FARMING SYSTEMS FOR LOW-FERTILITY ACID SANDY SOILS

5-9 DECEMBER 1988 - GEORGETOWN, GUYANA

CARIBBEAN AGRICULTURAL RESEARCH AND DEVELOPMENT INSTITUTE
UNIVERSITY CAMPUS, ST. AUGUSTINE TRINIDAD AND TOBAGO

TECHNICAL CENTRE FOR AGRICULTURAL AND RURAL COOPERATION
ACP-EEC LOMÉ CONVENTION EDE-WAGENINGEN, THE NETHERLANDS
FARMING SYSTEMS FOR LOW-FERTILITY ACID SANDY SOILS

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Caribbean Agricultural Research and Development Institute
Representative in Guyana

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FORMAL OPENING

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INTRODUCTION

Dr James Smith

CARDI Representative, Guyana

Honourable Minister of Agriculture, Dr Patrick McKenzie; Excellencies of the Diplomatic Core; Deputy Secretary General of the CARICOM Secretariat; Deputy Director of the CTA, Dr Werner Treitz; Professor Ahmad; Deputy Executive Director of CARDI, Mr Hugh Saul; Distinguished Guests, Eminent Scientists, Ladies and Gentlemen.

First of all I would like to introduce to you the members of the head table. Immediately on my right is Dr Sam Parasram who is the Director of Special Services of CARDI; the distinguished, world-renowned Professor Nazeer Ahmad of the University of the West Indies; the Honourable Minister of Agriculture from Guyana, Dr Patrick McKenzie; the Deputy Director of CTA, Dr Werner Treitz; and the Deputy Executive Director of CARDI, Mr Hugh Saul.

There are two items on the programme which facilitate (or allow) welcome. Notwithstanding that, it is the prerogative of the Chairman, I think, to elect to do certain things as he or she sees fit. In this case I want therefore to take the prerogative to be the first to extend to all of you a very special welcome to this seminar/workshop on low fertility acid sandy soils. These soils are to be found in fairly large quantities in Guyana, in Suriname and elsewhere in the world. This workshop therefore, which brings together so many eminent scholars, will help us to deal with the many issues relating to managing these soils for greater agricultural production, both crop and livestock. This workshop then is of great significance not only to Guyana but to the region as a whole and to the extent that this workshop hopefully will facilitate the use of these soils for expanded agricultural output which could possibly provide or contribute to improving the world food situation, then, to that extent, this workshop can be said to have even international proportions.

For myself, apart from those brief remarks, my task is simple, and that is to try to manage the proceedings of this opening ceremony. In doing so, I therefore would like to go straight to the programme and to invite Mr Hugh Saul, the Deputy Executive Director of CARDI in charge of Development, to welcome you. Mr Saul, of course, is a distinguished scientist and manager in his own right. He brings to CARDI and the region considerable expertise in the area of agriculture, marketing and management on the whole, and it is his privilege this afternoon to extend the first formal words of welcome to you. Mr Saul.
WELCOME FROM CARDI

Mr Hugh Saul

Deputy Executive Director - Development,
Caribbean Agricultural Research and Development Institute

Mr Chairman, Honourable Deputy Prime Minister, Honourable Minister of Agriculture, other Ministers of the Government of the Co-operative Republic of Guyana, Ministers from CARICOM Member Countries, Gentlemen of the High Table, Members of the Diplomatic Corps, Distinguished Participants, Colleagues, Ladies and Gentlemen, Members of the Media, Comrades and Fellow Countrymen.

A few days ago my colleague, Samsundar Parasram invited me to attend this conference on "Farming Systems for Low Fertility Acid Sandy Soils" here in Guyana. My first thoughts were to thank him for being so gracious. On my way to Guyana, I learnt that our Executive Director, Derrick Dyer would be otherwise engaged; later I also learnt that I was assigned responsibilities within the programme and still later that I have to stand in for the Executive Director of CARDI. I now remember the words of my old professor - "In life there are no free lunches".

So Ladies and Gentlemen, first let me apologize to you for the absence of the Executive Director of CARDI, Mr Derrick Dyer. Derrick sends his best wishes for a successful conference and hopes that the cumulative experiences of the participating scientists would aid the creation and development of new and improved technologies that would benefit not only Guyana but countries with similar soil types.

This conference affords us the opportunity to examine and discuss options in farming systems for low fertility acid sandy soils. We in CARDI interpret this opportunity as a challenge. Our defined role as the primary research institution in the English-speaking Caribbean is the mandate that allows us to support the region's Food and Nutrition Strategy whose key goals are:

- To achieve regional food self-sufficiency by reducing dependency on imported food
- To increase foreign exchange earnings through increased exports of food commodities
- To improve income and productivity in the agricultural sector.

The goal of regional self-sufficiency is empty if a production strategy that seeks to harness the productive capabilities of our great CARICOM land masses is not designed. We have two challenging land masses — Belize and Guyana. Development strategies dictate that we must first examine our environments; for it is the environment that dictates not only the technology that should be adapted but the rate of adaption.

With a high regional food import bill, we need to maximize on the carrying capacities of our various soil types for both crop and livestock, and further we need to ensure that relevant technology adaptation and transfer programmes are designed for implementation.

The soils and the geographical area we are most concerned with at this seminar, as far as the Guyana region is concerned, are found in a 2,700 km² zone of the Berbice River area called the Intermediate Savannahs. That area has played a significant role in the past development of this country and maybe, if we are sufficiently creative, history may repeat itself in a positive way.
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It was in this approximate area in the 17th century that the Dutch established the Colony of Berbice. The several plantations of the area were the mainstay of the Colony’s economy, producing dyes, cotton, coffee, cocoa and other export crops.

It was of this area that A.J. Seymour, a Guyanese poet, wrote:

"There runs a dream of perished Dutch plantations, in these Guyana rivers to the sea. Black waters, rustling through the vegetation, run silently over lost stellings, where the craft once rode easy before trim dwellings in the sun, and fields of indigo would float out broad, to lose the eye right on the horizon".

On the planned field trip on Wednesday many of you may be able to see from the air the still existing layouts and remains of these early farming systems for acid, sandy soils.

The tables of history and economics are giving us a new opportunity. The coast is now showing symptoms of overcrowding and Guyana may have to look at the Intermediate Savannas once more to find the vast production areas needed for regional food self-sufficiency and food security.

We are therefore grateful that CTA has joined with us in sponsoring this conference of eminent scientists many of whom are currently engaged in research and development activities on these soils and others who have worked on such soils, in the past.

CTA helps ACP countries to gain easier access to the information which they need in order to further their agricultural and rural development, to increase their agricultural production, to develop their own documentation capabilities, to improve their extension services and to expand their capacity to carry our research and training in these fields.

Under a Memorandum of Understanding signed on 15 September, 1987, CTA established a regional office within CARDI. The establishment of this office within CARDI should be considered as a means of pooling resources of CTA and CARDI with a view to strengthening their activities within the ACP states of the region so as to assess and supply their information needs for improved agricultural and rural development.

This is the fourth in a series of co-operative efforts and meetings held in the Caribbean. The others were held in: Trinidad and Tobago, St. Lucia and Jamaica.

Within the past year, CARDI has been re-organized and its delivery capabilities strengthened. CARDATS, a sub-regional agricultural project serving the East Caribbean States has been integrated into CARDI. This integration coupled with a farming systems research project funded by USAID have been merged under a Technology Adaptation and Transfer Programme. The Technology Adaptation and Transfer Programme encompasses technology adaptation and transfer of production systems into commercial production-marketing systems at the farm level. Through this programme, CARDI addresses the challenge of increasing farm income through diversification and productivity while also improving food security.

CARDI’s experiences in farming systems research and the CARDATS project are matured enough to be packaged and presented as inputs into national and regional programmes.

In welcoming you here today it is my wish that as we deliberate the agricultural research experiences of our brothers and sisters from Suriname, Brazil, Thailand and the Caribbean islands we will conclude with recommendations that will enrich our storehouse of knowledge and present to Guyana a new beginning.

Thank You.
WELCOME FROM CTA

Dr Werner Treitz

Deputy Director,
Technical Centre for Agricultural and Rural Co-operation

Mr Chairman, Honourable Ministers, Your Excellencies, Distinguished Guests and Participants, Ladies and Gentlemen.

I consider it a great honour and pleasure to address this seminar on acid sandy soils in the Caribbean region here in Georgetown.

During the last year the term "sustainable development" has become a catchword in international conferences, symposia and many technical meetings. And I would say, rightly so. In order to ensure food security and to increase agricultural production for a rapidly growing population it is an absolute must to safeguard and protect our natural resources and the most important natural resource apart from water is without any doubt our soil. Increased production and protection of this resource is not contradictory as some people believe, but these are indeed the two sides of one and the same coin.

In many parts of the world — in Africa, in Asia, in Latin America and not at least in a number of island states—tropical soils with pH values lower than 5 cover millions of hectares. The proper management of these soils requires special technologies in order to ensure sustained production. When CARDI proposed a common seminar on these issues, CTA very much welcomed this initiative, the more so as CTA has organized, together with the International Board for Soil Research and Management (IBSRAM), a similar workshop for the Pacific countries earlier this year in the Solomon Islands.

We are happy to have a representative from IBSRAM, Dr. Spaargaren among us. I am sure he will not only be able to report on the results of the Pacific workshop but also to participate in our discussions in the light of his experience in Africa and other parts of the world.

Let me say at this stage a few words about what CTA is, and what CTA is doing.

CTA is the Technical Centre for Agricultural and Rural Co-operation and the acronym stems from its French name "Centre Technique de Coopération Agricole et Rurale". It was created under the Lomé Convention. The Lomé Convention establishes formal relationships between the 12 countries of the European Community on the one hand and 66 African, Caribbean and Pacific States on the other. The ACP group is often referred to as the "Georgetown Group" because it was established here in this city.

