on cassava with special emphasis on shifting cultivation systems in Africa and Zaire in particular. Its purpose is to examine to what extent strategic and adaptive research has been concerned with the constraints and limitations on cassava production imposed by the breakdown of shifting cultivation systems, and whether component technology exists that can be adapted to these cropping systems.

Cassava research has expanded tremendously from the 1970s onwards, and '*cassava appears to be one of the most rapidly growing activities in tropical agricultural research*' (Nestel & Cock 1976:5). Nevertheless, the crop had not completely escaped the attention of colonial researchers in the Belgian Congo (or East Africa, for example (Beck 1982)). Before discussing issues in current international research in Africa, in particular by IITA, and research in Zaire, the first section looks at INEAC's work on cassava and on the improvement of cassava based cropping systems.

Pre-Independence research by INEAC

Among the impressive range of crops studied by the *Institut National pour l'Etude Agronomique au Congo* (INEAC) in the years before 1960, cassava was accorded only a minor role. In contrast to colonial medical research, INEAC did not seem to be particularly interested in the crop, notwithstanding the essential role of cassava in the traditional diet. Aspects of cassava research that are relevant to this chapter are studies on varietal selection, cultural practices and cassava pathology. The discussion will be concluded with a review of the research conducted by the Kiyaka station on improving traditional cropping systems in the Kwango-Kwilu.

Varietal selection

The main emphasis in INEAC's cassava research in Zaire as well as in the Kwango-Kwilu has been on the selection of improved varieties, mainly through mass selection from true seed (Sapin 1958:181). New genetic material was obtained from various external sources (Brazil, Ivory Coast) as well as locally. The criteria for selection were as follows: reduced branching; strong stems; resistance against root rot, CMD and lodging; short and fat roots, regularly spaced around the plant; a high protein content in the leaves. Sapin (1958:191) provides a very detailed description of the most promising clones at Yangambi, including data on root colour, which he thought to be correlated with CMD resistance. There seem to have been no contacts with the East African interspecific (*M. glaziovii x M. esculenta*) breeding programs. Kiyaka station in the Kwango-Kwilu was established in the course of 1947, and already in 1948, 21 clones from the Gandajika station in the Kasai were planted in a comparative trial with six local varieties. In the annual report of 1951 one finds details on the yields of five selected clones and one local variety, harvested from station fields on the plateau and in the valley after a twenty month cycle. The improved clones include *Criolinha*, *Tekela* (which may be a misspelling of *Tshela*), *Tolili* (presumably *N'tolili*) and 0219 or 0129, which ranked highest among the Yangambi selections. Yields (probably without fertilizer) vary from 43 to 47 t/ha in the valley (control 37 t), and 8 to 9.5 t/ha on the plateau (control 5.6 t). The high yields in the valleys may be explained by the fact that the trial fields were established on newly cleared (virgin) forest; in any case, the difference with the yields on the plateau is remarkable. In 1952, another 11 clones were received from Yangambi, increasing the total collection to 77. The following year, there is a first mention of 3,500 seeds that are received. The 'elite' varieties are still *Tekela*, *Tolili* and '*manioc de 6 mois*' (most likely a short cycle local variety). Trials were also conducted on optimal harvesting dates. In 1954, the cassava collection comprised 200 clones, and an unknown variety *Masodi Sali* produced the record yield of 50 t/ha in the valley and 17 t/ha on the plateau, all presumably without fertilizer. In 1955 more material was obtained, but the annual report concluded that '*clones from Yangambi are not adapted to the savanna environment on the Kalahari plateau*' (INEAC 1956:414). Further testing and multiplication of *Masodi Sali* and *N'tolili* occurred during 1956 in a continued search for suitable varieties for the plateau. However, all Yangambi varieties but one were eliminated that year because they did not yield more than the local ones on the plateau. For the first time, multilocational trials were conducted, and *N'tolili* and *Ngudi Fwani* (obviously a local variety from the name, referring to the woman (*ngudi*) who introduced it) emerged as the highest yielding, '*contrary to the clones from Yangambi*'. In other words, *N'tolili* is probably also a local variety, although not necessarily from the Kwango-Kwilu. In 1957, four varieties were finally recommended for both plateau and valley conditions: *Matuluku 1*, *Masodi Sali*, 2715 and 2961, while *Ntolili* and *Matuluku 2* were recommended for the plateau only. It was shown in 1958 that *Matuluku 2* performed even better than *Ntolili* on the plateau (24 versus 20 t/ha after twenty months). Further multiplication took place during the year 1959, but the promising yields in the savanna were not obtained again.

The annual reports of Kiyaka station do not give any information on the number of cassava cuttings that have been introduced in the area. Rassel & Hardy (1954-55, 1956) quote various figures on stem cuttings (of undefined length and origin) distributed to farmers: two million in 1956, and even more may have been distributed in subsequent years. However, under farmer conditions these introduced cultivars did not produce any better yield than traditional ones: 3 t/ha against 2.8, and were also infected by CMD. Only *N'tolili* produced 10 t/ha in 18 months and was only slightly attacked by CMD (80% of the plants showing few if any symptoms). The few references on yields obtained from selected varieties on farmers' fields point to considerable differences between on-farm and on-station yields.

In their 1954-55 report Rassel & Hardy stress the need for the introduction of multiple cultivars in order to spread risks. There is also a reference to the introduction of *Tshela*, a late maturing and low yielding variety tested in the early 1950s at Kiyaka, that is susceptible to CMD. It is this variety (also referred to as 0932), possibly the only one of all INEAC introductions, that has survived by name until the 1980s on plateau fields in the Feshi and Gungu zones.

Improving cassava cultural practices

The first reference to improving cultural practices in cassava was by Ghesquière (1928:603), who proposed the planting of straight cuttings with a diameter of 3 cm, inclined at an angle of 60° instead of traditional methods then used by farmers. Rassel & Hardy (1954, 1955 & 1956) conducted various studies of traditional cassava cultivation in the Kwango-Kwilu with a view to defining the best cultural practices. They were particularly concerned with yield reductions caused by mosaic virus (CMD). Apart from the lack of resistant cultivars, Rassel & Hardy blamed low yield levels on traditional cultural practices, in particular the use of long and diseased cuttings, inadequate planting methods and low densities. They recommended therefore the following measures (1956):

– the multiplication of a new variety called *N'tolili*, which seems well accepted by the population, to replace traditional cultivars;

– the use of healthy cuttings (if needed treated with DDT) and the elimination of diseased plants;

– the interdiction of any other introduction of new cultivars;
– the introduction of sole stands of cassava at 'normal' (presumably 10,000/ha) densities; the elimination of the intercropping of cassava with sweet potato in order to reduce competition for K;
– maintaining millet as a subsistence crop to overcome any periods of food shortage;
– reducing infestation by planting in the off-season (presumably the second rainy season).

In their confidential report on the (probably 1955) famine in the southern Kwango-Kwilu, Desneux & Hardy (undated) formulated two additional cultural practices:
– deep soil preparation for ridges as well as for flat planting;
– one or two cuttings of 25-30 cm planted horizontally.There are no indications, however, to what extent these improved practices were tested on farmers' fields and whether they were in fact introduced.

Diseases and pests

In comparison to other food crops few systematic observations on cassava pathology have been carried out by INEAC, and there appear to be some inconsistencies between the various research reports.

The first reference to a 'mosaic disease', in the Kasai, was made by Janssens (1917). As early as 1931, Staner provided a more detailed description of mosaic symptoms on cassava leaves, but concluded that little damage was done and farmers seemed to care little because *'they have not observed any (root) yield reduction, although they do not consume the infected leaves'* (Staner 1931:77). However, in 1935 Lefèvre reported that yield reductions could be severe, but that sweet cassava suffered much more from mosaic virus (CMD) than bitter cassava (Lefèvre 1935:443). He recommended that farmers be prevented from harvesting cassava before it is two years old, because young plants appeared to suffer more from attacks. A few years later Opsomer confirmed yield reductions of 44% due to mosaic virus (Opsomer 1938). With respect to the Kwango-Kwilu, there are few detailed observations on CMD (with the exception of Rassel & Hardy 1954-55).

Little is found on pests in cassava before 1960. Lefèvre (1944) provided a detailed account of insects found in cassava fields in northeastern Zaire. Fassi (1957:313) mentioned root rot caused by *Phytophtora* as a problem at the end of the rotation, possibly caused by the piercing of cassava roots by the rhizomes of *I. cylindrica* which facilitates infection. Among other things, he proposed the introduction of a tolerant variety *(Criolinha)*, fixed planting distances and early harvesting.

Improving traditional cropping systems in the Kwango-Kwilu

Around 1955, Hardy, then director of the Kiyaka research station in the Kwango-Kwilu, summarized the main constraints on agricultural development in the area as follows (undated mimeo): 'There are no means of transportation; fields are dispersed far away from the villages, and there are no feeder roads. No cattle, apart from a few goats and pigs, no draught animals. No farmyard manure, no lime, no fertilizer whatsoever. Apart from hoes and bush knives, no tools, and everything is done by hand. The people are undernourished (...) In these conditions, there is but one thing to do: to try to make the best possible use of the only thing that exists locally in great quantities: savanna grasses'.

The Kwango-Kwilu was indeed considered a 'basket case' with little agricultural potential, at least on the Kalahari plateau. In INEAC terminology, agricultural potential mainly referred to the introduction of cash crops. In the forested valleys the *couloir* system was recommended (see chapter 2), which included improved rotations, and coffee and oil palms as cash crops. The problems in the valleys were not considered very different from those in the rest of the Congo Basin, so research concentrated on the Kalahari plateaus. The poverty of the Kalahari sands was a continuing concern to all early researchers. Hardy (undated mimeo) quotes an unknown soil scientist as saying: '*the poverty of these soils is bewildering*'. It was not thought possible to establish a system of permanent agriculture on the plateau (Jurion & Henry 1967:135) and there was little or no scope for cash crops. Research focused mainly on improving soil fertility and crop rotations. Trials with chemical fertilizers were inconclusive, with the exception of lime at 400-500 kg/ha on cotton. Jurion & Henry (1967) describe how work on cotton was soon abandoned in favour of groundnuts, the only promising cash crop in the Kwango-Kwilu. The importance of Ca and P for groundnuts was established in various experiments; inoculation with *Rhizobium spp* was recommended. Lime application to cassava, planted on ridges or flat, seemed to have no effect on yield (INEAC 1960). As suggested by Hardy, only savanna grasses provided a viable source of nutrients. Several versions of a system of *buttes* (or *bandes*) *enrichies* were developed. This system was based on the incorporation of grasses from an area two to three times the surface of the cultivated ridges or mounds.[1] The improved cropping system proposed by INEAC involved the use of grasses and a groundnut – groundnut – *voandzou* – maize – groundnut – cassava rotation. The yields obtained with this system were relatively high: 0.7 t/ha of dried unshelled groundnuts (Jurion & Henry 1967:135), nearly 1 t/ha if one considers only the area planted (not the total area from which the grasses are taken). Cassava produced 15 t/planted ha or 7 t/real ha.

Apart from general work on soil fertility, the INEAC station at Kiyaka studied various traditional and introduced crops in order to develop improved rotations. The need to diversify agricultural production was emphasized occasionally (e.g. Desneux & Hardy undated). Most of this work does not seem to have had a direct impact on cassava production, although the introduction of new varieties of other crops could greatly have influenced traditional cropping systems. In this context, trials with early maturing varieties of groundnuts are of interest.[2]

Discussion

INEAC's work on cassava, in the Kwango-Kwilu and Zaire as a whole, was part of a large-scale effort to improve and 'rationalize' traditional agriculture. In that sense, even if today one questions some of the ulterior motives, it constituted commodity research with a perspective on the improvement of entire cropping systems. Because the natural resource endowment of the Kwango-Kwilu appeared poor in comparison to other regions of the Congo, no program of agricultural intensification was ever carried out. Low population densities did not necessitate fundamental changes along the lines of the *paysannat* system which provided methods to stabilize shifting cultivation (chapter 2). In contrast to many of its programs in other parts of the colony, INEAC's cassava research in the Kwango-Kwilu was therefore limited to small improvements – cultural practices, varieties – in the traditional cropping system.

Its impact in the Kwango-Kwilu, however, seems to have been very limited, as shown by some of the yield data (chapter 9). Of the varieties introduced by INEAC, only one has been traced, but more may have been multiplied by farmers under new local names. Nearly the entire INEAC collection at Kiyaka has unfortunately been lost in the years after Independence. Certain of INEAC's recommendations, such as the use of savanna grasses are impractical, even more so today than in the 1950s.[3] A major difference with the present situation was the absence of pests and diseases, with the exception of cassava mosaic virus. Although the colonial administration seems to have been concerned by the emerging shortage of land and the reduced growth rate of cassava, apparently this did not lead to a modification of Kiyaka's research program.

Current research on cassava in Zaire and Africa

Rather than trying to summarize present research efforts, this section examines the overall thrust of cassava research undertaken internationally, mainly by IITA, partly by CIAT, and the national program in Zaire.

Varietal improvement

A very large proportion of international cassava research is devoted to breeding for higher yields and for pest and disease resistance, and related research on cassava physiology, entomology, biological control and pathology.[4] Cassava breeding in Africa is based on local as well as imported germ plasm.

The development of high-yielding disease and pest resistant cultivars or varieties is considered the main research priority at IITA. From its start in 1972, IITA's breeding program has aimed to produce varieties with high dry matter yield per unit of land area and time; multiple resistance to pests and diseases; with improved root and leaf quality; adaptation to a wide range of environments; improved plant types (Hahn et al. undated). In the beginning, the main emphasis was on the identification of resistance to CMD and CBB (Nestel & Cock 1976). Work on entomology and pest resistance since the late 1970s reflects the growing concern with cassava pests in Africa. From the original germ plasm acquisitions a small number of varieties is currently being tested in farmers' fields. The varieties TMS 50395 and TMS 30555 have consistently produced outstanding results even on poor acidic soils and appear resistant to CMD and CBB and tolerant to CM and CGM. Several other varieties also look promising (Hahn et al., undated), although it is not always clear to what extent they are adapted to a wide range of environments.[5]

Other research is largely concerned with the modelling of cassava growth and the definition of ideal plant types for breeding purposes (e.g. Cock et al. 1979, Cock & Howeler 1978). The ideal cassava plant has a LAI (leaf area index) of 3-3.5, large leaves with long individual leaf life, and branches late without developing side branches. Optimal patterns of dry matter partioning have also been determined (Boerboom 1978, de Bruijn 1982, Veltkamp 1985). Ezeilo (1979) suggests that a medium height plant that resists lodging, branches at approximately 1 m and displays a narrow angle of branching is most suitable for intercropping.

Soil fertility requirements

Research on soil fertility requirements of cassava is rapidly progressing. Most of the basic work has been carried out by CIAT. Cock & Howeler (1978) have determined cassava's range of tolerance of soil acidity (pH from 4.5 to 8), Al and its needs for lime application (Cock & Howeler 1978). Because cassava is more tolerant of soil acidity than other crops, it is usually planted late in the rotation when soil pH, which has been temporarily increased due to burning, is lowered again (Edwards & Kang 1978). Cassava yield is reduced less than that of other crops when grown at low nutrient levels. With the exception of

Zn deficiencies, nutrient deficiency symptoms may only be observed in extreme cases.

Flach (1980) suggests that in comparison to other moisture rich staples cassava's nutritional requirements are low, probably because the cassava root is not used for vegetative multiplication and therefore does not serve to store nutrients. Furthermore, the root system of cassava may entertain a symbiotic relationship with mycorrhiza resulting in a very efficient uptake of P at low P levels in the soil (Howeler 1980a). The presence of mycorrhizal funghi also explains cassava's ability to grow on P deficient soils and its apparent lack of response to fertilizer (Howeler 1980a). Because worldwide cassava has its greatest potential on acid and low phosphate soils, Howeler suggests that mycorrhizal inoculation may become of utmost practical importance.

Cassava rarely responds to more than 100 kg N/ha. High N applications increase leaf production at the expense of roots (Nestel 1976, Howeler 1980a). Cassava responds well to N applied as organic matter and to farmyard manure and wood ash applications (Howeler 1980a). Positive responses to N and K are not great and occur more frequently in the presence of P (Howeler 1980a). Cassava extracts high quantities of potassium. K fertilizer is essential for high root yield and quality, because at low K levels the dry matter content of the roots drops and the cyanide content rises (Cock 1985). The harvest index increases at higher K levels (Cock & Howeler 1978). The removal of soil nutrients by cassava has been studied by many authors, starting with Nyholt (1935); however, few observations are available on nutrient removal at yield levels below 20 t/ha.

Cassava requires well drained soils but does not demand extensive soil preparation. Mulching with weed and crop residue is a common traditional practice, which may be considered beneficial as an anti-erosive measure, but could be instrumental in maintaining a high level of pathogens. Mulches vary in their effectiveness: maize stalks and grass straw, among other things, proved quite effective in Colombia (Howeler 1980a). Hahn et al. (1979) caution that mulches with high C:N ratio may immobilize N.