CTA became operational in 1984 and has its headquarters office in Wageningen, the Netherlands. The regional office for the Caribbean of CTA is situated in the headquarters of CARDI in Trinidad.

The Deputy Director of CARDI, Mr. Saul, has mentioned already that according to its mandate CTA is at the disposal of ACP States in order to provide them with better access to information, research, training and innovations in the spheres of agricultural and rural development and extension. Among the specific functions mentioned in the Convention I may name especially the following:

- to provide national and regional documentation centres and research institutes in ACP states with easier access to publications and data banks
to sponsor and organize meetings of specialists, research workers, planners and development personnel

to facilitate the dissemination of scientific and technical information.

Generally speaking CTA may be defined as a professional information, documentation and development centre, as well as a relay between the EC countries and the ACP countries not forgetting that a main function is to disseminate scientific and technical information between ACP countries and LDCs, in general.

During the short time of its existence CTA has executed a vast programme in the dissemination of scientific and technical information among which I may mention:

- the organization of a number of seminars, conferences and workshops in Africa, Europe, the Pacific and the Caribbean with participation of nearly 1500 decision makers, scientists and other experts from EC and ACP countries, international and regional organizations and from elsewhere

- the preparation of a substantial number of technical and professional studies

- the translation of technical and professional publications from French into English or *vice versa* or from German and Dutch into English, French and Portuguese

- the publication of nearly 130 technical and professional publications.

All these publications are available to professional institutions and authorities in ACP countries free of charge.

In 1985 CTA established a question-answer-service which provides researchers, extension workers, training officers, farmers, documentalists and decision makers with bibliographic references, primary documents and specific technical advice on request. This service has developed during its short time of existence at a fast growing rate as you may see from the following figures:

In 1985 CTA received 126 requests; in 1986, 1052; in 1987, 4626; and this year (1988) we expect approximately 12,000 requests.

In addition, CTA has assisted documentation centres, research institutions and other institutions in ACP countries in different ways, such as purchase of publications, equipment and provision of training.

We hope that this seminar will strengthen the relationship between our headquarters and the regional office on the one hand and the countries of the Convention on the other. Here, I should like to say a word of appreciation to CARDI, its management and staff with whom CTA has maintained, right from the beginning of its existence, an excellent relationship. This is the fourth seminar CARDI is organizing on our behalf. As in all the other seminars it has again been organized in an efficient and smooth way. And I would also include in my thanks all the members of the secretariat who are doing a fine and efficient job to make our stay not only comfortable but who also ensure all the technical facilities for a successful meeting.

It is also a special pleasure for me to thank CARDI for its excellent co-operation and willingness to house and operate our regional office.

Last but not least, I especially would thank our host country, the Co-operative Republic of Guyana and its authorities. In its answering letter on CTA's request to have this
conference held in Guyana, the embassy of Guyana in Brussels stated: "I wish to assure that this initiative is welcome and it is viewed as another expression of the CTA’s interest in responding to the needs of the ACP states"

My special appreciation goes to the Honourable Minister of Agriculture Dr Patrick McKenzie (who, only two weeks ago, chaired a common conference of the European Presidency and CTA in Athens) and his Ministry. Furthermore CTA is grateful to the National Agricultural Research Institute, the Livestock Development Company, the National Edible Oil Company and the Guyana National Service for their contributions to the organization of this seminar.

I am sure that we’ll spend a fascinating and exciting week in Georgetown, the birthplace of the Lomé Convention.

Thank you.
I wish to thank CARDI for the invitation extended to me to participate in this seminar. I wish also to congratulate both CARDI and the Technical Centre for Agricultural and Rural Co-operation (CTA) for choosing Guyana as the host country where this topic is particularly relevant. I estimate that here in Guyana we have approximately 1 million hectares of low fertility acid sandy soils in the Intermediate and Rupununi Savannahs and in the Wauna/Yarakita areas.

These acid sandy soils, the white sands excepted, are vital to the long-term development of Guyana's agriculture. To this end we need even at this time to acquire all the relevant information to allow us to extract from them the full potential. A.H. Bunting said:

"No new innovation which was not already in the stage of field testing in 1988 is likely to have any significant effect on the volume of output in any nation in the year 2000"

It is with this in mind that I welcome any scientific examination on the use of these soils so that our information base will be adequate to allow full development during the last years of the twentieth century.

I have interpreted the request for me to give these remarks at this Opening Ceremony as an indication of the organizers' wish to be informed on the broader conceptual issues and not the details of my understanding of the specific commodity programmes for the acid soils.

In this light I wish to share with you some thoughts of my interpretation of what the direct beneficiaries of research want from those involved in agricultural research. The thoughts are not likely to be new nor novel but I hope that in repeating them researchers in Guyana will be able to keep a clear focus on the needs of those whom they serve.

I am tempted to say to you in very descriptive language that the direct beneficiaries of whom I purport to represent are the "grassroots" of agriculture but I suspect that, particularly for politicians, the word "grassroots" is rather trite. Consequently, I say to you that those whom you serve directly are represented by the farmer, the marketeer, the consumer and the government.

The farmer wants from you genetic material for the various commodities, and:

- they want that material with a capability to improve yields
- they want it in adequate quantities
- they want the final product to be saleable
- they want assured reliability in the material
- and they want it in adequate time.

The marketeer whether for export or the local market place requires a product he can sell - one that meets the demand in size, colour, shape, conformation and other relevant characteristics. He wants the assurance that if he finds a market within the natural
resource capability that you will be able to react with relative speed in keeping with commercial demands.

The consumer wants commodities to be available in assured quantities at affordable prices. In this case, this demand of you must be shared with several others along the chain of supply.

The Government for its part wants you to manage the funds allocated so as to provide the requirements of the farmer, the marketeer and the consumer.

This is a simplified version of what the role of research is all about and each agricultural researcher whether he or she is in the laboratory or field needs to ensure that this focus is never lost.

I would expect that agricultural researchers have their own demands in equal measure as the farmer, the marketeer, the consumer and the government and while some of these will be addressed by the funds allocated, others will be outside the ambit of financial provisions.

Cde Chairman, the times in which we live are difficult and challenging times when special attention has to be given to national imperatives — times when agricultural production as an important component of those national imperatives must show its mettle and win for this country. To me this is not simply a matter of words to please an Opening Ceremony audience, it is a matter of necessity.

I have no doubt that you are aware that agriculture has been playing an increasing role as a contributor to the Gross Domestic Product. This importance of agriculture in the economy at this time poses for us a heavy responsibility — a responsibility to perform at the highest level inspite of the constraints.

Cde Chairman as I see it, our Economic Recovery Programme is intended to provide the vital capital inflows into the system, so that electricity, communication, transport, agriculture, forestry, mining, and consumers among others, can have the necessary inputs.

These inputs will come under agreements, the terms of which we will have to meet. Since the economy will depend heavily on agriculture you then see why I alluded to the heavy responsibility.

We in agriculture must see the present situation as what in my Caesar Gallic war days would be referred to as a *causa belli*. Indeed it is a war — a war of economic survival and make no mistake, we in agriculture are at the forefront.

Cde Chairman, I see this seminar on acid sandy soils as a training for a new geographic location—one which we have exploited minimally in the past. In these locations large acreages are available for investment. I would expect that this seminar will be the catalyst towards medium and large-scale investment in the commercial production of cereal grains (such as soyabean, sorghum), legumes, orchard crops (such as citrus, mango, pineapple, pear, cashewnut, oil palm), cotton and pastures—that it will set the stage whereby technical parameters in these areas can be identified and made available to investors. I would expect that it would stimulate a more intensive production on the coastal clays where our traditional crops of rice, sugar, coconut, root crops, plantain and fruits are produced.

As researchers you may not be the most visible at the frontline of the battle, but you must be there. Indeed there can be no victory without your full and active involvement.
Just over one year ago I spoke here at a CARDI-sponsored workshop on the Milk Production Systems Project. At that workshop I pointed to the part research had played in several countries. I said then:

"When an entity invests, it does so in order to receive dividends. It assumes that scientists will lead vigorously in establishing goals and developing strategies for swift and orderly increases in agricultural productivity at reasonable cost and that they will provide direct technological support to national agricultural development programmes or projects. Yet, some of our third world researchers tend conceptually to follow some North American and European models which are not designed to support the fast pace of growth most third world countries must achieve.

It is my opinion that, for sustained rapid agricultural development, Third World nations must have a highly effective problem-solving agricultural research capability.

To illustrate the viability of the investment of resources in research, Grillices found in his study of hybrid corn that the accumulated past research expenditures on hybrid corn research, private and public, as of 1955 came to $131 M on which for each dollar, the social return came to $7 annually, indicating a rather high repayment on the investment.

Japan in its research on wheat and rice found that the internal rate of return was 25-27 per cent from 1915 to 1950 and 73-75 per cent thereafter until 1961. Ardito-Barletta recorded the annual rate of return on Mexico's wheat research programme as 90 per cent and that of its maize programme as 35 per cent. Kahlon calculated the economic returns to investment in India after 1960 at 63 per cent while in Colombia the estimated internal rate of return on rice research during the period 1957-72 was 60-82 per cent, on soyabean research (1960-71) it was 79-96 per cent, but for wheat the return was only 11-12 per cent and for cotton the annual return was zero.

Cde Chairman, there has been a proliferation of studies which indicate that returns to a great deal of investment in agricultural research have been two to three times higher than returns to other agricultural investment.

I have no doubt that, as in the case of cotton in Colombia, there were many programmes for which the payoff was nil or perhaps negative. What is clear is that large returns to investment can be expected from effectively planned and implemented research programmes. It is my conviction that a demonstration of the full awareness of these potentially high returns should increase support for agricultural research programmes.

In the CARICOM region, and certainly in Guyana, I would hazard a guess that perhaps as much as 80 per cent of agricultural land today is farmed with little or no use of chemicals, machinery, improved seed or improved technology.

This points to the significant potential and scope available to the researcher to have high rates of return for investment in agricultural research which is organized to achieve ambitious development goals. This approach identifies the researcher as an important catalyst of rapid agricultural development".

Cde Chairman I would hope that as we seek to pursue further research on the acid sandy soils that we will attempt to develop an indigenous research particularly where it is based on increased output. To do this you must have a sound knowledge of what farmers do now and why, and what they would like to do in the future. You must involve them at the beginning and incorporate their views in the development of your
research programme. After all, the research station represents but one special environment, usually the best of what is available in the area. The ultimate tests of practical options must be with the producer.

There are two other areas I wish to discuss with you and which I wish you to bear in mind as you proceed into the details of this Seminar. One is the new environment in which you enter. As scientists I have no doubt that you are aware that acid sandy soils are very different from hard clay soils. The area of sandy soils which you are about to embark upon will require a modern approach at the commercial level.

Modern agriculture however, depends increasingly on advance technological knowledge. It is highly dependent nationally on infrastructure which includes research, legislation, education, information and control systems that are more characteristics of developed than developing countries.

This difference between agriculture in the developed and developing countries is also mirrored in the early approach of these two groups to the environment.

To their credit, in the more developed countries, many recognized early that the unplanned growth of economies and populations would not necessarily improve the quality of life. This early recognition of the insights of ecology apparently helped a large number of these in the developed countries to appreciate the inter-connectedness of all life on earth.

The Third World initially showed some scepticism, if not hostility, to the new devotion displayed by the affluent to the environment. The representatives of the Third World argued that their problem was too little industry rather than too much and that what little environmental abuses they admitted was a small price to pay for attempting to improve the conditions of their masses.

Indeed some in the Third World felt that concerns about the environment was a luxury for rich nations and something the Third World could not afford.

As a Third World person, I find that this early concept was not unreasonable in the light of the growing tendency for developed countries and international institutions to attach to funds for development, conditions ranging from low population growth, anti-terrorism programmes, anti-drug programmes and more recently environmental programmes. All of this at a time when few developed countries have any exemplary environmental programmes of their own and in many ways having become rich in spite of, or as a result of, environmental abuses.

Today, Third World governments, have learnt through experience that unconstrained environmental abuses can have savage effects. The famine in the Sahel, the spread of the Sahara, the Bhopal incident, the denuded mountain slopes of parts of Africa and Asia, the shanty towns in many cities where people live in environmental squalor, the washing away of hill-sides because denuded of vegetation to grow bananas, the damage and loss of beaches, the loss of endangered species, these are all part of that experience that has informed them, that concern for the environment is not a luxury.

As you deliberate on the use of the acid sandy soils of our savannahs you must consider carefully the flora and fauna of that area, the abuses in the form of erosion that can come from the use of inappropriate equipment and excessive chemicals among others. Gavino Ledda, author of "Padre padrone", in that novel portrays the struggle for survival of the rural poor in the tortuous terrain of his native Sardinia describes the land as:

"A land made from fire and stones by a pact between the Creator and the Devil"
We would hope that for religious and other self-evident reasons that Ledda's observation is a gross exaggeration at the least or at best it is literary licence taken to the extreme.

When all the inconsequentials are removed however, Ledda's statement reveals an unmistakable truism, that is, that whether it is Sardinia or Sahara, developed or developing, First or Third World, the environment needs urgent and adequate attention.

Finally let me say how pleased I am over the relationship between CARDI and CTA. I would expect that our National Agricultural Research Institute will make full use of that relationship.

There is a high cost for scientific and technical information which itself is the normal result of research. Each year several hundreds of thousands of articles in the field of agriculture are published. We have reached the point where the problem is not a lack of data but rather it is the difficulty of obtaining the relevant information from the mass of information available.

The CARDI/CTA link can serve as a data base which in effect is a sophisticated document file containing descriptions of documents. The documents themselves are stored and can be obtained through the post.

I would hope that both CARDI and NARI will be so knowledgeable in the use of this source of scientific and technical information that in time they can expose the rest of the scientific community so that all can benefit.

The essence of my message to you today is that as you enter a new geographic location of research, namely the acid sandy soils

- never lose sight of the needs of those who are the beneficiaries of your service.
- recognize the urgency of this period of our history and that at this time the nation expects results not excuses from agriculture.
- appreciate that the care of the new environment is not a luxury, indeed it is a necessity.
- finally, much research has been done and documented in many parts of the world. Utilize international institutions as CTA to collect and analyse the necessary scientific and technical information so that you do not re-invent the wheel.

Cde Chairman I have great pleasure in declaring this Seminar open.
KEYNOTE ADDRESS

ACID SANDY SOILS OF THE TROPICS WITH PARTICULAR REFERENCE TO THE GUYANAS

Professor Nazeeb Ahmed

Department of Soil Science, University of the West Indies

Extent and occurrence

Transported soils

Acid sandy soils are widely distributed in the tropics in all rainfall regimes. From the aspect of agricultural potential and use, they can be divided into those in the semi-arid to sub-humid rainfall areas and those in humid climates.

The largest occurrence of these soils in the world is in West Africa in the Sahelian and sub-Saharan region extending from Cape Verde to the Cameroons. This is an extremely large geographical area. Here the ancient Pre-Cambrian rocks are covered to varying depths by wind-blown Saharan sands and it is on these sands that the soils are formed. There is a gradation in texture southwards from the Sahara, the deposits being coarser in texture closer to the desert. Today, with increasingly drier conditions wind-blowrn material originating from the Sahara is carried as far away as over the Caribbean during the long dry seasons.

Another area in the tropics in which acid sandy soils are found is in Malaysia and Thailand. Along the east coast extensive sands dunes have been deposited as a result of marine and wind action and soils have developed on these. The deposits occur as parallel ridges separated sometimes by swamps and are commonly succeeded inland by fresh-water peat swamps.

In the Guyanas, particularly in Suriname and Guyana, a large area of these soils occurs, stretching as an east-west belt south of the coastal plain and occupying approximately 2 million hectares (Bullen et al., 1982; Soe Agnie, 1982). The belt terminates in French Guyana where the sandy soils occur in isolated patches (Lucas and Boulet, 1982). The formation rests unconformably on the Pre-Cambrian crystalline basement complex, which in Guyana has been deeply weathered, with the resulting formation of bauxite which is mined by first removing the sand over-burden. The sandy belt is expressed along Suriname where it ranges from 5 to 10 km wide in the eastern part to 60-70 km in the western part. Here, it is known as the Zanderij or Coesewigne formation. The belt extends into Guyana and it reaches its maximum expression along the Berbice river; in Guyana it is known as the Berbice Formation. The belt tapers westwards across Guyana into Essequibo where it occurs as discontinuous patches. These soils will be specially considered in this presentation.

The landscape comprises level to undulating plains described as "monotonous" by Bullen et al. (1982) but "charming" by Soe Agnie (1982) in Suriname. The altitude varies from 6 to 10 m above sea level in the northern part of the landscape to about 70 m above sea level in the most southern part where isolated occurrences of it are found. In Guyana, this goes up to 150 m. The plains or plateaux are dissected by many creeks and rivers, forming a regular drainage pattern. In some places they are only shallow gullies whereas in others they may form 10-15 m deep valleys. The flat base of
such valleys consists of a narrow strip of swamp or marshland on either side of the creek. There is still some uncertainty as to the origin and mode of deposition of these sandy soils. Van der Eyck (1957) studied the mechanical composition of the deposits of all facies of the materials and concluded that the particle distribution was similar to those of river deposits. The surface layers were probably homogenized by soil forming processes but the bedded nature of the material is evident in the deeper sections in bauxite mines in Guyana (Van Kersten, 1955). It is possible, therefore, that the materials were deposited by a great number of south-north running, relatively short, braided river systems. The origin of the material is most probably weathered products of the basement rocks of the same mechanical composition of soil developed in situ over such rocks. During an undetermined period, truncation of this soil mantle resulted due to increased erosion. The eroded material was transported by rivers and deposited in their present locations as alluvial fans. In support of river deposition, the base of the deposits is consistently marked by a thin bed of smooth quartz pebbles. Continuous thin layers of water-worn quartz pebbles also occur upwards in the sediments as seen in the deep excavations in the Guyana bauxite mines (Bleakley and Khan, 1963).

From the original parent material, widely different soils have developed, often under topographically similar circumstances. Part of these soils, down to a great depth, is completely bleached white and highly sandy. Elsewhere, the soils are predominantly brown to yellowish or yellowish red in colour, the A horizons containing 3-25 per cent clay. According to Van der Eyck (1957), the difference between the bleached and unbleached soils is caused by a difference in the clay content of the parent material. Where this clay content had been already relatively low, it dropped below 2-3 per cent due to eluviation and consequently bleached soils developed. Where the original clay content had been relatively high, it has not yet been as exhaustive and the soils are not as bleached. Bleakley and Khan (1963) studied large sections in bauxite mines in Guyana and observed that within the white sand body, towards the base, several large patches of red sandy loam are present showing signs of partial bleaching. Further, samples from the centre of the body, the intermediate zone, and the flanking red sandy loam share about identical particle size distribution which would be improbable if more than one sedimentation were involved. According to the authors, the most conclusive evidence that the sediments were laid down at the same time was provided by the occurrence of a horizontal layer of gravel passing from the white sand through the mottled intermediate zone into the red sandy loam. There is a transitional zone between the white sand and the adjacent and sometimes underlying brown and red loams in which progressive loss of iron and clay has taken place. Where the plateau has not been dissected, the white sand bodies occur in irregular areas varying in extent from a few square meters to many square kilometers. In the more dissected parts, the white sand frequently occurs as elongated bodies known as "muris" in Guyana and are normally found on the topographically highest parts of the area. Klinge (1965) expressed different views for deposition and occurrence of the sandy soils of the Amazon basin.