Water requirements and planting dates

During the initial three months after planting, water requirements in cassava are relatively low, but a regular supply is essential. Optimal planting dates depend on the soil-moisture regime, and are therefore location-specific. Yields depend highly on the time of planting (De Vries 1978), and the determination of optimal planting times may be a priority in shifting cultivation. Early planting produced higher yields in north Thailand (Zandstra 1979), but if rainfall is uncertain this may result in poor establish-

ment (Ezumah & Okigbo 1980). According to Ezumah & Okigbo late planting is an important factor resulting in low yields in Africa: every month's delay causes a 10% reduction in root yield.
Supra-optimal soil temperature above 35°C at 5 cm depth and resulting moisture stress, as commonly occurs in the field if the crop is planted on ridges at the beginning of the wet season, can cause significant reduction in growth.

Improved planting material

The quality of planting material is determined mainly by physiological, pathological, entomological and climatic stresses (Lozano & Bellotti 1980, Centre for Overseas Pest Research 1978). Detailed recommendations on improving planting material are provided by CIAT (Lozano et al. 1977). In contrast, there seems little agreement concerning the most appropriate planting position of stem cuttings. Sprouting under field conditions is always more rapid with vertical planting (Toro & Atlee 1980). However, Ezumah and Okigbo (1980) have observed increased leaf yield from horizontally planted stakes, in contrast to Godo (1983) who obtained higher leaf yields with vertical planting. Flach (pers. comm.) suggests that the optimal position of cuttings depends on moisture availability, with horizontal planting occurring only in relatively dry regions, while vertical planting is common in high rainfall areas. Under the climatic and soil conditions of the Kwango-Kwilu shallow horizontal planting practiced by farmers could result in heat damage, exposure of the roots to erosion effects and the risk of lodging from wind due to poor anchoring.

Planting densities

The literature on optimal planting densities is conflicting (Toro & Atlee 1980), possibly because density is a function of factors like soil fertility, growth cycle and intercropping, and varies therefore according to cropping system. Cock (1985:64) mentions the need for high populations if soil fertility is low and weed control constitutes a problem. De Vries (1978) concludes in his review that optimum plant density is 10,000-20,000 for root production, and 60,000-110,000 for leaf production. Higher densities have been demonstrated to diminish the number of roots/plant and to reduce the average root weight (IRAT 1983).
Because single-shoot plants supposedly outyield multi-shoot plants (Nestel 1976), pruning or thinning is recommended to obtain only two shoots per stem cutting, especially if these have been planted horizontally (Toro & Atlee 1980).

Intercropping

Although cassava has been intercropped with other crops at research stations, few studies have been undertaken of existing intercropping practices (for an example, see Moreno & Hart 1979). Ezeilo (1979) mentions that in the drier savannas, the number of plants in intercropping arrangements with cassava tends to decrease. In African shifting cultivation systems, cassava dominates terminal crop sequences. Silvestre & Arraudeau (1983) point out that wherever cassava is the dominant crop, it will be found both at the beginning and at the end of the cropping cycle.

Intercropping has economic as well as agronomic advantages for small farmers. However, the effects on labour inputs, the division of labour and its distribution require further study. Okigbo (1977) concludes that intercropping maize with cassava gives highest yields of component crops when cassava is planted at the same time as maize or not more than two months later. This confirms earlier work by Hart (1974) demonstrating that the highest net economic return is obtained from an arrangement of beans, maize and cassava planted simultaneously and harvested after 9, 18 and 36 weeks respectively. Weed control and the modification of maize and cassava architecture were the most important factors in obtaining high yields. Zandstra (1979) concludes that for intercropping, cassava varieties should be tolerant to early shading, and LAIs should be low in order to avoid self-shading. Soil loss may be prevented by intercropping cassava with a fast growing cover crop (Burgos 1980).

Highest LERs (land equivalent ratios) have been obtained in cassava-legume intercropping with both crops at their optimum sole crop populations. The usual spacial arrangement of 1 x 1 m may be successfully replaced by double rows of cassava or a 2 x 0.5 m spacing (Leihner 1979, Okeke 1983). The multivarietal and/or the intercropping practices of small farmers greatly reduce the risks of sudden disease and pest outbreaks (Lozano & Bellotti 1980). The low populations of individual hosts per hectare, changes in micro-environment and the influence of barrier crops seem to explain the positive effects of intercropping (Weber et al. 1979).

Weed control

Weeds present a serious problem in cassava cultivation due to cassava's slow initial development during the first three months of growth. This applies in particular to sole cropped cassava. The inability to carry out the first weeding in time because of other demands is one of the reasons for low yields in farmers' fields even when improved varieties and fertilizer are used (Hahn et al. 1979:199, Ezumah & Okigbo 1980). When weed control is delayed both root number and root yield are depressed (FAO 1982). In an extensive review Toro & Atlee (1980) conclude that if labour is scarce, weed control during the third month is most effective. Doll & Piedrahita (1976) demonstrate that when no weeds are removed, cassava yields are extremely low, but that higher crop densities may compensate for the effects of weed competition. A fast growing and extensively branching variety may provide a natural weed control measure (Ezumah & Okigbo 1980). Taking into account that adequate weed control is always bound to be labour intensive, cultural practices may improve control, in particular planting vertically to ensure optimum early establishment; increased planting densities; legume covers and intercropping. Mulching, which provides a shorter duration weed control than perennial legumes, has the advantage of not being competitive and of increasing moisture (Leihner 1980, Doll 1978). Herbicides have been evaluated for weed control in cassava and are found to be effective only when high rates are applied during the first 12 weeks (Doll 1978).

Pest control

The need for integrated pest control in cassava, i.e. based on a combination of host plant resistance, biological control and cultural practices, has been stressed (Brekelbaum et al. 1978). Recommended practices include a combination of crop rotations, fallowing, proper soil preparation, use of clean and high quality planting material, weed control, removal and destruction of infected plant material and plant debris, crop rotation, intercropping, spacing and proper fertilizer (Lozano & Bellotti 1980). The long production cycle of cassava, the consumption of leaves and the costs prohibit the chemical control of pests and diseases.

Leaf harvesting

In central Africa, leaf harvesting is common. Yet leaf production in cassava and the effect of leaf harvesting on root production have been relatively neglected by researchers. Lutaladio & Ezumah (undated) mention that highest leaf yields are obtained when leaves are harvested once monthly. Harvesting leaves every two months does not seem to influence root yield, but leaf harvesting increases the incidence of mosaic virus, while apparently decreasing anthracnose incidence. Dahniya (1983), however, reports that total fresh root reduction ranges from 22 to 42% when leaves are harvested monthly from five months onwards. The number of roots/plant seems unaffected by leaf harvest; this may be so because the number of storage roots is determined early in the growth of plants. He also demonstrates that local varieties are better adapted to leaf harvesting, because individual root size and number were not significantly affected. Although the improved varieties were more severely affected by leaf harvesting, their total leaf and root yields were far superior to those of local ones. This suggests that at low production levels local varieties may be better adapted to farmer practices.

Discussion

In the thirty or so years that have passed since INEAC's cassava research in the Kwango-Kwilu was at its peak, important progress has been made, in particular in the field of soil fertility requirements and breeding. There is also a major shift of emphasis towards cassava entomology and pathology. It may be tentatively concluded that international research on cassava shows an increasing concern with constraints and limitations inherent in shifting cultivation, as witnessed by the work on intercropping, weeding and soil fertility.

The development of improved cassava varieties, on the other hand, demonstrates little of this concern. Varietal improvement appears mainly focused on criteria that neither reflect the constraints imposed by shifting cultivation nor farmers' preferences. Firstly, high cassava root yield per unit of area may not be farmers' main priority. Secondly, there may be a conflict between plant types suitable for intercropping and for pure stands. Nevertheless, the great majority of varietal testing concerns sole cropping. There is a strong need to evaluate improved varieties, that have been selected in pure stands, in various intercropping patterns and under traditional cultural practices. Thirdly, branching patterns, plant height and the speed with which maximum height is attained, in particular of single shoot plants, seem rarely designed for leaf harvesting by women. Finally, optimal LAI values in improved varieties may not suit farmers in those areas where cassava is important as a vegetable. Rapidly branching cultivars that readily shade the ground may be more adapted to fields where cassava is grown in monocropping and weed control is deficient (e.g. the plateau fields in the Kwango-Kwilu).

Although IITA and other institutes have established impressive collections of genetic resources, the absence of an inventory of cassava varieties in Africa is striking. It may be recommended that local varieties be evaluated for their adaptation to intercropping, low soil fertility, leaf/root production ratios and disease and pest resistance. Furthermore, the conservation of the genetic variability seems important, in view of the fact that native varieties in each edapho-climatic zone have the highest levels of resistance to the limiting factors of that environment (Lozano et al. 1980). The genetic material introduced recently into Africa from Latin America has been developed under selection pressures imposed by tropical American conditions and may not be very well adapted to African savanna ecosystems.

A more fundamental question is of course, whether a strong orientation towards breeding is justified in the light of the poor soils in many parts of Central Africa. International research, in particular by IITA, has emphasized breeding for pest and disease resistance, and related entomology and pathology research. This suggests that pests and diseases are seen as the main yield constraining factors in African cropping systems, and that it is assumed that these can be addressed through the introduction of resistant varieties and/or biological control.

Maraite & Meyer (1978) indicate that disease incidence is strongly related to environmental factors and that genotype-environment interactions cannot be ignored. The analysis of constraints and limitations on cassava production in the Kwango-Kwilu also points to a multitude of constraining factors at various levels, of which pests and diseases are but one. Moreover, the severity of pest and disease incidence (as opposed to the introduction of pathogens per se) may be a function of other factors in the system, such as planting methods, field selection, and the trend towards monocropping of cassava. It seems essential to further investigate the relation between pests and diseases and environmental factors, especially soil fertility and cultural practices. In any case, even if it is assumed that pests and diseases would be the main constraining factors, research should be broadened to involve more than varietal improvement and biological control alone.

Adaptive research on improved cropping systems is necessarily location-specific and one of the objectives of national programs. The following section examines to what extent the *Programme National Manioc* (Pronam) in Zaire has developed and adapted improved cassava technology.

The Programme National Manioc in Zaire

In response to the growing concern about the incidence of cassava bacterial blight, the *Programme National Manioc*, Pronam, was established in 1974 through a cooperative agreement between the Government of Zaire and IITA as a research and training project.[6] Pronam's research objectives are the improvement of cassava in Zaire through breeding for resistance to diseases and pests and for improved root and leaf quality; and the definition of cultural practices that will enable cassava yields to attain an economic optimum

(Ezumah 1981). The program's headquarters are located at M'vuazi in Bas Zaire while subprograms have been progressively established at other stations, including Kiyaka in the Kwango-Kwilu.

Varietal selection

From the beginning, Pronam has emphasized germ plasm collection and evaluation. The base population for the breeding program was provided by INEAC/INERA clones and some 300,000 seeds that were introduced during the 1970s from various sources (mainly IITA and CIAT). Screening procedures have been developed to identify clones resistant to mosaic disease (CMD), blight (CBB) and anthracnose (CAD) (Singh 1981). Pronam's criteria for selection are: high root yield, resistance to major pests and diseases, high starch concentrations and consumer acceptability. All local clones that were evaluated have proven susceptible to CBB, CMD, and CAD; therefore, other sources of resistance were required (Singh 1981). In 1978, it appeared that resistance to CBB and CMD developed at IITA was maintained at M'vuazi, but that CAD incidence was severe, in particular in the Kwango-Kwilu. Moreover, selected clones are all susceptible to mealybug which has increasingly become a cause for concern (Ezumah 1981, Pacumbaba et al. 1979). Pronam's entomology section is mainly concerned with CGM and CM in view of IITA's Africa-wide biological control program. Natural predators of mealybug (*Epidinocarsus lopezi*) have been released in Bas Zaire since 1982, and in the Kwango-Kwilu in 1984. The distribution of mealybug populations throughout the country has also been studied.

Unfortunately, in 1981-1982 '*many valuable (planting) materials were lost because of poor supervision*' (USAID 1983), in particular in the Kwango-Kwilu, and Pronam decided to concentrate its activities in Bas Zaire. Multiplication and distribution of planting material has started in 1979. Throughout the country, the extension of improved planting material (cuttings) meets with great storage and transportation problems. In 1983, Pronam has officially released variety 30085/28 (local name: *Kinuani*) for wide diffusion, which is now grown on an estimated 850 ha (IITA 1984). *Kinuani* proves superior to the control variety at various locations, but the majority of varietal testing of Kinuani and other varieties has taken place in Bas Zaire, so it is too early to draw conclusions about its suitability for the Kwango-Kwilu. The variety F 100 which has been tested over several seasons on plateau fields shows stable and higher yields than the best local varieties (IITA 1984). No comparative trials comparing F 100 and *Kinuani* are reported. The absence of an effective extension service greatly limits Pronam's ability to conduct multilocational and on-farm trials (Singh 1981).

Testing methodology

Given the importance of varietal testing in adaptive research, this section raises a number of methodological issues about Pronam's testing program. Firstly, Pronam's annual reports and IITA's country reports often show little similarity from one year to another between the lists of tested varieties. As a result, it is often unclear for how many seasons tests have been carried out, or on what criteria 'most promising' varieties are selected for further trials. There are several examples of varieties that are considered 'most promising' but are in fact quite susceptible to pests and diseases as demonstrated by other trial data. For example A56, 'most promising' variety with the highest yields (IITA 1980) appears rather susceptible to CBB (IITA 1981). In 1979, for example, of Pronam's four most promising clones (300704, A56, 30346, 301792) all but one (A56) seem to have disappeared from subsequent trials. As far as could be traced, the variety 30085/28, *Kinuani*, has not been mentioned under that number or name in any reports on advanced or multilocational trials previous to 1983. Variety 30058/28 is only recorded in the 1983 IITA annual report in a section on stem tip dieback disorder, and reported to have a 68% disease incidence rate. As *Kinuani* is the only variety that has officially been released in Zaire (in 1983), it is not clear what varieties have been multiplied and distributed in the country between 1979 and 1982. Other reports mention the distribution of 'most promising clones' that have been diffused (e.g. 100,000 m of cuttings in the Bandundu, IITA 1983:124). It may be noted that in their recent review of cassava production, Silvestre & Arraudeau (1983:78) do not mention any improved variety that is currently cultivated in Zaire.

Secondly, trial fields are classified by Pronam as forest/valley or savanna/plateau. This dichotomy does not reflect the large variations in savanna environments, in particular as they exist between Bas Zaire and the Kwango-Kwilu. In 1983-84, for the first time, multilocational trials were conducted that took into account toposequential positions, thus reflecting differences between field types (IITA 1984:141). Furthermore, all trial fields, including on-farm trials, are planted at a standard population of 10,000/ha in single rows, notwithstanding the fact that it has been demonstrated that higher yields are obtained in a double row pattern (as traditionally practiced in some areas) (Ezumah & Okigbo 1980).

Thirdly, the selection of control varieties may also be questioned. Whereas INEAC used up to six local varieties as controls, nearly without exception Pronam trials include only one local variety. Most frequently, this variety is *Mpelolongi*, a common variety in Bas Zaire which does not seem to occur in the Kwango-Kwilu. In other cases the local variety is not specified. There is no indication of how this local variety has been selected and whether it represents the 'best' alternative, both agronomically and according to farmers. Given the wide range of traditional cultivars it is likely that for each type of environment a different set of local varieties ought to be included in comparative trials. There is an urgent need to evaluate the potential of local cultivars in Zaire. This has been recognized by the USAID evaluation which recommended the increased use of local varieties in the breeding program (USAID 1983:14). Finally, Pronam's on-farm trials have the limited objective of including a larger range of edaphic and climatic conditions, and are in fact multilocational trials. They do not allow the evaluation of new technology within the context of the existing cropping systems, because traditional practices such as intercropping, leaf harvesting, staggered root harvesting, and varying plant densities are excluded. Although farmers are asked to rate varieties for root and leaf consumer characteristics, there is no overall evaluation of the agronomic and economic acceptability of the improved varieties.

Improving cultural practices and cropping systems

While the main emphasis has been on varietal improvement, Pronam has conducted also some research on cultural practices. Preliminary results of the agronomy program show that time of planting is very important in determining yield. The testing of improved practices, i.e. fertilizer and plant densities, has mostly been limited to M'vuazi station. A survey in Bas Zaire determined that soil type and planting date are decisive factors in determining yields. Weeding during the first three months is critical; delays in first weeding cause yield reductions of 40-60%. In a comparison of ridging with flat planting, ridges have shown an advantage over flat plots but further testing may be required (Ezumah & Okigbo 1980, Singh 1981, Pronam 1980, IITA 1983).

Work on intercropping indicates that when groundnuts are intercropped with double rows of cassava at a density of 50,000 to 100,000, groundnut yields are higher than in any other type of intercropping. In Bas Zaire, intercropping with groundnuts or *Phaseolus spp* provides a higher cash income than a sole crop of cassava. Root yields are significantly reduced irrespective of groundnut densities (IITA 1977). In poor soils the optimum plant population is situated around 10,000 to 15,000 plants/ha. In a comparative trial of both improved and one local varieties at two fertility levels and two plant densities, it appeared that, when planted at high density, the local variety gave yields comparable to those of the improved varieties irrespective of their plant population. In other words, increasing density to 20,000/ha had no significant effect on the yield of improved varieties but increased the yield of the local variety by more than 50% (IITA 1983). This finding is particularly interesting in view of the high densities found in some farmer fields in the Kwango-Kwilu, and should also have implications for Pronam's testing procedures,

since all variety testing has thusfar been done at a standard density of 10,000/ha.
There has been no systematic effort to analyse traditional cropping systems. There is no evidence of an assessment of farmers' needs and priorities with respect to cassava production, and it seems unlikely that farmers have had any direct or indirect contribution to the definition of Pronams' research programs.

Discussion

The adaptation of component technology to the specific cropping systems in different agro-ecological zones of a country belongs to the mandate of national research programs. A review of Pronam's work suggests that rather than testing IITA varieties in local cropping systems, Pronam has replicated IITA's emphasis on genetic improvement and related basic (entomology and pathology) research. It has not yet been established that *Kinuani*, the variety that has officially been released, is adapted to cropping systems in the Kwango-Kwilu. The methodology of multilocational variety trials merits further critical evaluation, in particular in view of the results of the agronomy program on intercropping and densities. Nearly all of the agronomy work is confined to Bas Zaire.
As in the case of IITA, the underlying assumption appears to be that cassava production can be improved through the introduction of pest and disease resistant varieties and biological control. The breakdown of shifting cultivation systems in Zaire, and the resulting problems of soil fertility and weeds, are therefore overlooked.
This brief review of cassava research suggests that while interesting work has been carried out, little component techology exists that can be adapted in the Kwango-Kwilu. The Pronam or IITA reports seem to reflect very little awareness of the contraints on cassava production caused by the crisis in shifting cultivation in regions like the Kwango-Kwilu. Relevant areas for adaptive research on cassava in the Kwango-Kwilu are: the improvement of soil fertility under cassava based cropping systems and cassava's response to nutrient application; weed control; relay and mixed intercropping patterns; the improvement of planting material and planting methods. Further strategic research would be required on optimal leaf and root harvesting patterns. Ideally, cassava technology will need to be developed within the perspective of 'whole system change' (CGIAR 1985).
The final chapter examines future trends in cassava production and the consequences for technology development for cassava based shifting cultivation in the Kwango-Kwilu.

Notes

1 Grasses were either incorporated at the time of soil preparation immediately after the end of the rainy season, or left to dry on top of the ridges to be burnt by a slow fire at the beginning of the new rainy season (September). Sometimes a combination of both incorporation and ashes were used in a 1/2 system (the first figure referring to the width of the ridge and the second to the proportion of the area required for fertilization; for more details see Jurion & Henry 1967, Hardy (mimeo), Renier 1957, Fresco 1984c). Thus, grasses provided organic matter and ashes (thereby lowering soil pH) and protected the soil during the dry season. However, considering the unfavourable C/N ratio of dry Gramineae (over 50), the application of N was still recommended.

2 It seems probable that the short cycle groundnut variety A 28 was diffused among farmers. Trials with *Setaria italica* were also conducted, but this crop has not been introduced.

3 The use of savanna grasses seems quite unfeasible at present. Firstly, it is very labour intensive, requiring some 2,000 hours/ha (Hardy undated mimeo). Secondly, it depends entirely on the successful protection of the fields against bush fires. This is a much greater problem today than it was thirty years ago, because much larger stretches are burnt for hunting, and small patches of forest, acting as firebreaks, are rapidly disappearing. Thirdly, grasses have to be obtained from a greater area than required for cultivation alone, which is likely to present problems in areas of relative land scarcity, close to villages. Finally, it is unlikely that the loss of soil nutrients due to the massive crop removal (due to the increase in cassava production), erosion and leaching can be compensated by manuring with grasses.

4 Other work has been carried out on cassava processing and storage, toxicity, the use of cassava as animal feed and energy source and so on, but these aspects will not be considered here.

5 That new cultivars are not always pest resistant may be illustrated by the fact that the CIAT cassava protection workshop saw the need to stress that '*new introductions of cultivars should be no more susceptible to pests than currently established varieties*' (Brekelbaum et al. 1978:241).

6 From 1978 onwards, financial assistance was provided by USAID, and increasingly so after 1980 when the GOZ could not meet its planned expenditures on agricultural research in general (which, in any case, are among the lowest of all developing countries: less than 0.2% of GDP (Oram 1985)).

11 GENERAL CONCLUSIONS AND DISCUSSION

Cassava production in the Kwango-Kwilu: constraints and potential

Cassava production in the Kwango-Kwilu today

Despite disincentives, such as extensive government control, a poor marketing structure and disadvantageous prices, farmers in the Kwango-Kwilu today produce more cassava than ever before. According to available statistics, cassava production increased from about 0.9 million ton (1952, Colonial Agricultural Service for the Kwango) to an average of well over six million tons in the early 1980s (regional agricultural statistics). It has been argued that the latter figure may be grossly overestimated. Nevertheless, even a conservative estimate based on the lowest production figures suggests that production may approach 3 million tons. The extent to which these statistics must be interpreted with caution may again be illustrated by a last example. According to regional sources cassava production in the Kwango-Kwilu is reported to amount to 3.2, 3.8 and 10.3 million tons in 1981, 1982 and 1983 respectively. Apart from an exceptionally long dry season in 1981, there seems to be no explanation for the massive production increase in 1983.

The production of maize, groundnuts and rice has also increased, but cassava is by far the most important crop in terms of volume and value. In the mean time, again according to official figures, the area under food crops has grown from 1.8% of the total Kwango-Kwilu area in the mid-1950s to over 5% today. This means that, although large stretches of the region are still empty (mainly because of the distance to water sources), the R value (land-use factor) of the arable land around the villages is rapidly increasing and may reach values over 50. In these areas, inframarginal land scarcities are emerging.

Population increase during the same period is not known, but the growth rate of the total population in the Bandundu province during the 1970s has been estimated at annual rate of 2.7% (République du Zaire/Département du Plan, undated). Thus, it would seem that, in contrast to the aggregated picture of food production in Africa, cassava outputs in the Kwango-Kwilu have well kept pace with and probably even surpass population increases. The crisis in the Kwango-Kwilu is therefore not primarily one of deficiencies in food production or distribution, but a crisis of shifting cultivation as the dominant mode of land use.

The growth of cassava production has been brought about by a series of changes at all levels of the agricultural system. At the crop system level, cassava now dominates every association and sequence of food crops, leading to what could be called a trend towards monocropping. Cultural practices have been adjusted to deal with the increased demand for cassava, which is planted at higher densities and harvested earlier than before.

At the cropping systems level, in the forest as well as the savanna, cultivation is expanding rapidly into the less fertile uplands. Fields on the plateau, uncommon thirty years ago, are increasingly cultivated by farmers in areas of inframarginal land scarcities. There is some circumstantial evidence suggesting that field sizes have increased slightly. The length of fallowing has declined ubiquitously, resulting in changes in fallow vegetation and declining soil fertility.

At the farming systems level, women are now nearly solely responsible for the production of cassava and other food crops. The disappearance of the forest vegetation, which was cleared by men, implies that the latter have lost their traditional role in agriculture.

At the regional level, the growth of cassava production does not appear to have resulted in changes in system structure, although system function (the processing of inputs into outputs) has been affected by the growth in cassava outputs. On the contrary, under the institutional conditions prevailing in the Kwango-Kwilu, cassava of all food crops probably has the greatest comparative advantage. Because of its flexibility in harvesting times and its capacity to be stored as *cossettes*, cassava has been more adapated to an inadequate marketing structure than other crops such as maize or groundnuts. It could even be suggested that because of cassava's special properties, the regional system did not have to adapt in a structural way. Because of its performance on poor soils, the increased urban demand for food could be relatively easily met by expanding the cassava area.

One important finding is that farmers in the Kwango-Kwilu have been remarkably flexible in adapting their selection of crops and crop varieties, their cultural practices and labour allocation to external changes. Farmers' adaptive practices are therefore also source of internal change (Long 1984), and perhaps also of new technology.

The consequences of increased cassava production

The growth of cassava production is nearly exclusively explained by an expansion in area and not by an increase in yields. While official statistics, in particular those referring to the post-Independence period, are sometimes conflicting, there is sufficient evidence to conclude that cassava yields have been slowly declining from the mid-1950s onwards. Some figures suggest that in the Karroo valleys the decline may have been as high as 50%, from about 15 to 7 tons/ha or less, but this is not warranted by the data on area. Major exports of soil nutrients from the Kwango-Kwilu through the supply of cassava have in no way been matched by the application of chemical fertilizers or organic matter.

Yield declines in cassava are the direct result of two interrelated factors: the fall in soil fertility levels as a consequence of reduced fallowing and the spread of cultivation to more marginal areas, in particular the plateau fields. The increased incidence of pests and diseases may have contributed, but is hardly reflected in the statistics because pests and diseases are a very recent phenomenon in the region.

Both the reduction of fallowing and the expansion to upland fields have been caused by the need to increase the area under cassava. The emergence of inframarginal land scarcities around large villages and townships is reinforced by the influence of government extension staff on field sizes and location. Government policies that affect the price relations between agricultural and consumer goods, incite farmers to harvest earlier and grow larger areas of cassava.

Pests and diseases in cassava have increased dramatically in the last decade. While most pathogens have been introduced from outside the cropping system, there are indications that the severity of their incidence is related to environmental factors such as soil fertility and (micro)climate. This suggests that the poor conditions – referring to soils as well as planting dates – under which the crop is grown may have aggravated pest and disease incidence.

Circumstantial evidence, mainly based on farmers' own observations, points to increased female labour inputs in cassava production and processing. Because women are already burdened with domestic tasks, the net result seems to have been a decline in the quality of agricultural work. Weeding, planting and the construction of ridges are less strictly carried out today than in the past. This may be worrying in light of the poor physical properties of Kwango-Kwilu soils.

Consequently, low cassava yields do not only reflect the limited resource endowments of the Kwango-Kwilu, but also farmers' compromises. Farmers continuously strike compromises between their limited resources and

priorities on the one hand and agronomic desirability on the other (Collinson 1984). Examples of farmers' compromises in cassava production are:
- the early harvesting of late maturing varieties in order to obtain an immediate, although reduced cash income;
- the staggered planting of cassava, which enhances the presence of sources inoculum in the fields, but allows farmers to spread labour inputs and limits losses due to drought;
- the frequent burning of fallows and weed infested fields in order to save labour on soil preparation and weeding, which leads to considerable losses of nitrogen in above ground vegetation;
- the planting of cassava and supra-optimal densities to offset the yield decline of individual plants. The ecological costs of these practices are considerable, although impossible to quantify using the current data base.

In final instance, the consequence of increased cassava outputs has been the breakdown of the shifting cultivation system. A degraded shifting cultivation system has resulted, in which shortened fallows and land pressure are not matched by changes in cultural practices or nutrient restoration. Although land-use factors of over 50 have been found, there is no trace of the adaptations in the cropping system suggested by Ruthenberg in his discussion of the evolution of shifting cultivation towards fallow systems (Ruthenberg 1980).

Discussion: the future of shifting cultivation and cassava production in the Kwango-Kwilu

The shortening of the fallow period has disrupted the low level equilibrium inherent in the shifting cultivation system of the Kwango-Kwilu. Future prospects appear gloomy. In the next decade, population is expected to increase with approximately 2.8% annually. There is a continuing demand for food from the urban centres, which is unlikely to be met through food imports in view of Zaire's balance of payments. Cassava provides the mainstay of the diet of Kinshasa's estimated three million inhabitants, about half of whom are fed by the Kwango-Kwilu. One may speculate that if current trends continue, the final stage of shifting cultivation, at least on the Kalahari plateau, will be the monocropping of cassava on exhausted soils.

Short term developments

Differences between the Karroo and Kalahari zones may be accentuated in the near future. On the one hand, there is a trend towards further land-use intensification. Already, in the densely populated Karroo valleys, hydromorphic valley bottoms are increasingly brought into cultivation with rainfed rice. In the dry season, vegetables are grown in river gardens near small townships. In some areas, fish ponds are established in conjunction with rice plots. Although still on a limited scale, men seem to become involved in these types of commercial production. Prices, marketing and employment alternatives will determine whether in the future men will continue growing crops for sale, thus increasing the possibilities for higher labour inputs and intensification.

On the other hand, there appears also a trend towards extensification of agricultural production. The expansion of the area under cultivation leads to fields that are located at considerable distances from the homesteads. These plateau fields, that occur in forest and savanna, are managed in an extensive way. Women will visit them occasionally to cultivate and harvest them according to needs. On the basis of current labour utilization trends, an increase in savanna and plateau field cultivation could lead to higher female work loads and more pronounced labour bottlenecks.

As a result of these trends towards both extensification and intensification, one may expect a shift in cropping systems in the near future. The traditional dichotomy between forest and savanna cropping systems may be replaced slowly by a distinction between valley-bottom fields with rice and male labour inputs and cassava based cropping systems on other fields. Plateau fields, slope and valley fields in the savanna, and to a lesser extent also slope fields in the forest, seem to be merging into a common pattern based on cassava and a few minor crops. Women are exclusively associated with the latter cropping system. Cassava's future potential lies in this cropping system where its comparative advantage is greater than that of any other crop.

The future of shifting cultivation

In the long run, it is unlikely that long fallow systems such as prevail now in the Kwango-Kwilu in sparsely populated areas will be able to provide sufficient quantities of staple foods to urban centres (Boserup 1985). There would be a strong case for limiting agriculture to those soils that can support intensified systems, but this is hardly acceptable from a social perspective. Apart from the intensification of valley bottoms, which involves only a very small proportion of the total area, there are no easy solutions to the intensification of shifting cultivation. The high rainfall and poor soils of the Kwango-Kwilu make it unlikely that shifting cultivation will be replaced by permanent upland cultivation, unless massive fertilizer inputs would be made available, erosion could be controlled and labour bottlenecks could be overcome. Perennial crops could be envisaged from an agronomic point of view, but apart from coffee and subspontaneous *Rauwolfia spp* there is little scope for the immediate introduction of tree crops that require extensive marketing and extension services. Oil palm has always been marginal in the region because of the length of the dry season, and carries too many associations with forced labour to be attractive to farmers.

Extensive ranching of *N'dama* cattle, if accompanied by adequate veterinary care, has proven successful on the Kalahari plateaus. Investments in cattle, however, are only feasible for a few *'fermiers'* (non-traditional farmers) who have adequate access to land. The availability of water sources will limit the amount of land that can be used as pastures. In the Karroo valleys small herds of large cattle or small ruminants could fit into the present mode of land utilization, but the conflicts between crops and livestock are already becoming apparent in some areas, where animals damage the fields. The introduction of a livestock system, whether based on extensive ranching or small herds, into existing farming systems will demand careful consideration of the social and economic consequences. Complementary aspects could be the use of cattle manure and animal traction. Manure, although useful in the immediate surroundings of kraals, cannot be expected to substitute the removal of soil nutrients through cassava exports. Animal traction in a setting where there is no pastoral tradition and where the need for intensification is only recently arising, does not appear a solution for the immediate future.

Whatever system evolves, the involvement of male labour will be essential in the future intensification of shifting cultivation, as women's present work loads leave little or no room for additional labour inputs. Improving female productivity, in particular in cassava processing, seems one of the priorities.

In Ruthenberg's (1980) terms, one may expect that, ultimately, the cropping systems in the Kalahari and Karroo zones will evolve in separate ways. In the Kalahari towards regulated ley farming or a combination of ranching and arable cropping, and in the Karroo towards a combination of perennial crops, ley farming and arable cropping.

The future of cassava

One may speculate that cassava will remain important on the extensively managed plateau fields as well as in the more intensively cultivated valleys, for diverging reasons. In the valleys, the importance of cassava is unlikely to reduce as land values and land-use intensities around small centres increase, because of its comparative advantage on depleted soils and its high productivity per unit of land and labour. In the Karroo zone, therefore, it may be expected that cassava will increasingly move to the top of the slopes and the

plateau fields, as the lower parts of the slopes and valley bottoms are used for cash crops such as rice and perhaps coffee.
On low fertility plateau fields there are no alternative staple crops apart from cassava. In the Kalahari zone, grass fallowing will continue, as well as a heavy reliance on cassava. It is likely that a steady state of low inputs/low outputs will be reached in most areas.
It may be noted that the modern farmers (*fermiers*) do not appear to form a nucleus for the modernization of cassava production: while their farms may cover a larger area, their cultural practices are hardly different from those of other farmers.

Developing agricultural technology for cassava in shifting cultivation systems

The specific manifestation of the African crisis apparent in the Kwango-Kwilu – degraded shifting cultivation systems with continuing surplus production of cassava – can only partially be attributed to the lack of agricultural technology. Nevertheless, there is a strong case for looking critically at current research on cassava. Not only does current research fail to take into account some of the most pressing constraints on cassava production, it also requires a clearer focus if it is to deal with future problems in shifting cultivation.

Deficiencies in current cassava research

Thusfar, research on cassava in African shifting cultivation systems has emphasized the increased incidence of pests and diseases, and in particular mealybug and cassava green mite, as the most important yield constraining factors. In two respects this focus seems insufficient. Firstly, pests and diseases in cassava are a symptom of a wider problem rather than an independent cause of low yields. Although present selection programs by IITA and Pronam involve multilocational testing there seems to be a neglect of genotype-environment interactions occurring in real farm situations, and in particular of those interactions induced by current cultural practices (field types, planting dates and densities etc.). Hahn et al. (1979:202) suggest that yield levels may be improved through the introduction of new varieties without great changes in cultural practices or cropping systems. The data on the Kwango-Kwilu presented here tend to suggest the opposite, namely that research should be broadened to include the effects of current and improved agronomic practices on pests and diseases.