Soils developed in situ

Throughout the Guyanas, Brazil and Venezuela large areas of acid sandy soils occur which are developed in situ as residual products from rocks such as sandstones, granite and granitic gneisses. In many respects these soils have similar properties to those which have developed on transported materials, having lost clay and sesquioxides through eluviation. Such soils, whether they are now essentially bleached or brown in colour are in seasonal evergreen rain forest except where man-made savannahs have been created through shifting cultivation.
Related environmental factors

Vegetation

The vegetation of the bleached acid sandy soils has not been exhaustively studied. In Guyana, the northern limit of the plateau is marked by a sudden change in vegetation pattern. A narrow fringe of high mixed forest gives way inland to walaba (Eperua falcata) in the Supenaam and Essequibo-Demerara river areas in an evergreen seasonal forest association, and low bush, scrub or savannah (Zanderij savannah) between the Demerara and Corentyne rivers. In the higher parts the scrub areas normally have a sparse vegetation of bunch grass (Trachypogon plumosus) and sedges with small shrubs and woody herbs, together with trees such as muri (Humiri floribunda), hicha (Byronima sp.), sand paper tree (Curatella americana), kumakabalh (Ficus sp.), and Clausia sp. In the lower, marshy spots Mauritia palms (Mauritia flexuosa), kokerite (Maximiliana regia), manicole (Euterpe edulis) and corkwood (Pterocarpus officinalis) occur. There are also small areas of herbaceous swamps in depressions, containing mainly razor grass (Scleria and Rhynchospora spp.).

One other tree species, a legume, dakama (Dimorphandra conjugata) occurs in pure stand in some areas on the bleached sands in drainage conditions which can be described as somewhat excessive to somewhat poor. Due to the thick, waxy leaves, the soil can have an organic layer of between 40 and 60 cm and this makes the forest type highly inflammable. However, if it is not burnt prematurely, it can reach a height of about 25 m. It is interesting that under walaba, which is also a very dense vegetative cover, there is no litter layer.

On the bleached sands, except in the open savannah, the forest associations, whether walaba or dakama, consist almost entirely of the single species. This contrasts sharply with the unbleached, so-called Brown Sands, on which the forest is luxuriant mixed seasonal evergreen, in which, according to Lindeman (1953), up to 100 tree species grow together, among them some of the most valuable tropical hardwoods. An exception is the walaba forest where it occurs on the unbleached sands, again in pure stands. Such locations would be the freer drained members, poorer in clay and probably transitional to the White Sands. Within the unbleached soils are savannah areas but these are of man-made origin and have resulted from shifting cultivation.

In Guyana as well as in Suriname, between 60 and 70 per cent of the acid sandy soils is forested, some having considerable economic value for useful timber. In Guyana, it is the savannah areas which are being considered as potential agricultural soils while in Suriname soils with both vegetative covers are being considered. Bleakley and Khan (1963) contended that the present dakama and walaba forests represent an edaphic climax since the present infertile sands are now incapable of supporting a higher forest formation. It could therefore be that the soils on which the forest first flourished were originally of considerably higher fertility, associated with a higher clay content which has since been reduced by mechanical eluviation and chemical degradation. This has been accompanied by the leaching out of iron through the influence of organic compounds washed out of the leaves of the luxuriant tropical forests which can now no longer be rejuvenated, the present forest obtaining a cyclic supply of nutrients largely from the fallen litter. Both species are leguminous, however, and this may have implications in their nutrition.

Climate

The climate of the sandy region in the Guyanas has been described as tropical humid. The mean annual rainfall is about 2,250 mm, with a bimodal distribution, 40-60 per cent of it coming in the long rainy season (mid-April to mid-August) and less than 20 per cent
in the short rainy season (mid-November to mid-January). Mean annual temperature for the region is 26°C and diurnal variations of up to 10°C are more pronounced than seasonal changes. Relative humidity is high in the early morning (>90 per cent) with minimums in the early afternoons of about 65 per cent. Evapotranspiration has been averaged at 110 mm per month. The climate pattern with its bimodal rainfall distribution would normally allow two rainfed annual crops per year although there may be problems depending on the rainfall distribution during the annual cycle.

**Soil development and classification**

Most of the sandy soils of the tropics are formed on materials that have been severely impoverished by repeated decomposition and transportation before final deposition. Since the materials are sandy in nature and highly permeable, they have been subjected to further leaching and eluviation since deposition. The initial clay material was highly water dispersible which facilitated eluviation. Downward movement of clay in percolating water and of sesquioxides in organo-mineral complexes are the main processes of soil formation. In the latter, the type of vegetation is important since the chemical activity of the leachate from the litter layer and from the canopy drip would facilitate this process of complexation. According to observations in Suriname (Van der Eyk, 1957) and Brazil (Klinge, 1965), once the clay content has been reduced to around 3 per cent by eluviation, bleaching of the residual sand inevitably follows.

The appearance of these very deep, very bleached sands inspired Richards (1947) to describe these soils as giant podzols developed in the lowland tropics, since up to that time it was considered that podzolic soils were unique to colder climates. Since then several authors (Van der Eyk, 1957; Bleakley and Khan, 1963; Klinge, 1965, Turenne, 1974; Sombroek, 1962; Dost, personal communication) have agreed that podzols (Spodosols) are important among the bleached soils. However, since most of them have very deep profiles (upwards of 20 m) the spodic horizon is often too deep for the soils to be classified as Spodosols according to Soil Taxonomy (USDA, 1974). Consequently, these soils are mostly classified as Entisols (Psamments). The Brown Sands which show marked eluviation of clay have properties which fit them in the Ultisols or in some instances in the Oxisols depending on the ratio of sesquioxides to clay.

The surface and drainage waters from the bleached White Sands are characteristically dark brown in colour and the humic matter in solution is readily precipitated at pH 2. This colouration is characteristic of all the drainage waters in rivers and creeks which drain through the belt of sandy soils. The Rio Negro which is a major tributary of the Amazon River is so named because of the dark brown colour of its water which drains through bleached quartz sand below a "Catinga" type forest (Vieira e Filhos, 1962). These dark coloured waters are some of the chemically purest natural waters in the world, being almost as pure as distilled water. The dark colouring material is extremely low in concentration but it is strongly coloured and is in very small colloidal particles.

A characteristic feature of the bleached sands is a rather permanently high water table, within 1-2 m from the surface. This is probably due to the fact that the aquifers in the coastal artesian basin with which these sediments are in hydraulic continuity are full, the surplus precipitation flowing as effluent seepage into the rivers. It is not uncommon that a pan of precipitated iron and humic material occurs at or below the level of the water table. The large reservoir of ground water is an important resource in any agricultural development of these soils.
Soil properties

Chemical properties and fertility status

Chemical properties of the important soils of the sandy region of the Guyanas have been published by the FAO (1964) and Bullen et al., 1982; some representative data are shown in Table 1. For comparison, similar data for a representative soil in Niger are also presented (Table 2). With respect to texture, the data for the Guyana soils cover the range normally found in the white sands (Tiwiwid) through brown sandy loam (Ebini), while the data for the Niger soil are representative for all the eolian sandy soils found in Sub-Saharan Africa. The white sands are almost devoid of clay and experience in Suriname shows that they generally have less than 3 per cent (Van der Eyk, 1957); they typically have over 99 per cent of quartz which dominates all size fractions. In the natural state, the top soils can be strongly coloured by organic matter but this is present in discrete particles and is subject to mechanical eluviation once the soil is disturbed and then the soil can be reduced to the white colour of silica sand within one wet season. The other soils in Table 1 show a progressive increase in clay content and particularly, an increase in clay with depth due to eluviation, which is the main feature for their classification in the Ultisols. The soil from Niger shows no essential variation in texture with depth and it is intermediate in clay content between the White Sands and the most sandy of the Brown Sands of the Guyanas.

One of the most revealing properties of these soils is the pH : CEC : cation saturation : exchangeable Al relationships. The soils are extremely acid and essentially have no exchangeable cations except Al. This situation worsens as the clay content increases in the Brown Sands. The cation retention capacity is also negligible, even in the case of Ebini sandy loam in which the sub-soil may have over 40 per cent clay. These data have extremely important implications for fertility management of these soils.

The total N content is a reflection of the distribution of organic matter. It is interesting to note that while there is an important concentration of organic materials in the surface layers, there is a fairly even gradation with depth. Evidently, the N which is held in these soils is fairly readily available to crops even though the C/N ratios may be high. In this regard, Chesney (1979) did not get a response to N fertilizers with pangola grass in white sand soils with a previous dakama vegetation if the litter layer was not destroyed on land clearing; his experiment lasted for 3 years. Similarly, Lucas and Boulet (1982) reported no response to N by sugar cane on white sandy soils although minor element deficiencies were present as was the case with Chesney’s experiments.

For light textured soils such as these, the available P as indicated by the data in Table 1 is considered good. Since retention of P is not severe in these soils, the available form would closely parallel the total P. In this regard, Chesney (1979) showed that added P is leached in these soils rather than being fixed.

In Niger where the annual rainfall is about 300-500 mm per year coming in 3 months, leaching is restricted; accordingly, the data show an increase in base status with depth as a result.