Secondly, even if biological control and the breeding of resistant varieties are successful – however, it is too early to judge this in view of the limited diffusion of both technologies – other factors associated with low cassava yields still prevail. Ultimately, the introduction of biological control and resistant varieties in shifting cultivation without changing other elements in the system, in particular the use of external inputs, is bound to quicken the pace of soil exhaustion. It is also highly unlikely that improved varieties will be able to express their full genetic potential under present cultural practices and soil fertility. From a systems perspective, the question is not how cassava yields can be increased, but rather how cassava yields per unit of land and labour can be stabilized without further environmental degradation, and how sustainable cropping systems can be developed.

Future research strategies

In technology development for low-input agriculture two related questions need to be considered, one about the time frame and the other one about the role of component technology. It is here that the differences between Anglophone and Francophone farming systems research become apparent. Typically, Francophone farming systems research takes the long-term perspective and aims at developing the potential of an entire region through a transformation of traditional farming systems (in the latest jargon: new farming systems development), whereas most Anglophone farming systems research has been concerned with small step-by-step adaptations of component technology (*thèmes légers*).

Rather than presenting contrasting strategies, these two options are complementary, at least to some extent. The foregoing analysis of factors associated with low yield levels in cassava suggests, in the immediate future, that improved cultural practices accompany the introduction of pest and disease resistant varieties. However, in the long run, step-by- step improvements in component technology alone cannot improve cassava yields unless unfertilized annual cropping on depleted soils is replaced by a stabilized, intensive system.

These options are not only complementary in time but also in space. Regional specialization and the creation of development poles in the central Kwilu (Karroo zone) around the cities of Kikwit and Idiofa would allow the creation of a modern, high input sector which produces food for the urban population, while the remaining majority of farmers continue an improved version of shifting cultivation on the Kalahari plateau. This trend may be emerging already, and could result in the marginalization of an important part of the rural labour force, with disastrous effects on rural poverty. Nevertheless this trend as well as its potential for solving some of the food problems in the cities cannot be ignored. In order to fully develop the potential of the Kwango-Kwilu region, research should not be limited to one type of farming system or target group of farmers – or recommendation domain – only.

Binswanger (1985) suggests research in Africa should concentrate on areas where land is inframarginally scarce with a view to developing input-intensive yield raising technology. In land abundant areas, only research on pest and disease resistance, or yield reducing factors generally, is recommended, whereas input-intensive, and in particular labour-intensive technology is unlikely to be successful. Binswanger's point underscores the differences between the Karroo and Kalahari zones in the Kwango-Kwilu. Emerging inframarginal land scarcities, relatively fertile soils and access to urban markets in the Karroo zone make it likely that the introduction of modern inputs at acceptable prices, in particular fertilizer, is but a matter of time. This does not apply to the Kalahari zone, where land abundance and relative labour shortages are not subject to rapid change.

Constraints at various levels in the hierarchy of systems change over time, at varying rates. Farming systems as well as cropping systems are changing rapidly, which means that research must aim at trends, rather than at a static picture. The development of improved systems – as opposed to improved technology – should not take present constraints into consideration, but determine optimal land-use systems given the ecological potential of the region. It is unlikely that major changes in resource availability and infrastructure will occur in the next ten years. In the short term, cassava researchers have to select improved technology that fits the constraints of climate, soils, labour and farmer priorities in general. Price relations should of course be taken into consideration, but given the great fluctuations, current prices alone cannot constitute a guideline for the economic feasibility of improved technology. However, constraints change over time and what is considered optimal today need not be so in the near future.

A dual approach to research is therefore required, which aims at a transformation of the shifting cultivation system in the long term, while at the same time retaining and adapting elements of the existing cropping system, such as the varietal mix and certain intercropping techniques. Crop improvement research can thus provide a range of options rather than a standard package to farmers in different stages of transition from shifting cultivation to more intensive systems.

Options for adaptive commodity research

The review of cassava research and the analysis of constraints in cassava production in the Kwango-Kwilu point to a number of priorities for future commodity research, which should be carried out within the framework of a long-term program of new farming and cropping systems development. Future adaptive research on cassava in shifting cultivation must focus on the development of cultural practices that improve the environment in which cassava is grown.

A With respect to soil fertility, a better understanding of nutrient removal in various intercropping arrangements with cassava is required in order to determine nutrient requirements and fertilizer applications. Researchers can no longer ignore the diversity in field types. The introduction of inorganic fertilizer constitutes a first priority. On- and off-farm trials are required to determine the break-even point of fertilizer rates. Fertilizer application should be considered in the light of optimal intercropping and crop rotation practices.

B The issue of physical soil structure, organic matter and erosion is of particular concern, because the incorporation of organic matter meets with serious labour bottlenecks and because recent findings suggest that physical soil properties are more difficult to restore than soil nutrient levels (Lal 1979). Green manuring with annual legumes may be a real possibility because of the adequate rainfall, although losses due to mineralization at high temperatures may be considerable. This issue, including some of the improvements suggested by INEAC (*culture en bandes*, Hardy undated), deserves further study in the Kwango-Kwilu. Given the low C/N ratio of grasses on the Kalahari plateau, composting of grasses seems of little use, if no N, P and perhaps lime are added.

C The improvement of the fallow deserves consideration, perhaps through the introduction of legumous perennials fodder crops, such as pigeon pea. However, Webster & Wilson (1966:181) suggest that the effects of 'weedy' cassava on soil fertility are similar to those of pigeon pea, at least on sandy soils. Planted fallows have rarely been adopted by farmers (Ruthenberg 1980:64). Optimal fallow periods need to be redefined if fertilizer is being used during the cropping period.

D Optimal relay and mixed intercropping patterns must be determined in an effort to halt the monocropping of cassava and diversify the diet. The introduction of new or little known crops such as pigeon pea, cow pea and other legumes merits further study. In the immediate future, weed control will be difficult to achieve other than through intercropping. Nevertheless, alternatives deserve further investigation in view of its high labour requirements.

E While the introduction of new varieties can only be successful if accompanied by improved cultural practices, the screening of new and local varieties for pest and disease resistance must continue under conditions that closely reflect the stresses that occur in actual cropping systems. The first step must be to screen improved varieties now released in Bas Zaire in the ecological conditions of the Karroo and Kalahari zones. Multilocational testing should pay close attention to genotype-environment interactions. In particular, the following variables must be included, because they characterize the cassava crop system and make up cassava's comparative advantage vis-à-vis other crops:

- intercropping patterns;
- leaf harvesting;
- staggered root harvesting practices.

It is of utmost importance to define a range of most suitable control varieties for various cropping systems. Control varieties must include those that are best adapted to the current environment (i.e. highest yielding) as well as those local varieties that reflect desirable consumer characteristics. With respect to varietal selection, attention should be given to farmers' preferences for certain plant types. Basic research is further required to define how farmers' needs for cassava roots and leaves can be met (through varieties that combine high root and leaf yield or through different varieties for root and leaf production).

F Short-term pest and disease control measures that can be extended without little further testing are:

- the selection of clean planting material;
- the eradication of severely infected plants;
- the inclusion of a 12 months 'cassava free' period in the fallow;
- the adaptation of planting dates to prevailing pest and disease problems (e.g. no cassava planting after February in areas with high CBB and CM levels).

G The following issues merit further research but improved techniques in this field can probably be easily introduced as they do not greatly affect labour allocation:

- optimal plant densities and plant spacing of cassava according to the type of field and cropping system. Trials could include IITA recommended spacing, traditional low densities and current high densities, as well as the double row versus single row arrangements;
- planting techniques, in particular horizontal, vertical and intermediate positions, again on different types of fields (slopes, plateau).

Implementation of adaptive research

The implementation of this research program meets with some serious problems since the national research program, Pronam, is probably insufficiently equipped for any work beyond multilocational testing. Kiyaka station, the only regional research station in the Kwango-Kwilu has been chronically understaffed and lacks the directions of a national on-farm testing program. At the same time, IITA as well as the other international research institutes are supposed to move increasingly towards strategic and basic research. Therefore, IITA's outreach program in Zaire will have to bear the brunt of the implementation of adaptive research on cassava.The extension service, however weak, must be included in this type of work, even if its impact on agricultural production has thusfar been negative.

Elements for new farming systems development

Crop improvement research on cassava is of course insufficient to develop new farming systems. New farming systems development entails the careful investigation of component technology and the evaluation of these technologies in light of constraints and limitations at all levels of the hierarchy. The main purposes of new farming systems development in the Kwango-Kwilu would be to prolong the cropping period (now only one cassava cycle), to reduce fallows, and to develop non-cropping systems, such as livestock and perhaps fish farming.

With respect to cropping system improvement, consideration should be given to the extension of swamp rice and the cultivation of valley bottoms, the inclusion of perennials in various arrangements (hedgerows, fallow crops, fruit trees).

While the potential of livestock may be limited, the integration of small ruminants in the system merits consideration in the entire Kwango-Kwilu. It requires research on feed sources and labour allocation, as well as methods to dispense minimal veterinary coverage. The development of fish ponds – a program already launched in the 1950s by the colonial administration and taken up since the late 1970s by USAID – may be useful for farmers in the Karroo zone who dispose of titles to valley bottom land. The introduction of aquaculture constitutes perhaps one of the few ways to provide men with an incentive to engage in agricultural production.

From agricultural research to agricultural development: implications for other system levels

Although the urgency of agricultural technology development in Africa has been questioned, on grounds that the problems are economic and political rather than technical (Berry 1983), the findings from the Kwango-Kwilu suggest a slightly different conclusion. In view of the continuing importance of cassava and the problems associated with its production, technical improvements are required, even if they constitute only necessary and not consumption needs will determine to a great extent what crops, and in particular what cassava varieties are grown. The use of external inputs will depend, apart from availability, on income and income spending opportunities. Processing and postharvest handling of cassava are however areas of research that have been sorely neglected. These need to be addressed at the farming systems level, in order to release labour for agricultural production as well as to accomodate potential yield increases.

Systems analysis reconsidered

The underlying assumption of this book has been that a systems approach to agricultural technology development provides a more effective framework than conventional component or commodity research. And furthermore, that a broader systems approach based on systems ecology is more effective than most farming systems research. Time has come to examine these claims in some detail and discuss some issues that require further study.

Levels of analysis

The most important contribution of a systems approach is the definition of distinct but interrelated levels of analysis: the crop-herd system, the cropping-livestock system, the farming system and the regional system. The definition of levels at which scientific knowledge of different disciplines can be meaningfully integrated promotes a clarification of exogenous constraints and endogenous limitations. This may be expected to improve the finetuning of research objectives to development issues.

An illustration of the way a systems approach can fulfil this function has been given in the review of ongoing research on cassava. Because an overall analysis of cassava production in shifting cultivation systems has been lacking, research has thusfar had a nearly exclusive focus on one component of the crop system – cassava – without attention to other constraining factors at that level or at other levels. This has resulted in the neglect of cultural practices, which are not exogenous constraints but limitations within the crop system that need to be dealt with at that level. Research on cassava, therefore, cannot ignore cultural practices or dismiss them as irrelevant.

A systems approach is never a substitute for component and commodity research, but aims to render this research more effective through:

a the distinction between levels of analysis allowing the integration of disciplinary data into a meaningful framework;

they depend on income generated outside agriculture, or in the proportion of labour allocated to the livestock or cropping systems. Regional systems may be similar with respect to the absence or presence of a secondary, food processing sector, or in the degree of urbanization and rural-urban migration. Thus, rather than defining similarities between farmers, similarity and dissimilarity should be defined at each level of the hierarchy of systems, resulting, if one wishes, in a hierarchy of recommendation domains.
Likewise, environmental characterization programs could also be based on a hierarchy of criteria. The outcome of such an exercise would be the definition '*system gradients*': systems with similar suprasystem conditions (exogenous constraints) but reacting differently because of varying endogenous limitations. An example of such a gradient would be the varying degrees to which farmers, in a similar savanna environment, use animal traction or hand implements on their fields, according to farm household composition, market accessibility and so forth.

Farmer knowledge

An important characteristic of systems analysis is the extent to which real problems provide the focus for research, rather than the body of existing scientific knowledge. Within the context of real problems, existing farmer practices and knowledge can be a starting point for further research. The analysis of changes in cassava cultural practices in the Kwango-Kwilu reveals the degree to which farmers can adapt to new constraints and how external constraints are modified by internal factors. Farmers' detailed knowledge of toposequence variations and cassava varieties, for example, constitute worthwhile elements for future research.
The importance of farmer knowledge tends to be emphasized in recent farming systems literature (e.g. Tourte 1984). However, there is a need to clearly specify to what extent farmer knowledge can be relevant to the solution of technical problems and how this knowledge can be fully utilized. It would seem that in rapidly changing environments, such as occur when shifting cultivation systems are breaking down, many facets of farmer knowledge are not adapted anymore and must be interpreted as vestiges of former cropping systems that are now obsolete.

Participation of farmers and other interest groups

Systems analysis does not claim to be an agricultural development policy, but may provide important elements for such a policy. It can do so in two distinct ways. Firstly, it provides a common framework for research and development.

Secondly, farmers and other interest groups can be effectively in the formulation of systems models. The use of systems analysis as a participatory research method is still relatively new. Conway (1985) and IMSA (1985) provide interesting examples of a how various interest groups and scientists from different disciplines make use of a systems approach to reach agreement on problems and agricultural development objectives. Systems analysis then acts as a diagnostic tool in the process of technology development and evaluation. In this respect, a systems approach could be of particular relevance in Africa where farmers, let alone women farmers, have no political influence on research and development. Under those conditions, it seems very important to provide procedures to encourage the various interest groups (farmers, researchers, government officials and development workers) to come to a common understanding.

Methodological considerations

This study has demonstrated that, despite serious limitations in the available data, a systems approach is possible and provides a way to structure data that would otherwise be meaningless because of its diversity. The existing data base in many African coutries is poor, though perhaps not as poor as in the Kwango-Kwilu and Zaire. It may be concluded that the use of a systems model could be particularly appropriate under these conditions. The replicability of this approach is difficult to assess, since the strengths and weaknesses of the analysis, as is always the case in the interpretation of complex phenomena, cannot be separated from the analyst.

The African crisis reconsidered

Two last questions remain. Firstly, one may wonder about the usefulness of a systems approach in the analysis of food production in Africa. I am of the opinion that the ecological systems model presented in this study can be helpful in understanding the nature and causes of the African crisis. For one thing, it shows that the crisis manifests itself at each level of the hierarchy, in the shape of exogenous constraints and endogenous limitations. Rather than suggesting blueprint solutions to deal with Africa's food problems, the use of a systems approach supports the design of location-specific interventions, tailored to the characteristics of systems at each level. At the same time, it also provides a basis for the comparison and the application of solutions to similar systems across the continent.
Secondly, has the preceding analysis of changes in cassava production thrown

any light on the African crisis? I believe it has, in several ways. It shows the importance of looking in detail at how crop production has evolved under very adverse circumstances. The flexibility and potential for adaptation of African farmers is herewith clearly demonstrated. It also suggests that cassava may be a crop of great potential, not because of its current yield levels, but because of its potential to grow under marginal conditions, on poor soils and with low and intermittent labour inputs.

At the same time, however, the analysis suggests that at least in the Kwango-Kwilu, and perhaps in other parts of central Africa as well, the notion of crisis needs to be carefully redefined. If it is not a crisis in food production or even distribution this region is facing, it is definitely confronted with a very serious challenge in the light of the degradation of the natural resource base. The expansion of rainfed arable cropping in a humid environment requires the replacement of shifting cultivation by sustainable intensified cropping and farming systems. The technologies for this type of land utilization in the fragile ecosystems of Africa are only emerging. There can be no doubt in my mind that further research is required. I hope that I have demonstrated that such research, in order to produce technologies suited to farmers' needs, must be based on a thorough analysis of the constraints and limitations of existing agricultural systems.