However, the cultivation pressure here is very great for the production of annual food crops and apart from soil-water limitations, the next important limitation is soil infertility. In the Sub-Saharan countries, due to population pressure and the lack of more productive soils, the proper management of these acid sands is a matter of high priority.
Table 1: Characteristics of the four dominant kinds of soils in the Intermediate Savannahs area of Guyana

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<tr>
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Source: Bullen *et al.* (1982)
Table 2 Some properties of the main acid sandy soils of Niger

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<th>silt (%)</th>
<th>clay (%)</th>
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<th>Exchangeable Ca (meq/100g)</th>
<th>Exchangeable Mg (meq/100g)</th>
<th>Exchangeable K (meq/100g)</th>
<th>Exchangeable Al (NaOAc) (meq/100g)</th>
<th>CEC (NaOAc) (%)</th>
<th>Base saturation (%)</th>
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<td>0.4</td>
<td>0.7</td>
<td>39</td>
<td>-</td>
</tr>
<tr>
<td>173-200</td>
<td>95</td>
<td>3</td>
<td>3</td>
<td>0.04</td>
<td>4.9</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.4</td>
<td>0.7</td>
<td>24</td>
<td>1.70</td>
</tr>
</tbody>
</table>

Physical properties

Some physical properties of representative sandy soils in Guyana are given in Table 3. The soils are characterized by high bulk densities and low total porosities. The pore space distribution shows a high percentage of non-capillary pores, although this decreases as the clay content increases. Since the soils have low water-holding capacities an assessment of the available water in the rooting zone is of great importance as dry spells during the cropping cycle may cause yield depression due to temporary moisture stress. The amount of available water held between field capacity and wilting point depends on clay and organic matter contents but ranges from 10 to 70 mm in the upper 30 cm and 25 to 125 mm in the upper 60 cm. These values emphasize the low water-holding capacities of these light textured soils.

Permeability is also related to clay and organic matter contents, being very rapid for the loamy sands and moderately rapid to moderate for the sandy loams. Therefore, internal drainage poses few problems unless the subsoil has been compacted.

According to data obtained in Guyana (Table 3) tillage appeared to improve the physical condition of all the soils although there is no information as to how many tillage cycles the soils were subjected before the measurements were made.

History of the use of the soils

White Sands

Guyana

Following the construction of the highway between Timehri and Linden which is essentially on White Sands, there was some settlement along the route by food crop farmers. One of the most popular crops grown was pineapple. Farmers soon realized that the infertility of the soils was just too great to cope with and often they could manage only one crop on a newly cleared site which at best performed unevenly. The Ministry of Agriculture at the time developed a research station at Long Creek along this road to support such development and crops experimented with included pasture grasses, vegetable crops and even citrus. Plant nutrition problems were many, even grasses showing several deficiencies from the early stages of land clearing. The experimental site was cleared from dakama forest which represented a more favourable situation especially since land clearing was by hand and the litter layer was preserved as far as possible. The overall experience from this station was in accordance with the farmers experience and at some stage research was discontinued.

Suriname

In 1958, some 5000 ha of land in the White Sands were cleared and planted with Caribbean pine with the hope of developing a paper pulp industry. Due to lack of information not only on soil characteristics but on species grown, this was not successful. Besides the limited possibilities for utilization of the trees, it became clear that a productive forest cannot be maintained continuously on these soils. Growth rates were extremely slow, the trees developed nutrient deficiency symptoms and root disease proved to be serious.

Far East

In Thailand in particular as indicated earlier, white sands occur as beach deposits, inland from which are fresh water swamps. On these white sands a considerable amount of cashew is produced and there is also some coconut. To what extent the lateral movement of swamp water and a nearby marine environment are responsible for the nutrition of the trees is not known but may be important factors in sustainable production of these crops. Similar soils in Malaysia are little utilized.
Table 3  Some physical characteristics of the brown sand soils of the Intermediate Savannahs of Guyana

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Bulk density (g/m³)</th>
<th>Porosity</th>
<th>Sat. hydr. conduct (cm/hr)</th>
<th>Water retention at Sat'n 0.06 bar 0.3 bar 0.5 bar (%) dry weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>NCP&lt;sub&gt;a&lt;/sub&gt;</td>
<td>CP&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Tabela sand (virgin)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-15</td>
<td>1.55</td>
<td>42</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>15-30</td>
<td>1.67</td>
<td>34</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>Tabela sand (cultivated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-15</td>
<td>1.5842</td>
<td>22</td>
<td>20</td>
<td>12.6</td>
</tr>
<tr>
<td>15-30</td>
<td>1.7137</td>
<td>11</td>
<td>26</td>
<td>6.0</td>
</tr>
<tr>
<td>Kasarama loamy sand (virgin)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-15</td>
<td>1.65</td>
<td>35</td>
<td>4</td>
<td>31</td>
</tr>
<tr>
<td>15-30</td>
<td>1.66</td>
<td>34</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>Kasarama loamy sand (cultivated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-15</td>
<td>1.36</td>
<td>47</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>15-30</td>
<td>1.55</td>
<td>39</td>
<td>6</td>
<td>33</td>
</tr>
<tr>
<td>Ebini sandy loam (virgin)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-15</td>
<td>1.58</td>
<td>37</td>
<td>8</td>
<td>29</td>
</tr>
<tr>
<td>15-30</td>
<td>1.64</td>
<td>36</td>
<td>7</td>
<td>29</td>
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<tr>
<td>Ebini sandy loam (cultivated)</td>
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<tr>
<td>0-15</td>
<td>1.40</td>
<td>45</td>
<td>18</td>
<td>27</td>
</tr>
<tr>
<td>15-30</td>
<td>1.56</td>
<td>36</td>
<td>5</td>
<td>31</td>
</tr>
</tbody>
</table>

a) non capillary
b) capillary pores

Source: Bullen et al. (1982)
According to the present status of knowledge and level of technology, the White Sands of the Guyanas must be considered as unsuitable for agriculture and should be left in natural vegetation. At the same time though, it must be remembered that on similar soils in Florida, citrus is produced in large quantities and perhaps some appropriate technology may yet be transferred.

Brown Sands

Guyana

There are several examples of attempts at utilization of the Brown Sands in Guyana. At the commercial level, there are a few cattle ranches, for example Waranama and Dubelai. Since in the early 1930s it was recognized that these savannahs without inputs are not suitable for livestock production (Follett-Smith, 1930). According to Harricharan (1979), the average annual liveweight gain from native pastures was 3 kg per ha while on improved pastures such as at Ebini, this was 175 kg. The cattle on native pastures are always in poor condition and suffer from a diseased condition the external symptom of which is failure of the hind quarters and collapse of the animal when chased. Internally, there is cirrhosis of the liver. The cause can be a combination of toxicity of some of the vegetation and mineral deficiency.

At Ebini a great deal of experience on the potential and management problems of the Brown Sands has been obtained over a period of time commencing in 1942 to the present from investigational work carried out at Ebini. Earlier, this was the final resting place for cattle driven on the hoof from the Rupununi savannahs to the Berbice River before being shipped to Georgetown directly by boat or a combination of boat and rail. When slaughtering of cattle was carried out at Rupununi and the beef air-lifted to Georgetown, Ebini no longer served as a resting place for cattle. Very likely over the years it was so used, there was some indication that the cattle gained weight after their long trip during their sojourn at Ebini and there was therefore some potential for livestock production there. In 1942, the Ebini Livestock Station was established to investigate problems associated with economic beef cattle production in the Intermediate Savannas. Research was initiated along the lines of animal breeding and pasture management. The intention was to produce an animal best suited to the environment but at the same time, productive. The breeding stock consisted of the original Rupununi long horn cattle and imported Santa Gertrudis and Zebu. There was no doubt that considerable success was achieved in this aspect.

In the area of pasture management, several grasses and legumes were tested. Initially, B. decumbens was productive but it required too much management for best performance and its survivability was not good. None of the first introduced legumes, which were then selected for much higher soil fertility levels, proved successful. Presently, good pastures are maintained with B. humidicola and Calapogonium spp.. Initial infertility of the cattle has been solved by proper feeding and management. There is no doubt that the work carried out at Ebini over the years has shown that this aspect of agriculture has been technically successful. However, the economics of this production system probably needs fuller investigation and the means found to improve efficiency.

In the early 1960s, research at Ebini was expanded to include crop production. The first crops tested included maize, cotton, soybean and groundnut; in later experiments other crops such as cassava, sweet potato, onion, tomato, tobacco, sorghum, sesame, castor bean, cowpea and Phaseolus bean were studied. While it was possible to produce most of these crops, several problems were identified (Bullen et al., 1982). One such problem was the climate. The unreliability of the rainfall, the frequent severe dry spells and comparatively low humidity in the afternoons all affect water relations of the crops. The soils retain very little water due to the texture and low organic matter content. It was
concluded that outside the long wet season, commercial production of annual crops without irrigation would be impossible. Even during the wet season, a dry spell can be detrimental as observed in Suriname (Ahlawat and Samlal, 1978). As mentioned earlier, however, this area has abundant supplies of good water and therefore this problem can be solved with appropriate inputs.

With respect to soil fertility, major problems were also encountered. The experiments showed that without additions of N, P, K, Ca and Mg, no crop could be grown. The high levels of Al saturation made the addition of lime in the fertility management package essential. This was especially so for crops considered to have potential such as cotton, soyabean, tobacco and some vegetables which were sensitive to high levels of Al in the soil solution. There was evidence that applied fertilizers were not long lasting. Even soils which had received fertilizers for a number of years did not improve in fertility status. The effects of liming were observed only on the crop following its application and there was no residual effect.

Some perennial crops were also studied and these included citrus, mango, oil palm, coconut and cashew. Citrus proved to be the most successful and although the production problems have not been solved, there is indication that commercial citrus production could be a real possibility. There is an old grapefruit orchard at Ebini which has been productive but it is reputed that this was located where the cattle from Rupununi awaiting shipment from Ebini were traditionally corralled.