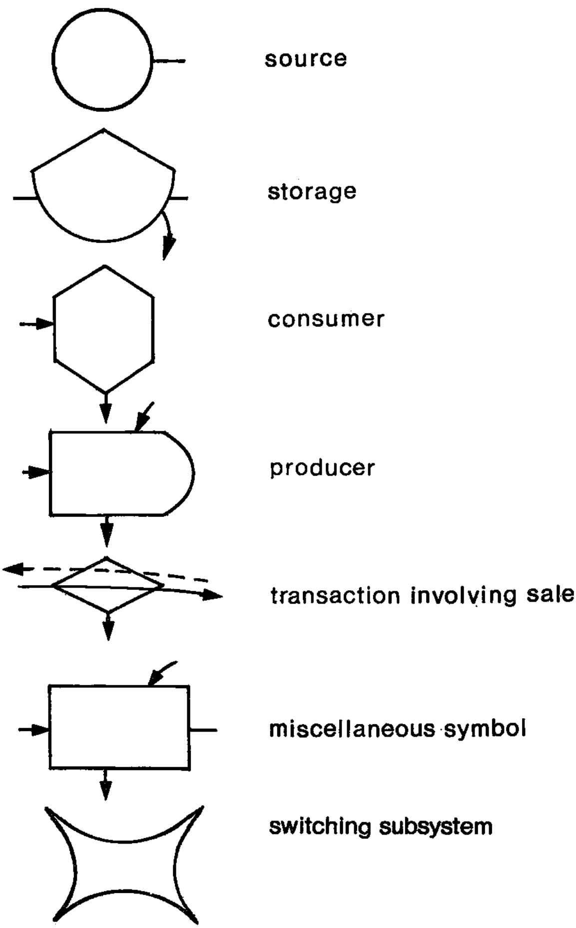
GLOSSARY

adaptive research – agricultural research conducted to adjust new technology to a specific set of environmental and socio-economic conditions. Adaptive research nearly always concerns the farming, livestock and cropping systems levels.
agricultural hierarchy or agricultural system – see hierarchy of systems.
agro-ecological zone – an area of similar soil, vegetation and population density characteristics, resulting in a similar (sub)type of cropping system. In the context of this study, because temperature and rainfall do not vary significantly throughout the region, climate is not included as a variable in the definition of agro-ecological zones. Two zones are distinguished: Kalahari table lands and Karroo valleys.
basic research – agricultural research conducted to generate new understanding of the structure and function of systems.
collectivité(s) (English: collectivity or collectivities) – lowest administrative unit in Zaire, comprising several villages.
commodity research – agricultural research focusing on the improvement of plant, crop, animal or herd systems.
component research – disciplinary oriented research on physical and biological production factors (e.g. soils, hydrology, mechanization).
constraints – exogenous factors limiting system performance that are situated at suprasystem level.
crop association – see intercropping.
crop sequence – see sequential cropping.
crop system – an arrangement of crop populations that transform solar energy, nutrients, water and other inputs into useful biomass. The crops in the crop system can be of different species and variety, but they only constitute one crop system if they are managed as a single unit. The crop system is a subsystem of the cropping system. In the cassava crop system cassava is the dominant crop which is grown in association with other crops.
cropping system – a land-use unit comprising soils, crop, weed, pathogen and insect subsystems, that transforms solar energy, water, nutrients, labour and other inputs into food, feed, fuel and fiber. The cropping system is a subsystem of the farming system.
elements (of a system) – the components, interactions between components, boundary, inputs and outputs.
farming system – a decision making and land-use unit comprising the farm household, cropping and livestock systems, that produces crop and animal products for consumption and sale. The farming system is a subsystem of a higher level land-use system, such as village or watershed, that, in turn, forms a component of the agricultural sector of the regional system.
farm household system – a group of usually related people who, individually or jointly, provide management, labour, capital, land and other inputs for the production of crops and livestock, and who consume at least part of the farm produce.
field type – the location-specific combination of cropping system components in a given agro-ecological and socio-economic environment.

herd system – the arrangement of (domesticated) animal populations and their feed sources.
hierarchy of systems – a model of agriculture involving units (systems) arranged according to increasing scale and complexity, ranging from the plant cell at the lowest and the region/nation at the highest levels.
inframarginal land scarcity (in shifting cultivation systems) – a degree of land-use intensity resulting in a shortage of land for adequate soil fertility restoration through fallowing.
intercropping – the cultivation of two or more crops simultaneously on the same field, with or without a row arrangement (row intercropping or mixed intercropping). Relay intercropping is the growing of two or more crops on the same field with the planting of the second crop after the first one has already flowered. The crops grown in intercropping are called a crop association, and are denoted with a + sign.
limitations – endogenous factors limiting system performance that are situated at subsystem level
livestock system – a land-use unit comprising pastures and herds and auxilliary feed sources transforming plant biomass into animal products.
multilocational experiments (or trials) – experiments conducted outside the physical location of a research station with a view to including a larger range of edaphic and (micro)climatic conditions.
monocropping (of cassava) – a cassava based crop system in which the populations of other crops grown in relay, sequential or intercropping with cassava are greatly reduced.
on-farm experimentation (or trials) – experiments aiming to evaluate new agricultural technology within the context of existing cropping and livestock systems, with varying degree of farmer management.
partial harvesting (of cassava) – the harvesting of one or two storage roots of a cassava plant while the plant is left in the field and continues to grow.
regional system – a complex large-scale land utilization unit that produces and transforms primary products and involves a large service sector. Components of the regional system are natural resources, human resources, the agricultural sector, the secondary and tertiary sectors.
research strategy – the allocation of research resources to specific activities in order to maximize the efficiency and effectiveness of research according to certain societal goals (such as improving the sustainability and availability of food to all sectors of the population).
sequential cropping – the cultivation of two or more crops in sequence on the same field, with the succeeding crop planted only after the first one has been harvested. The crops grown in sequential cropping are called a crop sequence and are denoted with a – sign.
shifting cultivation – a type of cropping system in which crop production alternates with extended periods of fallowing.
staggered harvesting (of cassava) – the harvesting of a few cassava plants from a field while the remainder of the cassava crop is left in the field.
strategic research – agricultural research designed to create new technology or new systems.
system – an arrangement of components (or subsystems) which process inputs into outputs. Each system consists of boundaries, components, interactions between components, inputs and outputs (see elements).
type of system – a group of systems of similar structure and function that can be classified together according to a certain set of criteria, usually referring to component characteristics. Cropping systems, for example, are commonly classified according to land-use intensity (e.g. perennial cropping, permanent upland cultivation, shifting cultivation). Within each type further subtypes can be distinguished, e.g. savanna and forest shifting cultivation systems.

Annex 1 Energy symbols (after ODUM 1983).

ANNEX ON ENERGY SYMBOLS



ABBREVIATIONS

CAD	Cassava anthracnose disease
CBB	Cassava bacterial blight
CGIAR	Consultative Group on International Agricultural Research
CGM	Cassava green mite
CIAT	Centro International de Agricultura Tropical
CIMMYT	International Centre for the Improvement of Maize and Wheat
CM	Cassava mealybug
CMD	Cassava mosaic disease
CMV	Cassava mosaic virus
FAO	Food and Agriculture Organization of the United Nations
FSR	Farming systems research
GDP	Gross Domestic Product
GOZ	Government of Zaire
IARC	International Agricultural Research Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Centre for Africa
IMF	International Monetary Fund
INEAC	Institut National pour l'Etude Agronomique du Congo
INERA	Institut National pour l'Etude et la Recherche Agronomiques (Zaire)
INS	Institut National des Statistiques (Zaire)
IRRI	International Rice Research Institute
ISRA	Institut Sénegalais de Recherches Agricoles
MAC	Mission Agricole Chinoise (Zaire)
OZACAF	Office Zairois du Café (Zaire)
PNE	Programme National Engrais (Zaire)
Pronam	Programme National Manioc (Zaire)
R-D	Recherche-développement

REFERENCES

ADRIAENS, L., 1946. *Contribution à l'étude de la toxicité du manioc au Congo Belge.* (Institut Royal Colonial Belge, Memoires 13/4) Bruxelles.

ADRIAENS, L., 1951. 'Recherches sur l'alimentation des populations au Kwango.' In: *Bull. Agr. du Congo Belge*, 42(3):227-269.

ADRIAENS, L., 1957. 'L'introduction du manioc en Afrique.' In: *Bull. Agr. du Congo Belge*, 48(3):743-746.

AHN, P.M., 1974. 'Some observations on basic and applied research in shifting cultivation.' In: *FAO soils bulletin*, 24:123-155.

ALLAN, W., 1965. *The African husbandman.* (Oliver & Boyd) Edinburgh.

ANDREW, C. & P.E. HILDEBRAND, 1982. *Applied agricultural research.* (Westview Press) Boulder.

ANGÉ, A., 1984. *Les contraintes de la culture cotonnière dans le système agraire de haute Casamance.* (PhD thesis INA) Paris-Grignon.

ANTHONY, K.R.M. et al., 1979. *Agricultural change in tropical Africa.* (Cornell University Press) Ithaca.

ARENE, O.B. & S.O. ODURUKWE, 1979. 'Limitations in the use of NPK fertlizer in the control of cassava bacterial blight.' In: TERRY, E.R. et al. (ed.), 1979. *Cassava bacterial blight in Africa – past, present and future. Workshop report.* (Centre of Overseas Pest Research) London.

ASHRAF, M. et al., 1985. *A case study of on-farm adaptive research in the Bida agricultural development project.* (IITA), Ibadan.

BECK, B.D.A., 1982. 'Historical perspectives of cassava breeding in Africa.' In: *Root crops in Eastern Africa. Proceedings of a workshop held in Kigali.* (IDRC 177e) Ottawa.

BEEBE, J., 1985. *Rapid rural appraisal; a critical first step in a farming systems approach to research.* (FSSP networking paper no.5, University of Florida) Gainesville.

BEETS, W.C., 1982. *Multiple cropping and tropical farming systems.* (Westview Press) Boulder.

BENOIT-CATTIN, M. & J. FAYE, 1982. *L'exploitation agricole familiale en Afrique Soudano-Sahelienne.* (ACCT/Presses Universitaires de France) Paris.

BERRY, S.S., 1983. *Agrarian crisis in Africa? A review and an interpretation. Paper prepared for the joint African studies committees of the social science research council and the American council of learned societies.*

BERTALANFFY, L. VON, 1968. *General system theory.* (Braziller) New York.

BILLAZ, R. & M. DUFUMIER, 1980. *Recherche et développement en agriculture.* (Presses Universitaires de France) Paris.

BINSWANGER, H.P., 1985. *Evaluating research system performance and targeting research in land abundant areas of sub-Saharan Africa.* (World Bank) Washington.

BINSWANGER, H.P. & V.W. RUTTAN, 1978. *Induced innovation, technology, institution and development.* (John Hopkins University Press) Baltimore.

BOERBOOM, B.W.J., 1978. 'A model of dry matter distribution in cassava.' In: *Neth. J. of agric. Sci.*, 26(3):267-277.

BOHER, B. et al., 1978. 'Les maladies cryptogamiques du manioc en RP du Congo.' In: MARAITE, H. & J.A. MEYER (ed.), 1978. *Diseases of tropical food crops. Proceedings.* Louvain-la-Neuve.

BOSERUP, E., 1970. *Woman's role in economic development.* (George Allan & Unwin) London.

BOSERUP, E., 1985. 'The impact of scarcity and plenty on development.' In: ROTBERG, R. & T. RABB (ed.), 1985. *Hunger and History.* (Cambridge University Press/MIT.)

BREKELBAUM, T., A. BELLOTTI & J. LOZANO, 1978. *Proceedings of the Cassava protection workshop.* (CIAT CE 14) Cali.

BROKENSHA, D. et al. (ed.), 1980. *Indigenous knowledge systems and development.* (University Press of America) Washington.

BRUIJN, G.H. DE, 1971. *Etude du caractère cyanogénétique du manioc*. (Meded. Landbouwhogeschool, Wageningen 71-13) Wageningen.
BRUIJN, G.H. DE, 1982. *Performance and dry matter distribution of cassava at different ages and ecological conditions in the Ivory Coast. Proceedings Fifth Symposium of the International Society for Tropical Root and Tuber Crops*. Manila.
BRUSH, S.B., 1980. 'Potato taxonomies in Andean agriculture.' In: BROKENSHA, D. et al. (ed.), 1980. *Indigenous knowledge systems and development*. (University Press of America) Washington.
BURGOS, C.F., 1980. 'Soil-related intercropping practices in cassava production.' In: WEBER, E. J. et al. (ed.), 1980. *Cassava cultural practices*. (IDRC 151e) Ottawa.
BUTARE, I. & F. BANYANAGABOSE, 1982. 'Effects of soil fertility on cassava bacterial blight in Ruanda.' In: *Root crops in Eastern Africa. Proceedings of a workshop held in Kigali*. (IDRC 177e) Ottawa.
BYERLEE, D. & M. COLLINSON, 1980. *Planning technologies appropriate to farmers: concepts and procedures*. (CIMMYT), Londres/Mexico.
BYERLEE, D. & L. HARRINGTON, 1982. *New wheat varieties and the small farmer. Paper presented to the conference of the international association of agricultural economists*. Jakarta.
CALDWELL, J., 1975. *Population growth and socio-economic change in West-Africa*. (Columbia University Press) New York.
CENTRE FOR OVERSEAS PEST RESEARCH, 1978. *Pest control in tropical root crops*. (PANS manual 4) London.
CEPLANUT (Centre de la planification nutritionnelle), 1982. *Rapport XXI*, Kinshasa.
CGIAR/TAC, 1978. *The review of farming systems research at the international agricultural centres*. (TAC secretariat, FAO) Rome.
CGIAR/TAC, 1985. *TAC review of CGIAR priorities and future strategies*. (TAC secretariat, FAO) Rome.
CHAMBERS, R. 1980. *Rural poverty unperceived: problems and remedies*. (World Bank) Washington.
CHAMBERS, R. & B.P. GHILDYAL, 1984. *Agricultural research for resource-poor farmers: the farmer-first-and-last model*. (Ford Foundation) New Delhi.
CIAT, 1976. *Cassava production systems program, annual report*. Cali.
CIPARISSE, G., 1978. 'An anthropological approach to socio-economic factors of development. The case of Zaire.' In: *Current Anthropology*, 19(1).
COCK, J.H. et al., 1976. *A rapid propagation system for cassava*. (CIAT EE20) Cali.
COCK, J.H., 1985. *Cassava. New potential for a neglected crop*. (IADS/Westview Press) Boulder.
COCK, J.H. & R.H. HOWELER, 1978. 'The ability of cassava to grow on poor soils.' In: JUNG, G. (ed.), 1978. *Crop tolerance to suboptimal land conditions*. (ASA special publication 32) Madison.
COCK, J.H. et al., 1979. 'The ideal cassava plant for maximum yield.' In: *Crop Science*, 19:271-279.
CONGO BELGE, Province de Leopoldville. *Rapports annuels 1945-1959*. (Service Provincial de l'Agriculture et de la Colonisation).
CONWAY, G.R., 1985. 'Agroecosystem Analysis.' In: *Agricultural Administration*, 20:31-55.
COURSEY, P.G., 1973. 'Cassava as food: toxicity and technology.' In: NESTEL, B. & R. MCINTYRE (ed.), 1973. *Chronic cassava toxicity*. (IDRC 010e) Ottawa.
DAHNIYA, M.T., 1983. *Evaluation of cassava for leaf and root production in Sierra Leone. Proceedings Sixth Symposium of the International Society for Tropical Root and Tuber Crops*. Lima.
DALTON, G.E., 1982. *Managing agricultural systems*. (Applied Science Publishers) London.
DANIEL, J.F. et al., 1978. 'Les maladies bactériennes du manioc en RP du Congo et en Empire centrafricain.' In: MARAITE, H. & J.A. MEYER (ed.), 1978. *Diseases of tropical food crops. Proceedings*. Louvain-la-Neuve.
DATTA, S.K. DE et al., 1978. *A handbook on the methodology for an integrated experiment-survey on rice yield constraints*. (IRRI) Los Banos.
DELANGE, F. & R. AHLUWALIA, 1983. *Cassava toxicity and thyroid: research and public health issues*. Workshop proceedings. (IDRC 207e) Ottawa.
DENT, J.B., 1975. 'The application of systems theory in agriculture.' In: DALTON, G.E. (ed.), 1975. *The study of agricultural systems*.
DESNEUX, R. & R. HARDY, undated. *La disette actuelle en territoire de Kahemba. Rapport confidentiel*. (probably 1955).
DEVRED, R., 1957. 'Limite phytogéographique occidento-méridionale de la region guinéenne au Kwango.' In: *Bull. du Jardin Botanique de l'Etat*, vol. XXVII/3.
DEVRED, R., 1960. 'La cartographie de la végétation au Congo Belge. In: *Bull. Agr. du Congo Belge*, 51(3):529-542.

DEVRED, R. & R. HARDY, 1957. 'Résultats et commentaires agronomiques d'une mission pédo-botanique au Kwango.' In: *Bull. Agr. du Congo Belge.*
DEVRED, R., C. SYS & J.M. BERCE, 1958. *Carte des sols de la végétation du Congo belge et du Ruanda-Urundi. Vol. 10, Kwango A & B. Notice explicative de la carte des sols et de la végétation.* (INEAC) Bruxelles.
DOLL, J.D., 1978. 'Weeds, an economic problem in cassava.' In: BREKELBAUM, T. et al. (ed.), 1978. *Proceedings Cassava Protection Workshop.* (CIAT CE 14) Cali.
DOLL, J.D. & W. PIEDRAHITA, 1976. *Methods of weed control in cassava.* (CIAT EE 21) Cali.
MCDOWELL, R.E. & P.E. HILDEBRAND, 1980. *Integrated crop and animal production: making the most of resources available to small farms in developing countries.* (Rockefeller Foundation) New York.
DRACHOUSSOFF, V., 1947. 'Essai sur l'agriculture indigène au Bas Congo.' In: *Bull. Agr. du Congo Belge*, 38(3):471-582 and 38(4):783-880.
DRACHOUSSOFF, V., 1954. *Reconnaissance agricole dans les territoires de Feshi et Kahemba.* (INEAC)
DRACHOUSSOFF, V., 1965. *Agricultural change in the Belgian Congo: 1945-1960.* (Food Research Institute, Stanford University) Stanford.
DUMONT, R., 1962. *L'Afrique noire est mal partie.* (Ed. du Seuil) Paris.
EDWARDS, E. & N. KANG, 1978. 'Tolerance of cassava to high soil acidity.' In: *Field Crops Research*, 1(4):337-346.
EICHER, C.K., 1984. *International technology transfer and the African farmer.* (University of Zimbabwe) Harare.
EICHER, C.K. & D.C. BAKER, 1982. *Research on agricultural development in sub-Saharan Africa: a critical survey.* (MSU international development paper 1, Michigan State University) East Lansing.
EZEILO, W., 1979. 'Intercropping with cassava in Africa.' In: WEBER, E.J. et al., 1979. *Intercropping with cassava.* (IDRC 142e) Ottawa.
EZUMAH, H.C., 1981. 'Cassava improvement in Pronam in Zaire: objectives and achievements to 1978.' In: TERRY, E.R. et al. (ed.), 1981. *Tropical root crops: research strategies for the 1980s.* (IDRC) Ottawa.
EZUMAH, H.C. & B.N. OKIGBO, 1980. 'Cassava planting systems in Africa.' In: WEBER E.J. et al. (ed.), 1980. *Cassava cultural practices.* (IDRC 151e) Ottawa.
EZUMAH, H.C. et al., 1980. 'Soil and water conservation and management for cassava production in Africa.' In: WEBER, E.J. et al. (ed.), 1980. *Cassava cultural practices.* (IDRC 151e) Ottawa.
FAO, 1974. *Shifting cultivation and soil conservation in Africa.* (FAO Soils bulletin 24) Rome.
FAO, 1978. *Regional food plan for Africa. Report of the 10th FAO regional conference for Africa.* Tanzania.
FAO, 1978. *Report on the agro-ecological zones project. Vol 1: Methodology and results for Africa.* Rome.
FAO, 1979. *Report of the World Conference on Agrarian Reform and Rural Development.* Rome.
FAO, 1982. *Weeds in tropical crops: review of abstracts.* (FAO plant production and protection paper 32) Rome.
FAO/UNDP, 1980a. *La commercialisation des produits vivriers.* Kinshasa.
FAO, 1980b. *Land evaluation guidelines for rainfed agriculture.* (World soil resources report 52) Rome.
FAO, 1983. *Développement rural integré du Kwilu, Zaire. Le milieu rural et son développement au Kwilu. Rapport établi sur la base des travaux de L. Fresco.* (Rapport technique 1) Rome.
FASSI, B., 1957. 'Premières observations sur une pourriture des racines du manioc, causée par un *Phytophtora*.' In: *Bull. d'Information INEAC*, 6(5).
FAYE, J. & M. NIANG, 1977. 'An experiment in agrarian restructuration and Senegalese rural space planning.' In: *African Environment*, 2(4)-3(1):143-153.
FERWEDA, J.D., 1984. 'Meervoudige teeltsystemen.' In: *Ldbk. Tijdschr*, 96(10).
FLACH, M., 1982. *'Ecological competition among the main moisture rich starchy staples in the tropics and subtropics.' Proceedings Fifth Symposium of the International Society for Tropical Root and Tuber Crops.* Manila.
FLINN, J., 1982. *Constraints research. Summary paper for the IITA conference on on-farm experimentation.* Ibadan.
FOREAMI, 1938. *Résumé des observations réunies au Kwango au sujet de deux affectations d'origine indeterminée, par le dr Trolli.* Bruxelles.
FOX, R.C., W. DE CRAEMER, & J.M. DE RIBEAUCOURT, 1965. 'The second independence: a case study of the Kwilu rebellion in the Congo.' In: *Comparative studies in society and history*, VIII (Oct).

FRANZEL, S.C., 1983. *Planning an adaptive production research program for small farmers*. (PhD thesis, Michigan State University) East Lansing.
FRESCO, L.O., 1982. 'Des cultures imposées aux cultures encadrées. Le système des cultures imposées revu dans le cadre de la relance agricole.' In: *Zaire-Afrique* (Janvier).
FRESCO, L.O., 1983. *Women and Cassava Production*. (FAO mimeo) Rome.
FRESCO, L.O., 1984a. *Comparing Anglophone and Francophone approaches to farming systems research and extension*. (FSSP networking paper 1, University of Florida) Gainesville.
FRESCO, L.O. 1984b. 'Issues in Farming Systems Research.' In: *Neth. J. of Agr. Sc.*, 32:253-261.
FRESCO, L.O., 1984c. *Techniques agricoles améliorées pour le Kwango-Kwilu*. (INADES/FAO/CODAIK), Kinshasa.
FRESCO, L.O. & S.V. POATS, 1986. 'Farming Systems Research and development: an approach to solving food problems in Africa.' In: HANSEN, A. & D. MCMILLAN (ed.). *Food in sub-Saharan Africa*. (Lynne Rienner) Boulder.
GERDAT, 1982. *La gazette des sytèmes*. (Mission Systèmes Agraires) Montpellier.
GHESQUIERE, J., 1928. 'Amélioration de la méthode de plantation du manioc.' In: *Bull. Agr. du Congo Belge*, 19(4).
GIETEMA-GROENENDIJK, E., 1970. *Bereiding van cassave*. (Agromisa) Wageningen.
GILBERT, E., D.W. NORMAN & F. WINCH, 1980. *Farming systems research: a critical appraisal*. (MSU rural development paper 6, Michigan State University) East Lansing.
GODO, G.H., 1983. *Yield components as influenced by method of planting cassava cuttings. Proceedings Sixth Symposium International Society for Tropical Root Crops*. Lima.
GOMEZ, A.A. & K.A. GOMEZ, 1983. *Multiple cropping in the humid tropics of Asia*. (IDRC, 176e) Ottawa.
GRAN, G., 1979. *Zaire, the political economy of underdevelopment*. (Praeger) New York.
GUYER, J., 1984. 'Women's work and production systems: a review of two reports on the agricultural crisis.' In: *Review of Afr. Political Economy*, 27/28: 186-191.
HAHN, S.K., 1983. 'Cassava research to overcome the constraints in Africa.' In: DELANGE, F. & R. AHLUWALIA, 1983. *Cassava toxicity and thyroid: research and public health issues. Workshop proceedings*. (IDRC 207e) Ottawa.
HAHN, S.K. et al., 1979. 'Cassava improvement in Africa.' In: *Field Crops Research*, 2:193-226.
HAHN, S.K. et al., 1980a. 'Correlated resistance of cassava to cassava mosaic disease and bacterial blight.' In: *Euphytica*, 29:305-311.
HAHN S.K. et al., 1980b. 'Resistance of cassava clones to cassava green mite, *M. tanajoa*.' In: *Tropical Pest Management*, 26(3):265-267.
HAHN, S.K. et al., undated. *Cassava breeding at IITA*. Ibadan.
HARDY, R., undated. *Un système cultural applicable en régions pauvres. Méthode de culture pour pays de savane*. (Document technique secteur Bas Congo; III secteur Congo Central) 72-90.
HARRINGTON, L.W. & R. TRIPP, 1984. *Recommendation domains: a framework for on-farm research*. (CIMMYT Economics program working paper 2/84) Mexico.
HART, R.D., 1974. *The design and evaluation of a bean, corn and manioc cropping system*. (PhD thesis, University of Florida) Gainesville.
HART, R.D., 1982. 'One farm system in Honduras: a case study in farming systems research.' In: SHANER, W. et al. (ed.), 1982. *Readings in farming systems research*. (Westview Press) Boulder.
HART, R.D. & A.M. PINCHINAT, 1982. 'Integrative agricultural systems research.' In: *Caribbean Seminar on Farming Systems Research Methodology*. (IICA/INRA, Basse Terre) Guadeloupe.
HEISER, C.B., 1973. *Seed to civilization. The story of man's food*. (Freeman & Co) San Francisco.
HILDEBRAND, P.E., 1981. 'Combining disciplines in rapid appraisal: the sondeo approach.' In: *Agricultural Administration*, 8:423-432.
HILDEBRAND, P.E. & F. POEY, 1985. *On-farm agronomic trials in farming systems research and extension*. (Lynne Rienner) Boulder.
HILTON, A., 1985. *The kingdom of Kongo*. (Clarendon Press) Oxford.
HOWELER, R.H., 1980a. 'Soil-related cultural practices for cassava.' In: WEBER, E.J. et al. (ed.), 1980. *Cassava cultural practices*. (IDRC 151e) Ottawa.
HOWELER, R.H., 1980b. 'The effect of mycorrhizal inoculation on the phosphate nutrition of cassava.' In: WEBER, E.J. et al. (ed.), 1980. *Cassava cultural practices*. (IDRC 151e) Ottawa.
IBE, D.G. & F.O.C. EZEDINMA, 1981. 'Gari Yield from cassava: is it a function of root yield?' In: TERRY, E.R. et al. (ed.). *Tropical root crops. Research strategies for the 1980*. (IDRC 163e) Ottawa.

IDAIKKADAR, N.M., 1979. *Agricultural statistics: a handbook for developing countries*. (Pergamon Press) Oxford.

IITA, 1984. *Project report: Africa-wide project for biological control of cassava pests*. Ibadan.

IITA, 1977-1985. *Annual reports of the International Institute of Tropical Agriculture for 1978-1984*. Ibadan.

IMSA (Instituut voor Milieu- en Systeemanalyse), 1985. *Systeemanalyse van de Nederlandse Landbouw. Proceedings van een studiedag*. Amsterdam.

INEAC, 1948-1961. *Rapports annuels pour les exercices 1947-1960*. (Ministère des Colonies) Bruxelles.

INEAC, 1958. *Normes de main d'oeuvre pour les travaux agricoles au Congo Belge*. Yangambi.

INEAC, undated. *Dossier technique secteur du Bas Congo III: un système cultural applicable en régions pauvres*. Station de Kiyaka.

IRAT, 1983. *Rapport Annuel 1982*. Paris.

JANSSENS, P., 1917. 'Note sur les cultures indigènes au district du Kasai.' In: *Bull. Agr. du Congo Belge*, 8.

JONES, W.O., 1957. 'Manioc, an example of innovation in African economies.' In: *Economic development and cultural change*, 4(2):92-117.

JONES, W.O., 1959. *Manioc in Africa*. (Stanford University Press) Stanford.

JURION, F., 1952. 'Le rôle de l'INEAC dans le développement de l'agriculture congolaise.' In: *Bull. d'Info. de l'INEAC*, 1(1):5-20.

JURION, F. & J. HENRY, 1967. *De l'agriculture itinérante à l'agriculture intensifiée*. (INEAC), Bruxelles.

KESSLER, J.J. & F. OHLER, 1983. *Interventies in Sahellanden: een ecologische benadering*. (Vakgroep Natuurbeheer, Agricultural University/CABO) Wageningen.

KEULEN, H. VAN & J. WOLF (ed.), 1984. *Modelling of agricultural production: weather, soils and crops*. (Simulation monographs, PUDOC Wageningen, 6th version) Wageningen.

KING, M. (ed.), 1966. *Medical care in developing countries. A symposium from Makerere*. (Oxford University Press) London.

KIRKBY, R.A. (ed.), 1984. *Crop improvement in Eastern and Southern Africa: research objectives and on-farm testing*. (IDRC, 218e) Ottawa.

KUILE, C.H.H. TER, 1983. *The nature, extent and development problems of shifting cultivation*. (Consultation paper FAO) Rome.

LAL, R. 1979. 'The role of physical properties in maintaining productivity of soils in the tropics.' In: LAL, R. & D.J. GREENLAND (ed.), 1979. *Soil physical properties and crop production in the tropics*. (Wiley) Chichester.

LATHAM, M.C., 1979. *Nutrition humaine en Afrique tropicale*. (FAO, Collection Alimentation et Nutrition 11, revised) Rome.

LEIHNER, D.E., 1979. 'The agronomic implications of cassava intercropping systems.' In: WEBER, E.J. et al. (ed.), 1979. *Intercropping with cassava*. (IDRC 142e) Ottawa.

LEIHNER, D.E., 1980. 'Cultural control of weeds in cassava.' In: WEBER E.J. et al. (ed.), 1980. *Cassava cultural practices*. (IDRC 151e) Ottawa.

LEIHNER, D.E., 1983. *Management and evaluation of intercropping systems with cassava*. (CIAT, mimeo) Cali.

LEFÈVRE, P., 1935. 'Quelques considérations sur la mosaique du manioc.' In: *Bull. Agr. du Congo Belge*, 26(4):442-449.

LEFÈVRE, P., 1944. 'Note sur quelques insectes parasites du *M. utilissima* Pohl dans la région de Kasenyi.' In: *Bull. Agr. du Congo Belge*, 35(4):191-198.

LEFORT, J., 1983. 'Integrated research and development for rural areas.' In: *Cahiers de la recherche-développement*. (IFARC/GERDAT) Montpellier.

LONG, N., 1984. *Creating space for change: a perspective on the sociology of development*. (Inaugural lecture, Agricultural University, Wageningen) Wageningen.

LOZANO, J.C. & A.C. BELLOTTI, 1980. 'Integrated control of diseases and pests in cassava.' In: WEBER, E.J. et al. (ed.), 1980. *Cassava cultural practices*. (IDRC 151e) Ottawa.

LOZANO, J.C. et al., 1977. *Production of cassava planting material*. (CIAT) Cali.

LOZANO, J.C. et al., 1980. *The relationships between cassava, ecosystems, diseases and pests and their influence on breeding strategy*. (CIAT) Cali.

LOZANO, J.C. et al., 1981. *Field problems in cassava*. (CIAT) Cali.

LUTALADIO, N.B. & H.C. EZUMAH, undated. *Cassava leaf harvesting in Zaire*. M'vuazi.

MAKAMBILA, C., 1978. 'L'anthracnose du manioc en RP du Congo.' In: MARAITE, H. & J.A. MEYER (ed.), 1978. *Diseases of tropical food crops*. Louvain-la-Neuve.
MARAITE, H. & J.A. MEYER (ed.), 1978. *Diseases of tropical food crops. Proceedings of an international symposium*. Louvain-la-Neuve.
MATILE-FERRERO, D., 1978. 'Cassava mealybug in the PR of Congo.' In: *Workshop on Cassava Mealybug Proceedings*. M'vuazi, Zaire.
MATLON, P.J., 1982. *On-farm experimentation. ICRISAT's farmer tests in the context of a program of farm-level baseline studies*. (ICRISAT) Ougadougou.
MATLON, P.J. et al., 1984. *Coming full circle: farmers' participation in the development of technology.* (IDRC 189e) Ottawa.
MAXWELL, S., 1984. *Farming systems research: hitting a moving target*. (IDS discussion paper 199, Nov. 1984) Sussex.
MEYER, J.A. & H. MARAITE, 1975. *La bactériose, une grave maladie du manioc en Afrique*. (Académie Royale des Sciences d'Outre-Mer) Bruxelles.
MILLER, J.G., 1978. *Living systems*. (McGraw Hill) New York.
MINISTÈRE DES COLONIES, 1945-1960. *Rapports annuels sur l'administration de la Colonie du Congo Belge*. Bruxelles.
MINISTÈRE DES COLONIES, 1955. *Aperçu sur l'économie agricole de la Province de Leopoldville*. Bruxelles.
MIRACLE, M.P., 1967. *Agriculture in the Congo Basin – tradition and change in African rural economies*. (University of Wisconsin Press) Madison.
MIRANDA, E. DE & R. BILLAZ, 1980. 'Méthodes de recherche en milieu sahélien: les approches écologiques et agronomiques d'une démarche pluridiscplinaire. L'exemple de Maradi au Niger.' In: *Agronomie Tropicale*, XXXV-4:357-373.
MORENO, R., 1979. 'Crop protection implications of cassava intercropping.' In: WEBER, E.J. (ed.), 1979. *Intercropping with cassava*. (IDRC 142e) Ottawa.
MORENO, R. & R.D. HART, 1979. 'Intercropping with cassava in Central America.' In: WEBER, E.J. et al. (ed.), 1979. *Intercropping with cassava*. (IDRC 142e) Ottawa.
NASSAR, N.M.A., 1978. 'Conservation of the genetic resources of cassava.' In: *Economic Botany*, 32(3):331-320.
NESTEL, B. (ed.), 1976. *African cassava mosaic*. (IDRC 071e) Ottawa.
NESTEL, B. & J. COCK, 1976. *Cassava. The development of an international research network*. (IDRC 059e) Ottawa.
NICOLAI, M., 1963. *Le Kwilu. Etude géographique d'une région congolaise*. (Ed. CEMUBAC) Bruxelles.
NIJHOLT, J.A., 1934. 'Opname van voedingsstoffen uit den bodem bij cassava.' In: *Ldbk. Tijdsch. voor Ned. Indië*, x(9):329-351.
NIJHOLT, J.A., 1935. *Opname van voedingsstoffen uit den bodem bij cassava*. (Buitenzorg, Mededeelingen proefstation 15) Buitenzorg.
NORMAN, D.W., 1980. *The farming systems approach: relevancy for the small farmer.* (MSU rural development paper 5, Michigan State University) East Lansing.
NORMAN, D.W., 1982. *The farming systems approach to research.* (FSR paper series 3, Kansas State University) Manhattan.
NORMAN, D.W., D.H. PRYOR & C.J.N. GIBBS, 1979. *Technical change and the small farmer in Hausaland, northern Nigeria*. (African rural economy paper 21, Michigan State University) East Lansing.
NWANZE, K.F. & K. LEUSCHNER (ed.), 1978. *Proceedings of the International Workshop on the Cassava Mealybug*. (IITA), Ibadan.
NYE, P.H. & D.J. GREENLAND, 1960. *The soil under shifting cultivation*. (Technical communication 51, Commonwealth Agricultural Bureaux, Farnham Royal) Bucks.
OAU, 1980. *The Lagos Plan of Action for the implementation of the Monrovia strategy for the economic development of Africa*. Lagos.
ODUM, E.P., 1984. 'Properties of Agroecosystems.' In: LOWRANCE, R. et al. (ed.). *Agricultural Ecosystems. Unifying concepts*. (John Wiley & Sons) New York.
ODUM, H.T., 1983. *Systems Ecology.* (John Wiley & Sons) New York.
OKEKE, J.E., 1983. *Cassava productivity in intercropping systems. Sixth Symposium of the International Society for Root and Tuber Crops*. Lima.
OKIGBO, B.N., 1977. *Preliminary cassava interplanting trials. 1st NAFPP National Cassava workshop*. (IITA) Ibadan.