Infertility is indeed a major problem of crop production on these sandy soils, a problem also highlighted in Suriname. However, this could be one of the easiest problems to solve once appropriate research on kinds of fertilizers, frequency of application, its placement and method of application has been done. The problem of ameliorating soil acidity would also have to be solved based on the Al saturation in the soils and the tolerance of particular crops for this element. On this basis, the need for lime can be reduced.

Initial observations also point to certain physical constraints to soil management. Once the soils have been loosened by tillage they become highly erodible by surface wash. The finer textured Ebini loam has particular moisture limits within which effective tillage can be done and some of the soils develop hard crusts on wetting and drying. Other problems such as fluctuations in soil temperature and deterioration of soil structure in the finer textured soils have not been studied.

The work done at Ebini so far only highlighted the many soil problems which may be encountered in annual crop production on these sandy soils. Their solution still largely awaits appropriate research. Apart from soil management with respect to fertility maintenance, research is needed on the extent of tillage which is actually necessary, taking into account the erodibility of the soils. Complete production systems in which the major problems are recognized and taken into account — such as crop selection, appropriate soil fertility maintenance, soil erosion control, soil crusting control and soil restoration — would have to be developed, the main principle being that the soil must be kept protected by surface cover at all times. Biological nitrogen fixation would have to be maximized in such systems through use of legumes since this nitrogen costs little and most importantly, it is provided without further soil acidification. These measures are extremely important in developing worthwhile and sustainable agriculture on these soils.

The role of irrigation in effective, predictable and successful crop production is another important problem which has to be studied and incorporated in particular production systems.
From the work at Ebini, several advantages of developing good agriculture on these soils have been identified and are of importance. Factors such as a favourable topography for mechanization, easy land clearing, low power requirements for tillage and land preparation and little or no external drainage requirements are important points in their favour. It is a fact that considering the population situations in both Guyana and Suriname, crop production on these soils in the immediate future would have to be as mechanical as possible.

In developing appropriate packages for managing these soils for various agricultural enterprises, it is important that economic considerations should be given at all stages for obvious reasons.

In Guyana there were other areas of Brown Sands in which there was parallel development to the research which was being conducted at Ebini. At Kilibiri an organization known as Global Agriculture Industries of Guyana was inaugurated in 1970 to apply research findings to large-scale mechanized crop production on a commercial basis. This enterprise operated for seven years during which commercial production of maize, soyabean, groundnut and cowpea was attempted. Many problems emerged and it was concluded that unpredictability of rainfall, non-uniformity of land preparation and planting and lack of precision in the application of inputs contributed to a consistent trend of non-realization of target acreages and yields (Bullen et al., 1982). A most obvious result was the very rapid soil deterioration which occurred. The high degree of soil loosening caused by unsuitable tillage led to massive soil erosion and mechanical washing of organic materials and clay. The system of soil management used was not appropriate to the particularly fragile soils. This area is now under the control of the Guyana Defence Force and it is not certain to what extent any crop production is being carried out.

Towards the latter years of this enterprise, some experimental work was done to assess the suitability of cotton as a crop for the Intermediate Savannas. In experiments the crop showed promise but yields were not as high in large-scale cultivations. Soil fertility factors may have been an important reason for the poor performance of this crop since cotton is known to be quite sensitive to high Al saturation in the soil.

Another agricultural development was initiated at Kimbia in 1974 by the Guyana National Service. One of the main crops was cotton of which over 1,000 ha were planted in 1976. Another important crop from the inception was cowpea and the cultivation of this was actually mechanized at all stages. Extremely severe plant disease and weed infestation are real problems to the cultivation of this to the present day. Once again, the crop is not grown within an appropriate farming system in which it is an important component. The rapid soil deterioration observed at Ebini was also characteristic at Kimbia.

Due to soil infertility and toxicity, the rooting of crops is sparse and only superficial which limits their ability to absorb water and plant nutrients (Bullen et al., 1982; Goense, 1987). In this connection, it is important to note that Dookie (1981) obtained only 25 per cent recovery of applied nitrogen in similar soils indicating that there was great scope for increasing this efficiency through appropriate soil management.

Another unsuccessful commercial agricultural development on the Brown Sands in Guyana was at Eberoabo. In this case the Governments of Guyana, Trinidad and Tobago and St. Kitts/Nevis formed a company known as the Regional Grain Production Company in 1975 with the initial aim of developing the cultivation of 3,200 ha of soyabean, 4,000 ha of maize and 800 ha of cowpea. At a certain stage, pigeon pea was cultivated on a fairly large scale; an important gain from this aspect was some experience on the
complete mechanization of this crop for dry seed production. There were many problems. One which was very impressive was the high insect infestation of the grain prior to harvest. After 7 years of continuous failures, the project was abandoned. The overall approach was similar to the Kibibiliri effort - i.e. large acreages, complete mechanization with heavy equipment using conventional management techniques. Basically, the results were the same.

In the mid-1970s a commercial milk production state enterprise with some satellite farmer participation was started at Moblissa. This farm is situated approximately 90 km south of Georgetown off the Soesdyke-Linden Highway. The initial aim was to rear high producing cattle on mixed grass/legume pastures. A number of grasses and legumes were tested in the environment but only one grass *B. humidicola*, and one legume, *C. mucunoides*, proved adaptable. It is somewhat unfortunate that most of the area consists of the most highly leached of the Brown Sands which grade into the White Sands, so that the soils are not among the best of the Brown Sands. In general, the soils have less than 20 per cent and often less than 10 per cent cation saturation. Al saturation generally exceeds 70 per cent (CARDI, 1983) and the average pH is about 4.5. An important problem which was also observed at other locations on the sands is the rapid deterioration of the soil after clearing.

The experience gained at Moblissa is not different from the Ebini experience as far as soil suitability and management and forage species adaptation are concerned. On the best soils, i.e. the Ebini loams, it is possible to maintain fairly productive *B. humidicola/C. mucunoides* pastures with moderate fertilizer applications. If mineral supplements are given, cattle can be reasonably productive. Therefore, there is considerable potential for livestock production on these soils if strict attention is paid to management of all components. It is not known to what extent there has been an economic evaluation of the Moblissa operation, and therefore to what extent the management practices can be justified in these terms.

The involvement of CARDI (Caribbean Agricultural Research and Development Institute) at Moblissa through its IDRC-(International Development Research Centre) funded project has been important in broadening the information base for livestock production on these soils. A highly selective forage grasses and legumes germplasm programme has been introduced where the species under study are being continuously evaluated in order to find more productive, nutritious and adaptable species. This involvement has also stimulated detailed soil studies of the project area which would serve as good base-line information against which changes in soil properties under management can be assessed.

**Suriname**

It is interesting to examine the approach to utilization of the acid sandy soils in Suriname. Two important scientific conferences were held there in recent years (Klas, 1978; Wienk and de Witt, 1982) which focused attention on the utilization of these soils. Apart from the Caribbean pine planting referred to earlier, there was no other attempt at commercial crop production on the sandy soils. In 1970, an Experiment Station of the Ministry of Agriculture was established at Coebiti in a Brown Sand area to examine the agricultural potentialities of low fertility acid soils. Research was carried out jointly by scientists of the Agricultural Experiment Station and the Agricultural University of Wageningen, the Netherlands, through the Centre for Agricultural Research (CELOS). It was later decided to concentrate on a few crops particularly groundnut and cassava in a cropping system. In 1978, another research station was established at Kabo as a joint project of the Agricultural University of Wageningen and the University of Suriname to examine all aspects of the permanent cultivation of rainfed annual crops on the loamy soils of the Zanderij
Formation; the possibilities and limitations for mechanized annual cropping on these soils was to be given special attention, with the eventual object of developing appropriate farming systems. The particular areas of mechanized agriculture which were to be investigated included: effect of primary tillage methods on crop yields and on soil chemical and physical properties; conditions under which mechanized field operations can take place; timeliness of planting and harvesting of crops; and formulation and evaluation of mechanized cropping systems with the use of the information from the studies. At a later stage, research in livestock and pasture production was included in the research protocol.

During the course of the research, several significant findings were reported. For example, it was found that initial land clearing can greatly influence physical and chemical soil properties (van der Weert, 1974; van der Weert and Lenselink, 1973; Goense, 1978). Some land clearing techniques resulted in soil compaction and reduction in root room leading to mechanical impedance of root growth. It was found that avoidance of structural deterioration implies that land clearing operations, and especially windrowing, should be done in the dry season and burning should preferably take place before windrowing. The distance between windrows should be kept to a minimum to avoid excessive trafficking and every care should be taken not to disturb the top soil. In general, a bulldozer with a Rome K.G. Stinger blade would cause less disturbance than a tree bulldozer and to reduce trafficking, the chain method of tree clearing has advantages. On mechanically cleared land, root penetration studies for banana (van der Weert, 1974) and maize (Goense, 1987) showed that the compacted layer which develops greatly reduced root penetration. By comparison, on hand-cleared land, it was found that there was much better root distribution with depth.

Experiments carried out on the Coebiti Farm over a 9-year period and 22 cropping cycles showed that with conventional tillage consisting of disc ploughing and harrowing, average crop yields were somewhat higher than with successive shallow or no tillage. The yield obtained under no tillage was 75 per cent of that under conventional tillage for maize, cowpea and sorghum, 85 per cent for soyabean and 90 per cent for groundnut. Comparable results were obtained at Kabo over a shorter period. From these results it was concluded that in managing these soils, complete ploughing may be done periodically to incorporate residual fertilizers and lime and this should alternate with crop production under no tillage. There is already indication that in this management the no-tilled crops produced higher yields than in the case of the 9-year continuous no-tilled treatment referred to earlier.

According to available data, very little detailed attention was given to soil fertility management and soil amelioration. As in Guyana, crop response to N was not as expected but the extent that this may be due to adverse soil factors such as Al toxicity, water stress, soil compaction, deficiency of other nutrient elements and actual loss of the applied N, is not known. A response to added P is generally expected but for K this is unpredictable. No studies have been reported in which responses to the other major nutrients have been studied.