OPSOMER, J.E., 1938. 'De invloed van de mozaiekziekte op de opbrengst van de cassava.' In: *Bull. Agr. du Congo Belge*, 29(2):317-323.
ORAM, P., 1985. *National agricultural research systems in developing countries: research needs and priorities for development assistance. Paper submitted to RAWOO. The Hague.*
PACUMBABA R.P. et al., 1979. 'The present status of cassava bacterial blight in Zaire.' In: *Cassava bacterial blight in Africa.* (IDRC/IITA/Centre for Overseas Pest Research) London.
PARLEVLIET, J.E., undated. *Plantenveredeling in relatie tot de kleine boer in ontwikkelingslanden.* (Dept. of Plant Breeding, Agricultural University) Wageningen.
PEARSE, A., 1980. *Seeds of plenty, seeds of want.* (Oxford University Press) Oxford.
PELISSIER, P., 1966. *Les paysans du Sénégal.* (Impr. Fabrègue) St Yrieux.
PNE/FAO, 1981. *Rapport sur les analyses des sols effectuées au Bandundu.* Kinshasa.
PERSLEY, G.J., 1978. 'Ecology of cassava bacterial blight in Nigeria.' In: MARAITE, H. & J.A. MEYER (ed.), 1978. *Diseases of tropical root crops.* Louvain-la-Neuve.
PHILLIPS, T.P., 1983. 'Overview of cassava consumption and production. In: DELANGE, F. & R. AHLUWALIA, 1983. *Cassava toxicity and thyroid: research and public health issues. Workshop proceedings.* (IDRC 207e) Ottawa.
PRONAM, 1980. *Rapport Annuel 1979.* (Rep. du Zaire/INERA) Kinshasa.
RAMOND, C. et al., 1970. 'La démarche de l'IRAT au Senegal. Application des resultats de la recherche à la définition des modèles d'exploitations.' In: *Agronomie Tropicale*, XXV(10):963-972.
RAPPAPORT, R.A., 1971. 'The flow of energy in an agricultural society.' In: *Sci. Am.*, 225(3):116-133.
RASSEL, A., 1958. 'Le mil à chandelles (*Pennisetum typhoides* Burm) et sa culture au Kwango.' In: *Bull. Agr. du Congo Belge*, Febr. 1958:1-22.
RASSEL, A., 1960. 'Le voandzou *Voandzeia subterranea* Thouars et sa culture au Kwango.' In: *Bull. Agr. du Congo Belge*, Febr. 1960:1-26.
RASSEL, A. & R. HARDY, 1954-1955. *La situation sanitaire du manioc en territoire de Kahemba.* (INEAC, internal report) Kiyaka.
RASSEL, A. & R. HARDY, 1956. *Compte rendu de la visite des champs de manioc en territoire de Kahemba.* (INEAC, internal report) Kiyaka.
REID, E., 1981. *Socio-economic base-line survey for the Kwilu road building component of the agricultural marketing development project.* (USAID) Kinshasa.
RENIER, M., 1955. *Flore pratique des légumineuses et de graminées du Kwango.* Louvain.
RENIER, M., 1957. Leçons d'agriculture nouvelles pour les régions du Kwango. Louvain.
RENVOIZE, B.S., 1973. 'The area of origin of *M. esculenta* as a crop plant – a review of the evidence.' In: *Economic Botany*, 26(4):352-360.
RICHARDS, P., 1983. 'Ecological change and the politics of African land use.' In: *African Studies Review*, 26/2.
ROCKEFELLER/FORD FOUNDATIONS, 1984. *Joint conference on intrahousehold processes and farming systems analysis.* Bellagio.
ROGERS, B., 1980. *The domestication of women. Discrimination in developing societies.* (Kogan Page) London.
ROGERS, D.J. & H.S. FLEMING, 1973. 'A monograph of *M. esculenta* with an explanation of the taximetric methods used.' In: *Economic Botany*, 27:1-113.
RÖLING, N.G., 1983. *Agricultural knowledge: its development, transformation, promotion and utilization. Paper for the 3d expert working group on information, analysis and consolidation.* (Unesco/Unisist) Kuala Lumpur.
RÖLING, N.G., 1985. 'Extension science: increasingly preoccupied with knowledge systems.' In: *Sociologia Ruralis*, 25:3/4.
RÖLING, N.G. & H. DE ZEEUW, 1983. *Improving the quality of rural poverty alleviation. Final report of 'The small farmer and development cooperation'.* (IAC) Wageningen.
ROSS, H.B., 1975. *The diffusion of the manioc plant from South America to Africa: an essay in ethnobotanical culture history.* (PhD thesis, Columbia University) New York.
RUTHENBERG, H., 1980. *Farming systems of the tropics.* (Clarendon Press, 3d edition) Oxford.
RYNEMAN, J., 1977. 'Comment le régime Mobutu a sapé ses propres fondements.' In: *Le Monde Diplomatique*, 23 Mai.
SAINT MOULIN, L. DE, 1976. *Atlas des collectivités du Zaire.* (Presses Universitaires du Zaire) Kinshasa.
SAPIN, P., 1958. 'Sélection du manioc à Yangambi.' In: *Bull. d'Information de l'INEAC*, 8/3.

SCHELTEMA, A.M.P.A., 1923. 'De ontleding van het inlandsche landbouwbedrijf.' In: *Meededelingen van de Afdeeling Landbouw*, 6, Buitenzorg.
SCHLIPPE, P. DE, 1956a. *Shifting cultivation in Africa. The Zande system of agriculture*. (Routledge & Kegan Paul) London.
SCHLIPPE, P. DE, 1956b. 'De L'anthropologie agricole.' In: *Problèmes de l'Afrique Centrale*, 33/3.
SCHLIPPE, P. DE, 1957. *Méthodes de recherches quantitatives dans l'économie rurale coutumière de l'Afrique centrale*. (Dir. de l'Agriculture, des forêts et de l'élevage) Bruxelles.
SCHWEIGMAN, C., 1981. *Toepassing van operations research in ontwikkelingslanden*. (Inaugural lecture, University of Groningen) Groningen.
SHANER, W.W. et al., 1982. *Farming systems research and development – guidelines for developing countries*. (Westview Press) Boulder.
SICAI, 1977a. *Etude agro-socio-économique de l'Ouest du Zaire*. Kinshasa.
SICAI, 1977b. *Enquêtes démographiques et budgetaires des villes de l'Ouest du Zaire. Vol. 6a Kikwit*. Kinshasa.
SILVESTRE, P. & M. ARRAUDEAU, 1983. *Le manioc*. (Maisonneuve & Larose) Paris.
SIMMONDS, N.W., 1985. *Farming systems research, a review*. (World Bank) Washington DC.
SINGH, T.P., 1981. 'Breeding cassava resistant to pests and diseases in Zaire.' In: TERRY, E.R. et al. (ed.), *Tropical root crops: research strategies for the 1980s*. (IDRC, 163e) Ottawa.
SMITH, R.E., 1976. 'L'administration coloniale et les villageois. Les Yansi du Nord de Bulungu 1920-1940.' In: *Cahiers du CEDAF 3*, serie 2. Bruxelles.
SOLLEWIJN GELPKE, J.H., 1875/1876/1877. *De padi-cultuur in de afdeeling Ngrowo (2e en 3e rapport)*. (Naar aanleiding van staatsblad 1878/110) Batavia.
SOW, 1981. *Summary description of the Thailand agriculture model, THAM 1*. (Centre for World Food Studies, research report) Amsterdam.
SPEDDING, C.R.W., 1979. *An introduction to agricultural systems*. (Applied Science Publishers) London.
STANER, P., 1931. 'La mosaique des feuilles de manioc.' In: *Bull. Agr. du Congo Belge*, 22(1):75-81.
STAVEREN, J.M. VAN & D.B.W.M. VAN DUSSELDORP, 1980. *Framework for regional plannning in developing countries*. (ILRI, publication 26) Wageningen.
TERRY, E.R., 1981. 'Cassava: ecology, diseases and productivity: strategies for future research.' In: TERRY, E.R. et al. (ed.), 1981. *Tropical root crops: Research strategies for the 1980s*. (IDRC 163e) Ottawa 1981.
TERRY, E.R. & S.K. HAHN, 1980. 'The effect of cassava mosaic disease on growth and yield of local and improved cassava.' In: *Tropical Pest Management*, 26(1):34-37.
TERRY, E. & R. MCINTYRE, 1976. *The international exchange and testing of cassava germ plasm in Africa*. (IDRC) Ottawa.
TIFFIN, M., 1982. *Economic, social and institutional aspects of shifting cultivation in humid and semi-humid Africa*. (FAO) Rome.
TIMMER, W.J., 1947. *Object en methode der sociale agronomie*. (PhD thesis) Batavia.
TORO, J.C. & C.B. ATLEE, 1980. 'Agronomic practices for cassava production: a review.' In: WEBER, E.J. et al. (ed.), 1980. *Cassava cultural practices*. (IDRC 151e) Ottawa.
TOURTE, R., 1971. 'Thèmes légers, thèmes lourds, systèmes intensifs, voies différentes ouvertes au développement agricole du Sénégal.' In: *Agronomie tropicale*, 26(5):632-671.
TOURTE, R., 1977. *La genèse des Unités Expérimentales. Compte-rendu du seminaire ISRA/GERDAT*. Bambey.
TOURTE, R., 1984. 'Introduction.' In: MATLON, P.J. et al., 1984. *Coming full circle: farmers' participation in the development of technology*. (IDRC 189e) Ottawa.
TOURTE, R. & R. BILLAZ, 1982. 'Approche des systèmes agraires et fonction recherche-développement. Contribution à la mise au point d'une démarche.' In: *Agronomie tropicale*, 37(3):223-232.
TRAUGOTT, M., 1979. 'The economic origins of the Kwilu rebellion.' In: *Comparative studies in society and history*.
USAID, 1983. *Pronam. Rapport d'évaluation*. Kinshasa.
US DEPARTMENT OF AGRICULTURE, 1981. *Food problems and prospects in sub-Saharan Africa: the decade of the 1980s*. (Foreign Agricultural Research Report 166) Washington DC.
VAN DEN ABEELE, M. & R. VANDENPUT, 1951. *De voornaamste cultures van Belgisch Congo* (2e uitgave, Ministerie van Coloniën) Bruxelles.
VELTKAMP, H.J., 1985. *Physiological causes of yield variation in cassava*. (PhD thesis, Wageningen Agricultural University) Wageningen.

VENEMA, L.B., 1978. *The Wolof of Saloum. Social structure and rural development in Senegal.* (PhD thesis, PUDOC) Wageningen.
VERHAEGEN, B., 1966 & 1969. *Rebellions au Congo. Vol. 1 & 2.* (Etudes du CRISP) Bruxelles.
VERHOYEN, M., 1978. 'Some observations on cassava mosaic in Zaire.' In: MARAITE, H. & J.A. MEYER, 1978. *Diseases of tropical food crops. Proceedings.* Louvain-la-Neuve.
VINK, G.J., 1946. 'Bedrijfseconomie van den bevolkingslandbouw.' In: HALL, C.J. VAN DER & C. VAN DER KOPPEL (ed.), *De landbouw in den Indischen archipel.* 's-Gravenhage.
VRIES, C.A. DE, 1978. 'New developments in production and utilization of cassava.' In: *Abstracts on Tropical Agriculture* (special issue).
VRIES, E. DE, 1931a. 'De cultuur- en bedrijfsontledingen in den Inlandschen landbouw.' In: *Landbouw Buitenzorg*, 6(2): 1-73.
VRIES, E. DE, 1931b. *Landbouw en welvaart in het regentschap Pasoeroean. Bijdrage tot de kennis van de sociale economie van Java.* 2 delen (Meededeling 16, Dept. van Landbouw) Wageningen.
WAUGH, R.K. et al., 1983. *Institutional assessment for implementing a systems approach to agricultural research and extension.* (FSSP working paper, University of Florida) Gainesville.
WEBER, E.J. et al. (ed.), 1979. *Intercropping with cassava. Workshop proceedings.* (IDRC 142e) Ottawa.
WEBER, E.J. et al. (ed.), 1980. *Cassava cultural practices. Workshop proceedings.* (IDRC 151e) Ottawa.
WEBSTER, C. AND P. WILSON, 1966. *Agriculture in the tropics.* (Longman) London.
WEISS, H.F., 1967. *Political protest in the Congo: the Parti Solidaire Africain during the Independence struggle.* (Princeton University Press) Princeton.
WHYTE, W.F., 1981. *Participatory approaches to agricultural research and development. A state-of-the-art paper.* (Rural development committee, Cornell University) Ithaca.
WIT, C.T. DE & H.D.I. VAN HEEMST, 1976. 'Aspects of agricultural resources.' In: W.T. KOETSIER (ed.), 1976. *Chemical engineering in a changing world.* (Elsevier) Amsterdam.
WORLD BANK, 1982-1986. *World Development Reports 1981-1985.* (Oxford University Press).
WORLD BANK, 1981. *Accelerated development in sub-Saharan Africa (The Berg Report).* Washington.
WORLD BANK, 1982. *Zaire Economic Memorandum. Recent Economic and Sectoral Developments and Current Issues.* Washington.
WORLD BANK, 1984. *Toward sustained development in sub-Saharan Africa (The Please Report).* Washington.
YOUNG, C., 1978. 'Zaire: the unending crisis.' In: *Foreign Affairs Journal*, 1978(3).
YUDELMAN, M., 1975. 'Imperialism and the transfer of agricultural techniques.' In: DUIGNAN, P. & L.H. GAN (ed.), *Colonialism in Africa 1870-1960.* Vol. 4 (Cambridge University Press) Cambridge.
ZAIRE, REP. DU/DEPT. DE L'AGRICULTURE, undated. Programme National de la Production Vivrière. Kinshasa.
ZAIRE, REP. DU/DEPT. DE L'AGRICULTURE/BDPA, undated. *L'agriculture zairoise de 1966 à 1971.* Kinshasa.
ZAIRE, REP. DU/DEPT. DE L'AGRICULTURE, 1975. *Recensement de l'Agriculture 1970. Résultats définitifs.* Kinshasa.
ZAIRE, REP. DU/DEPT. DE L'AGRICULTURE, 1982. *Plan de Relance Agricole 1982-1984.* Kinshasa.
ZAIRE, REP. DU/DEPT. DE L'ECONOMIE NATIONALE, 1984. *Conjoncture Economique 1983-1984.* Kinshasa.
ZAIRE, REP. DU/DEPT. DU PLAN, undated. *Perspectives démographiques régionales 1975-1985.* Kinshasa.
ZAIRE, REP. DU/INSTITUT NATIONAL DE LA STATISTIQUE, 1980. *Recensement mondial de l'agriculture 1970-1980. Données du Bandundu.* Kinshasa.
ZANDSTRA, H.G., 1979. 'Cassava intercropping research: agroclimatic and biological interactions.' In: WEBER, E.J., et al. (ed.), 1979. *Intercropping with cassava. Workshop proceedings.* (IDRC 142e) Ottawa.
ZANDSTRA, H.G., et al., 1981. *A methodology for on-farm cropping systems research.* (IRRI) Los Baños.

Note

Undated reports referring to the pre-Independence situation from INEAC or the Belgian Colonial administration are found in the archives of the Bibliothèque Africaine of the Bibliothèque Royale Albert I, and in the archives of INEAC, Avenue Defacz, both in Brussels. Undated reports from the Zaïre Government referring to the years after 1960 are found at various ministeries in Kinshasa.

SUMMARY

The background of this study forms the debate about the nature and causes of the 'African crisis', the declining food availability per head of the African population. Generalized statements on African agriculture, based on aggregated production figures, however, do not adequately reflect the diversity in performances between crops and regions and do not allow the formulation of solutions adapted to local situations.
In order to gain a better understanding of the African crisis, changes in cassava production in the Kwango-Kwilu region in central Zaire are analysed in detail. This analysis involves factors of different natures and rates of change. For that reason, a framework is developed that allows the integration of technical and socio-economic aspects of crop production. This framework draws upon ecological system analysis and, to a lesser extent, on farming systems research.
Chapter 1 deals with the debate on food production in Africa and the role of improved technology in agricultural development. There are several reasons to reassess some of the past research strategies on food crops. It is argued that the development of shifting cultivation will require a dual research approach. On the one hand, adaptive research is needed to tailor existing technologies to the complex production environments of small farmers. On the other hand, basic and strategic research is required to develop sustainable cropping systems for less favoured environments and increase our understanding of how these systems operate.
Chapter 2 explores the ways in which traditional farming in Africa has been studied as a system. It is concluded that, although a wealth of micro-level data has been accumulated, the various traditions of farming systems research do not provide a sufficient framework for the analysis of changes in cassava production. Their main shortcoming lies in the emphasis on adaptive research and on the farm as a unit of analysis.
Chapter 3, therefore, presents an attempt to apply ecological systems theory to the study of traditional agriculture in the tropics. A hierarchical model of

agriculture is proposed, that includes crop, cropping, farming and regional systems. Inputs, outputs, components and component interactions are identified at each system level. This model is applied to shifting cultivation, a type of cropping system, and provides the theoretical framework for the analysis of cassava production in the Kwango-Kwilu.

Chapter 4 discusses the data base and methods of data collection. It is argued that a specific set of data is required for each system level. Regional system analysis draws mainly upon secondary data, whereas the study of farming and cropping systems requires direct observations. A number of issues relating to the interpretation of official statistical data are discussed.

Chapter 5 analyses the regional system in the Kwango-Kwilu with a view to identifying regional level constraints on cassava production. Various sources suggest that cassava production has probably increased considerably since the 1950s and has kept pace with or even surpassed population growth, despite price and marketing disincentives, government control, male migration, relatively poor soils, and a complete lack of agricultural inputs.

Chapter 6 shows how this growth in cassava production can be explained by a reliance on cassava, female labour and the expansion of shifting cultivation. Cassava, cultivated for its roots and leaves, is the main food and cash crop. It allows great flexibility in harvesting times and cultural practices whenever marketing opportunities present themselves. Women have been able to increase outputs, therefore, because no fundamental changes in the farming system were required.

Chapter 7 deals with the evolution of cropping systems in the Kwango-Kwilu since about 1950. Cassava production growth was made possible at this level because of the opening of new fields on the more marginal soils of the plateaus, declining fallow lengths and the increased presence of cassava on all fields. Cassava now figures in all crop associations and sequences, in forest as well as savanna.

Chapter 8 describes the factors affecting the cassava crop system over the last thirty years. The changes in cultural practices are reviewed in detail. Cassava planting dates have been extended by several months, cassava densities have increased, ridging is disappearing, weeding is increasingly neglected and the number of intercrops is declining. 'Monocropping' of cassava seems an emerging trend. Furthermore, cassava pests and diseases are rapidly spreading. The extent of their damage may be related in part to environmental factors resulting from changes in the crop system. A classification of local cassava varieties is also presented.

Chapter 9 discusses the changes in cassava yields in the region. Methodological issues in measuring and comparing cassava yields are reviewed. Circumstantial evidence suggests that cassava yields may have been declining from the mid-1950s onwards. This decline is directly related to changes at all levels of the hierarchy of systems. At the regional level, a growing urban demand for cassava and the relative decline of agricultural prices lead to early harvesting of the crop. Increasing population densities cause fallows to shorten, resulting in changes in fallow vegetation and the increase of grass fallows. At the farming systems level, greater demands are put on female labour due to the absence of men from the agricultural sector and possibly due to the increase in area. This may be aggravated by the increase in grass fallows, requiring more female inputs in clearing. At the crop and cropping systems levels, many changes in agricultural practices are apparent. They result from the interaction of declining soil fertility, shorter fallows, shifts in the agricultural calendar and women's increased work loads. It is unclear to what extent pests and diseases are contributing to the yield decline. Yield data relating to the period before 1980 show already a decline, i.e. before any of the recent introductions of pests and diseases. Declining cassava yields must be seen as a symptom of the breakdown of the shifting cultivation system.

Chapter 10 examines to what extent agricultural research on cassava has managed to deal with the constraints imposed by the changes in cropping systems on cassava production. It provides a selective review of work during the colonial period in Zaire and of the research by the international institutes and the national cassava program. It is concluded that research on cassava shows an increasing concern with constraints and limitations inherent in shifting cultivation, as witnessed by the work on intercropping, weeding and soil fertility. Nevertheless, the work on varietal improvement appears focused on criteria that neither reflect the constraints imposed by shifting cultivation nor farmers' preferences. Cassava research seems to accord priority to breeding for pest and disease resistance and related entomology and pathology research, which suggests that pests and diseases are seen as the main yield constraining factors in African cropping systems.

Chapter 11 presents the final conclusions and discussion of the study. It reviews the effects of increased cassava production and the breakdown of shifting cultivation. Expected trends in cassava production and differentiation between farming and cropping systems are analysed. The consequences for future strategies of strategic and adaptive research on cassava, as well as the design of alternative cropping systems that can replace shifting cultivation are discussed. Improvements in the production of cassava and other crops will require changes at all levels apart from the crop and cropping system. The usefulness of the hierarchical agricultural systems framework is also assessed. Even where the existing data base is poor, systems analysis apparently provides an adequate way to structure very complex information. Finally, it is concluded that the analysis of changes in cassava production in the Kwango-Kwilu leads to a redefinition of the African crisis. Rather than a crisis of food production per se, the African crisis manifests itself in the Kwango-Kwilu as the breakdown of the shifting cultivation system and the degradation of the natural resource base under shifting cultivation.

SAMENVATTING

Deze studie moet gezien worden tegen de achtergrond van de discussie over de 'Afrikaanse crisis'; de afnemende voedselbeschikbaarheid per hoofd van de bevolking in Afrika. Algemene uitspraken over de Afrikaanse landbouw die gebaseerd zijn op gemiddelde cijfers, doen echter geen recht aan de grote verschillen in produktiviteit tussen regio's en tussen gewassen en leiden niet tot oplossingen die rekening houden met de lokale situatie.
Met het doel een beter begrip te krijgen van de Afrikaanse crisis worden de veranderingen in de cassavaproduktie in de Kwango-Kwilu in detail geanalyseerd. Een dergelijke analyse heeft betrekking op zeer uiteenlopende en complexe variabelen. Daarom is een analysekader ontwikkeld, dat het mogelijk maakt om technische en sociaal-economische factoren aan elkaar te relateren. Dit kader bouwt voort op de ecologische systeemanalyse, en tot op zekere hoogte ook op het onderzoek naar landbouwbedrijfssystemen.
Hoofdstuk 1 heeft betrekking op het debat over de voedselsituatie in Afrika en de rol van verbeterde landbouwtechnologie in ontwikkeling. Er worden redenen aangevoerd om bestaande strategieën van landbouwtechnologie-ontwikkeling te herzien. De ontwikkeling van zwerfbouw (shifting cultivation) in Afrika vereist een tweeledige benadering. Enerzijds is toegepast onderzoek nodig om bestaande technologie aan de lokale omstandigheden aan te passen. Anderzijds is meer fundamenteel onderzoek gewenst om duurzame landbouwsystemen te ontwikkelen en om onze kennis van bestaande systemen te vergroten.
In hoofdstuk 2 wordt nagegaan op welke wijze traditionele landbouwsystemen in Afrika bestudeerd kunnen worden. De conclusie is dat dergelijke methoden toch onvoldoende bruikbaar zijn voor de analyse van zwerfbouw, omdat ze te veel gericht zijn op toegepast onderzoek en het bedrijf als enige eenheid van analyse hanteren.
In hoofdstuk 3 wordt daarom een poging gedaan om de ecologische systeemtheorie toe te passen op traditionele landbouw in de tropen. Een hiërarchisch model wordt gepresenteerd, met als eenheden gewas-, teelt-,

bedrijfs- en regionale systemen. Inputs, outputs, componenten en interacties tussen componenten worden op ieder systeemniveau geïdentificeerd. Vervolgens wordt dit model toegepast op zwerfbouw; een type van teeltsysteem. Dit model wordt vervolgens toegepast op de analyse van cassaveteelt in zwerfbouwsystemen in de Kwango-Kwilu (Zaïre).
Hoofdstuk 4 is gewijd aan een bespreking van de aard van de gegevens en de wijze waarop deze verzameld zijn. Op ieder systeemniveau is een specifieke serie van gegevens relevant. De analyse van regionale systemen berust bijvoorbeeld voornamelijk op secundaire data en statistieken, terwijl de analyse van teelt- en bedrijfssystemen directe observaties behoeft. Ook wordt aandacht besteed aan een aantal problemen betreffende de interpretatie van overheidsstatistieken.
Het regionale systeem wordt geanalyseerd in hoofdstuk 5, met het doel om knelpunten in de cassavaproduktie op regionaal niveau op te sporen. Op grond van verschillende gegevens lijkt het aannemelijk dat de cassavaproduktie sinds de jaren vijftig aanzienlijk is toegenomen en de groei van de bvolking heeft bijgehouden, of misschien zelfs heeft overtroffen. Deze groei vond plaats ondanks prijs- en marktbelemmeringen, sterke overheidscontrole op de landbouw, relatief arme gronden, migratie van mannen en een volledig gebrek aan landbouwinputs.
Hoofdstuk 6 laat vervolgens zien hoe deze groei verklaard kan worden uit een toenemende afhankelijkheid van cassave, van de arbeid van vrouwen en de uitbreiding van het areaal onder zwerfbouw. Cassave is het belangrijkste voedsel- en handelsgewas. De aard van dit gewas staat een grote flexibiliteit in oogsttijden en teelttechnieken toe. Vrouwen zijn in staat geweest om een surplus te produceren zonder dat fundamentele veranderingen in het bedrijfssysteem nodig waren.
In hoofdstuk 7 worden veranderingen in de componenten van het teeltsysteem en in teeltmaatregelen geschetst aan de hand van een vergelijking tussen de situatie in de jaren 1940-50 en de huidige tijd. De groei van de cassaveproduktie was mogelijk, omdat nieuwe velden op de marginale gronden van de plateaus zijn ontgonnen, de braakperiode is verkort, en omdat cassave nu bijna overal het eerste gewas in de rotatie vormt. De traditionele verschillen tussen bos- en savannevelden zijn steeds meer aan het vervagen.
De factoren die in de loop van de laatste dertig jaar het gewassysteem hebben beïnvloed worden behandeld in hoofdstuk 8. Veranderingen in teeltmaatregelen worden in detail besproken. Zo zijn de plantdata van cassave over een langere periode uitgespreid, zijn de plantdichtheden toegenomen, is de verbouw op ruggen afgenomen, wordt het wieden in toenemende mate verwaarloosd en neemt het aantal in gemengde teelt met cassave verbouwde gewassen af. Er is in zekere zin sprake van een toenemende 'monocultuur' van cassave. Bovendien verspreiden ziekten en plagen zich steeds meer. De mate

van schade die daardoor veroorzaakt wordt, hangt mogelijkerwijs af van omgevingsfactoren, die een gevolg zijn van veranderingen in het gewassysteem. Een classificatie van lokale cassavevariëteiten wordt tevens besproken.
In hoofdstuk 9 komen veranderingen in cassave-opbrengsten aan de orde. Ook wordt ingegaan op de methodologische problemen die verbonden zijn aan het meten en vergelijken van cassave-opbrengsten op boerenvelden en in proefstations. Het wordt aannemelijk gemaakt dat cassave-opbrengsten misschien al sinds het midden van de jaren vijftig zijn afgenomen. Deze afname houdt direct verband met veranderingen op alle niveaus. Op regionaal niveau heeft de toenemende vraag naar cassave en de verslechterende ruilvoet voor landbouwprodukten geleid tot vervroegd oogsten. Een toename van de bevolkingsdichtheid veroorzaakt een verkorting van de braak en leidt tot veranderingen in braakvegetaties en een toename van de grasbraak. Op bedrijfsniveau komen vrouwen onder steeds grotere arbeidsdruk te staan als gevolg van de migratie van mannen, en misschien tevens als gevolg van een toename in areaal. Dit wordt versterkt door de toename van de grasbraak, waarvoor meer vrouwenarbeid noodzakelijk is. Op teelt- en gewasniveau treedt een groot aantal veranderingen op. Deze zijn het gevolg van afnemende bodemvruchtbaarheid, verkorting van de braak, verschuivingen in de gewaskalender en de toenemende arbeidslast van vrouwen. Het is echter onduidelijk in welke mate ziekten en plagen bijdragen aan de afname van de opbrengsten. De gegevens over de periode voor 1980 laten al een afname zien, dat wil zeggen voor de recente invoering van nieuwe ziekten en plagen. Afnemende cassave-opbrengsten moeten gezien worden als een symptoom van de ontwrichting van het zwerfbouwsysteem.
In hoofdstuk 10 wordt nagegaan in hoeverre het cassave-onderzoek oplossingen biedt voor de problemen die ontstaan als gevolg van de veranderingen in de zwerfbouw. Er wordt een beperkt overzicht gegeven van het koloniale en het huidige nationale en internationale onderzoek. De conclusie is dat er in het cassave-onderzoek in toenemende mate aandacht is voor de knelpunten en beperkingen als gevolg van zwerfbouw. Dit blijkt uit onderzoek naar gemengde teelt, onkruidbestrijding en bodemvruchtbaarheid. Niettemin wordt in de veredeling bijzonder weinig rekening gehouden met de knelpunten in de zwerfbouw, noch met de behoeften van boeren. Het huidige onderzoek concentreert zich op de veredeling van cassave tegen ziekten en plagen en het daarmee verbonden entomologische en fytopathologische werk. Ziekten en plagen worden als de belangrijkste opbrengstbeperkende factoren beschouwd.
Hoofdstuk 11 presenteert de uiteindelijke conclusies van het onderzoek. Het vat de belangrijkste effecten van de toename van de cassaveproduktie en de ontwrichting van het zwerfbouwsysteem samen. Een overzicht van de te

verwachten ontwikkelingen in de zwerfbouw en de cassaveteelt en van de toenemende verschillen tussen typen bedrijfs- en teeltsystemen wordt gegeven. De implicaties voor toekomstige strategieën voor toegepast en strategisch onderzoek naar cassave worden besproken, evenals de ontwikkeling van nieuwe teeltsystemen die uiteindelijk de zwerfbouw zouden kunnen vervangen. Verbeteringen in de produktie van cassave en andere gewassen veronderstellen veranderingen op alle niveaus van de hiërarchie. Ook de bruikbaarheid van het systeemanalytische kader wordt beschouwd. Zelfs waar weinig of slechte statistische gegevens voorhanden zijn, kan systeemanalyse toch een mogelijkheid bieden om complexe informatie te structureren. Tot slot wordt geconcludeerd dat de analyse van veranderingen in de cassaveteelt in de Kwango-Kwilu leidt tot een herdefiniëring van de Afrikaanse crisis. Veel meer dan een crisis in voedselproduktie, manifesteert de Afrikaanse crisis zich in de Kwango-Kwilu als de ontwrichting van het zwerfbouwsysteem en de verarming van de natuurlijke hulpbronnen.

CURRICULUM VITAE

After graduating from the Agricultural University in Wageningen, with a major in agricultural extension, in 1976, Louise O. Fresco (1952) joined FAO. After serving in Papua New Guinea, with the Wildlife and Natural Resources Department (1977-78), she spent a brief time at the FAO Headquarters in Rome in 1979, and went from there to Zaire, as an expert and later project manager in the rural development project in the Kwango-Kwilu (1979-83). She also worked as a short-term consultant for USAID and FAO (Haiti, Congo, Zaire, Burkina Faso, Togo and several other West African countries). In 1985, she acted as the agronomist on the World Bank's agricultural sector assessment mission to the Central African Republic. She is also an adviser to the Dutch Ministry of Development Cooperation, with special responsibility for Dutch contributions to ICRISAT and the ICRISAT Sahelian Centre, and is a member of the NAR (National Advisory Commission on Development Assistance). She is currently attached to the Department of Tropical Crop Science of the Agricultural University in Wageningen. Her recent publications deal mainly with farming systems research.

Although aggregated data for Africa show a declining food availability per head, these do not adequately reflect the diversity in performances between crops and regions.
This volume presents a case study from the Kwango-Kwilu region in central Zaire. In this area, cassava production has increased considerably in the last thirty years and has kept pace with or even surpassed population growth, despite socio-economic and agronomic disincentives. The author reviews the evolution of cassava production in the region, and its agronomic effects. Cassava, cultivated as a key component of a shifting cultivation system, allows great flexibility in cultural practices. The expansion of cassava onto marginal soils, the increased presence of cassava in crop rotations and associations, and the reliance on female labour explain much of the production growth. At the same time, however, cassava yields have declined and the shifting cultivation system is rapidly breaking down. Past and present research efforts on cassava are discussed with a view to determining strategies for agricultural technology development. The relevance of this study lies in its detailed analysis of changes in shifting cultivation as well as in its method of analysis. It draws upon ecological system analysis and, to a lesser extent, on farming systems research, and presents a systems framework that allows the integration of technical and socio-economic aspects of crop production which has wide application.
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