Summary of research and land development experience

Based on results of research carried out in both Guyana and Suriname, the following conclusions can be made:

(a) The White Sands should be avoided for any form of field crop production.

(b) The so-called Brown Sands include a range of soils, varying in texture. In general, the more
clay in the soil, the more productive it may be, given the same management. In Guyana, the best of these is the Ebini sandy loam.

(c) All the soils have extremely low cation exchange capacities, very low cation saturation, high acidity and high Al saturation and low levels of N, P, and organic matter. They have very low water retention and there is a problem of compaction at depth. The surface soils are highly erodible. Their agricultural potential is directly related to the organic matter content which is concentrated in the surface soil layer. These soils are therefore extremely fragile and must be handled with great care. Ways and means of appropriately managing them must first be found by research which must be carried out before or simultaneously with development.

(d) Land clearing can permanently impair these soils if not properly done; information is already available in this important area.

(e) The soils have extremely low water retentivity and crops can suffer moisture stress with only a few days of no rainfall. The subsoils have low macro-porosity which restricts deep root penetration. Increasing soil infertility with depth is also a factor restricting root penetration.

(f) The soils are extremely erodible and excessive loosening during tillage increases their proneness to erosion.

(g) There is evidence that these soils may benefit from special tillage procedures. Complete ploughing and harrowing may only be done once in every 3 or 4 years, mainly to incorporate lime and residual fertilizers; in the intervening cropping cycles, land preparation can be done as zonal or other forms of reduced tillage. This procedure would not result in reduced crop yields but would result in less soil compaction and erosion.

(h) Very little progress has been made in evolving soil amelioration and soil fertility management. There is evidence of loss of added P, K and Mg either by leaching or through erosion of the top soil. Recovery of N is very low and the major loss, especially in the case of urea, is probably by ammonia volatilization.

(i) Weed infestation and insect pest and plant disease problems can be profound.

(j) Mechanized farming is possible on these soils but a high standard of management is required for the proper planning and timing of the field operations.

(k) Based on available findings, only in the area of livestock production and pasture management may commercial agriculture be practised with a certain expectation for success. Even in this area, the economics of the production system are not clear at this time.

Research needs

The approach to land utilization for these soils should be based on the knowledge of their properties and behaviour and finding crops and farming systems that will be productive with the minimum of inputs. This has not always been the approach up to this time. More often than not, the approach was to pre-determine the crops to be grown and production systems to be followed based on national considerations and to establish production targets. This approach presupposes that the management requirements for the soils for the pre-determined crops and production systems are known and applied. Unfortunately, this has not been the
case and problems arose which led to failures.

For highly fragile ecological systems, the approach should be more logical and systematic, if slower, so that permanent harm may not be done to the environment. The steps should be as follows:

1. In crop selection, potentially adaptable crops and their cultivars should be rigorously tested. Such material must have the ability to be productive in acid soils with high levels of Al saturation so that corrective liming can be reduced to the minimum. Annual as well as perennial crops should be tested, since, based on the Florida experience, some perennials may be quite suited.

2. Appropriate farming systems should be developed in which legumes are important either for grain or for soil protection and improvement. Such cropping systems should aim to develop indefinitely sustainable agriculture and should therefore be based on soil erosion control, incorporation of crop residues, reduced tillage, proper soil water management, integrated pest and disease control, weed control etc. The best systems may not necessarily be suitable to large-scale complete mechanization involving heavy farm machinery.

3. Soil amelioration and fertility management packages should be worked out in detail since this could be the highest cost input factor. The aim should be to obtain maximum benefit from minimum inputs. Specifically, the fate of added fertilizers should be studied and ways found to reduce loss and improve efficiency. Studies should involve forms of fertilizer materials, timing and placing of applications and the long-term effects on soil properties of fertilizer use. The long-term aim should be to develop a rational basis for fertilizer use based on soil and/or plant chemical tests. The role of minor elements in these soils should also be studied.

4. Further studies should be done on amelioration of adverse soil physical conditions; periodic deep tillage may be tried to loosen compact subsoils; refinements in tillage requirements and techniques should be investigated.

5. The role of irrigation in continuous crop production should be studied since moisture stress is likely to be a constraint at any time of the year.

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VOTE OF THANKS

Dr Samsundar Parasram

Director Special Services,
Caribbean Agricultural Research and Development Institute

I wish to join those who have gone before me in extending a very warm welcome to you all to this "land of many waters", The Co-operative Republic of Guyana. In CARDI, we have been conscious of the region's drive to self-sufficiency in cereals and food legumes and to the attainment of food security. We are also aware that if these are to be achieved the Intermediate Savannahs of Guyana must play a key role.

I am told that there are some 30 overseas participants to this seminar many of whom have worked in Guyana or in similar ecosystems and I believe that during our technical sessions there will be some 40 local participants from various R & D organizations. This I feel demonstrates the great interest in, and importance of, the Intermediate Savannahs to agricultural development of Guyana, and indeed the region.

The Honorable Minister of Agriculture has been a keen advocate of such research and development and as a Scientist himself understands and supports the research thrusts. His Ministry and himself have provided immense support to this seminar.

The Technical Centre for Agricultural and Rural Co-operation (CTA) in recognition of the importance of this area to Caribbean agriculture and the need to pool our knowledge for these developments, has provided financial and human support to this workshop.

We have been very fortunate to have with us Professor Nazeer Ahmad, an eminent son of Guyana and a world authority on tropical soils based at the University of the West Indies, Trinidad, to deliver the Keynote Address. In Hugh Saul, the CARDI Deputy Director (Development) we have yet another son of Guyana and, if you look ladies and gentlemen, you will find a significant number of Guyanese in our overseas contingent. For they have worked and toiled here and with their local counterparts, they must have the answers and the solutions.

Several other agencies, the National Agricultural Research Institute (NARI) the Livestock Development Company (LIDCO), the National Edible Oil Company (NEOCOL) and the Guyana National Service (GNS) to name a few, have contributed to this seminar.

The CARDI Staff at headquarters, and at the Guyana office in particular, and those at in the various CARDI member countries have all contributed to this seminar to varying degrees.

A seminar such as this spanning five days, and with participants from Europe, Africa, South America and the Caribbean, notwithstanding the difficulties of travel at this time of year, does require much interest, goodwill, understanding and hard work on the part of all concerned — planners, organizers, sponsors, participants, agents and agencies, the media, hotel staff — to all of these persons and entities I would like to express my sincerest thanks and my genuine hope that this seminar will be a success.

I thank you all very much.
TECHNICAL SESSION I

Chairman: M. Granger, NARI
CHARACTERISTICS OF THE SOILS OF THE ZANDERIJ BELT

P.D. Rellum
Common Vegetable Oils and Fats Company (GPOV Ltd.), Paramaribo, Suriname.

A study was made on the main landscapes in Suriname generally and subsequently the several characteristics of the most important soils of the Zanderij belt. These soils of the Zanderij Belt may qualify as a very important group of the "low fertility acid sandy soils" and this was the main reason for this study. In the past years several soil surveys were carried out on these soils so that more information became available. For agricultural purposes the well-drained loamy soils on level to slightly undulating plateaus are the best, but they also have their limitations.

Main landscapes in Suriname

Suriname can be divided from South to North into four main landscapes as shown in Table 1.

The Residual Hills (The Interior Uplands), which cover 82 per cent of the whole country, consist of rolling to hilly (and locally mountainous) areas of mainly residual soils. The rocks are mainly of Precambrian origin. Bauxite and laterite caps of Oligocene age and recent valley sediments also occur (Bosma et al., 1984). This landscape is developed on the Precambrian Guiana Elevation Geological Relief

<table>
<thead>
<tr>
<th>Landscape</th>
<th>Area (km²)</th>
<th>%</th>
<th>Elevation (m above or below sea level)</th>
<th>Geological period</th>
<th>Relief</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual Hills</td>
<td>135,000</td>
<td>82.2</td>
<td>50-1280</td>
<td>Precambrian</td>
<td>rolling to hilly</td>
</tr>
<tr>
<td>Zanderij Belt</td>
<td>8,750</td>
<td>5.3</td>
<td>6-70</td>
<td>Pliocene</td>
<td>level to undulating</td>
</tr>
<tr>
<td>Old Coastal Plain</td>
<td>4,300</td>
<td>2.6</td>
<td>2-12</td>
<td>Pleistocene</td>
<td>flat to slightly undula­ting</td>
</tr>
<tr>
<td>Young Coastal Plain</td>
<td>16,200</td>
<td>9.9</td>
<td>1-4</td>
<td>Holocene</td>
<td>flat</td>
</tr>
<tr>
<td>Total</td>
<td>164,250</td>
<td>100.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Poels (1987)
Shield, a deeply weathered rain forest hill and mountain area, stretching from the Amazon river in Brazil to the Orinoco in Venezuela.

The Zanderij Belt, also called the Cover Landscape, is level to undulating with sandy and loamy deposits of coarse brown and white sands, subordinate gravels and kaolinitic clays (Bosma et al., 1984). The deposits rest on the weathered basement as a cover. This is the reason why this landscape is also called the Cover Landscape. The deposits are fluvial, because they consist of material that was sedimented by braided rivers, flowing northward in a relatively dry period.

The Old Coastal Plain, which was formed in the Pleistocene period, is a marine terrace that can be subdivided into a northern part with predominantly sand ridges and a southern part consisting of clay flats (Bosma et al., 1984). The ridges form broad bundles of predominantly east-west orientation with an elevation varying from 4-12 m above mean sea level. The dissected clay flats are found at 2-7 m above mean sea level and consist of firm grey silty loams and silty clays with commonly red and purple mottles at some depth.

The Young Coastal Plain along the Atlantic Ocean consists mainly of clayey brackish and fresh water swamps, beside sandy beach ridges, silty clay natural levees and peat swamp (Brinkman and Pons, 1968). The surface of the clays is situated from 1 m below to about 2.5 m above present sea level. These sediments are very heavy textured, non-calcareous clay with over 60 per cent clay-sized particles. These marine clays are interrupted by sand and shell ridges, running parallel to the coastline and range from 3 to 7 m in height.

The Zanderij Belt (Cover Landscape)

Geology

The parent material of the Zanderij Belt belongs to the Coesewijne formation (formerly Zanderij formation). This material is of Pliocene age and was deposited at the start of a rather dry period by short braided rivers. It was derived from the hinterland. The sediments are up to 25 m thick in the north and become shallower towards the south, resting on the weathered basement.

Before deposition, the sediments were strongly weathered and therefore contain few weatherable minerals. They consist mainly of quartz and kaolinitic clays and have a heavy mineral content that is very low.

Geomorphology

The Zanderij Belt is situated between the poorly drained Coastal Plain and the well-drained Residual Hills. With some interruptions, mainly along rivers, it extends in an east-west direction across Suriname and into the neighbouring countries. In the west of Suriname it is about 50 km wide, narrowing towards the east to 5-10 km. To the south there are several small outliers amidst the Residual Hill Landscape; within the Belt there are also small outcrops of residual material.

The Zanderij Belt comprises level to undulating plains, extending to vast areas, especially in the west. On the whole this landscape is well drained with some marshy regions, varying in altitude from 6-10 m above mean sea level in the north to about 70 m above mean sea level in the most southern part (Poels, 1987). The plains are dissected by many creek valleys, which are shallow in some places and 10-15 m deep in others. These creeks and rivers contain sediments from the Holocene age.
Soils and vegetation

The soils in the Zanderij belt may be grouped as follows (Krook and Mulders, 1971):

- Brown loams, approximately 30 per cent
- Brown sands, approximately 30 per cent
- White sands, approximately 40 per cent

The brown loams and brown sands, also called the unbleached soils, are generally well or moderately well drained. In the white sands, also called the bleached soils, the establishment of drainage classes is complicated. In most cases these soils are too wet in the rainy season and too dry in the dry season.

The vegetation of the Zanderij Belt is closely related to the soil. The white sands (the bleached soils) are covered with a savannah vegetation of grasses and low shrubs or savannah shrubs, or savannah forest. The brown loams and brown sands (the unbleached soils) are covered with high forest. This is a moderately heavy rain forest. Van der Eyk (1957) considers "the Coesewijne savannah type" on unbleached soils to be man-made, a result of repeated burning.

The most important soil forming processes are:

- Hydrolysis and leaching of silica and basic cations and consequent residual accumulation of quartz and sesquioxides
- Clay eluviation and illuviation
- Biological homogenization

The different characteristics of the bleached and unbleached soils are shown in Table 2.

Within the unbleached soils there are also differences in characteristics between the brown loams and the brown sands because of the higher clay and/or higher silt percentage of the loams. The brown sands have a very low fertility and poor physical properties, that is low available

### Table 2 Important differences in characteristics between the bleached and unbleached soils of the Zanderij Belt in Suriname

<table>
<thead>
<tr>
<th></th>
<th>Bleached soils</th>
<th>Unbleached soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>A horizon - colour</td>
<td>white</td>
<td>brown to yellow or reddish brown</td>
</tr>
<tr>
<td>A horizon - clay content</td>
<td>&lt;2 per cent</td>
<td>3-25 per cent</td>
</tr>
<tr>
<td>A horizon - organic matter</td>
<td>very low</td>
<td>low</td>
</tr>
<tr>
<td>B horizon - colour</td>
<td>dark brown to black hardpan</td>
<td>dark brown</td>
</tr>
<tr>
<td>B horizon - clay</td>
<td>very often higher content than the A horizon</td>
<td>very low</td>
</tr>
</tbody>
</table>
moisture and bad soil structure. The brown loams are better but their fertility is still low so they have a low availability of macro- and micronutrients and their cation exchange capacity and pH is low.

Melitz (1976) considers the well drained loamy soils, on level to slightly undulating plateaus, to be the best soils of the Zanderij Belt. Under forest these soils are permeable and provide a good supply of water and air to the plant roots. Goense (1987) estimated that the total area of this type of soil, suitable for agricultural purposes, to be about 157,500 ha.

Soil Management

As mentioned before the well-drained loamy soils on level to slightly undulating plateaus are the best soils of the whole Zanderij Belt and have in natural conditions very good physical and reasonable chemical properties.

After clearing and burning of the natural vegetation however, the circumstances in the neighbourhood of the soil change rapidly, especially the microclimate and bioclimate. As a result of this change surface sealing and compaction of the soil may become a great problem within a short period. Also the organic matter content may decrease because of a rapid decomposition of the material and subsequent leaching of several elements will take place.

Therefore it is very important that the soil is covered with a crop or that the fallow period is as short as possible. In the case of perennial crops it is necessary to use a cover crop, for example *Pueraria*, especially in the first years of planting when the soil lies fallow.

Bad soil tillage may also lead in several cases to a very fast fall-off of the soil structure and also of the crop yield. It is of the utmost importance to take special measures to retain the good physical properties.

Improving the chemical properties is also necessary, especially the cation exchange capacity, the pH and the availability of nutrients.

After years of investigation of mechanized farming on the well-drained loamy soils Goense (1987) concluded that these soils are not ideal for permanent mechanized annual rainfed crop cultivation for the following reasons:

- The waterholding capacity of 10-12 per cent is low and deep rooting is required to overcome periods of drought of even a week which are not unusual in the rainy season.

- Apart from fertilization with N, P and K, large amounts of lime are required on these acid soils at the appropriate depth.

- The soils have a poor structural stability and under a system of mechanized farming compaction occurs leading to an unfavorable environment for root growth.

References


no. 4, Netherlands Soil Survey Institute, Wageningen.


IMPROVEMENT OF SOIL FERTILITY ON ACID SANDY SOILS OF THE INTERMEDIATE SAVANNAHS OF GUYANA

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P. O. Box 272, Plymouth,
Monsterrat, W.I

Efforts directed toward agricultural development of the acid, infertile soils of the Intermediate Savannahs have been on-going for over 40 years. Initially livestock production was the sole objective, however, the easily mechanizable nature of these soils evoked interesting prospects for mechanizable field crop production. The soils have a low pH with free exchangeable Al and are inherently poor in CEC and exchangeable bases. P is low and is avidly fixed when supplemented. A fertility management technological package developed out of two decades of research and field experience, dictates that complete fertilization with major, secondary and micronutrients is essential for crop production. Judicious manipulation of fertilizer elements is vital to ensure well-balanced ratios, minimal losses from fixation and leaching, and efficient utilization by crops. Cost effectiveness of fertilizers based on soil reactivity and source of nutrients and other economic factors is a major consideration. The concept of soil fertility management within the wider context of soil and environmental management is discussed, and areas requiring more intensive research and investigation are identified.

The volume of scientific publications and the number of feasibility studies commissioned in relation to the agricultural development of the Intermediate Savannahs is legion. These reports, in most instances, are lying in Government offices, libraries and archives accumulating dust while the difficult and frustrating struggle to effectively conquer these vast tracts of acid sandy soils continues. A critical analysis of the nature of the various studies shows two distinctive trends.

Firstly, considerable emphasis was placed on soil chemistry and fertility in the development of primary technological packages to support agricultural development of this ecosystem. It is only quite recently that attention has been diverted to other important technological factors that also contribute significantly to the final productivity profile of the eco-system.

Secondly, the technology transfer process and other important developmental considerations have never been in step with technology development and adaptation, resulting in a high percentage of failure of new technology superimposed on the system. It is now generally accepted that the soil fertility problem is so integrally linked to the broader issue of soil and environmental management that a systems approach cast in an interdisciplinary mode is essential to dealing with it.

The ecosystem

Physical, geomorphological, topographic and climatic descriptions and characterizations of the Intermediate Savannah ecosystem can be found in numerous studies surveys and scientific papers. More recently a full description of the environment was done by Bullen et al (1981) in a publication dealing with the problems and constraints relating to the management of low fertility acid soils of the American humid tropics.
Location

The Guyana Intermediate Savannahs comprise approximately 3000 km² of sandy infertile soils located 58° W and 5° N. The area forms part of the White Sand Plateau which comprises old deltaic deposits of sands and clays interbedded with kaolinitic clay laterite and bauxite. White quartz sand predominates on the plateau surface with brown loamy and sandy clay sediment irregularly dispersed with the white sand. Topography is low, gentle and undulating. No markedly steep slopes occur, however in areas where natural vegetation has been removed soil erosion has resulted in severe gullying.

Climate is described as tropical humid with a mean annual rainfall of 2250 mm distributed bimodally. The long rainy season accounts for 40 - 60 per cent from mid-April to mid-August while about 20 per cent of the total comes in the highly unpredictable short rainy season from November to January. Mean annual temperature is 26°C. Highest temperatures are recorded from August to November with temperatures peaking in excess of 34°C. The early months of the year are coolest with a mean minimum of 20.8°C. The climatic pattern permits two rainfed cropping seasons per year, however the short rainy season is considered too unreliable for any large-scale cropping activity without irrigation.

The natural vegetation comprises primarily forest and shrub. Savannah areas comprise approximately 25 per cent of the total mix. The savannah vegetation is dominated by native grass Trachypogon plumosus and shrubby tree species (Curatella americana). The expanses of gently rolling grassed savannah are relieved by "bush islands" and forested strips along the wet depressed waterways and river beds.

Soils

Well-drained Ultisols, Oxisols and Entisols predominate. They are all coarse to medium textured, ranging from pure white quartz sand to yellowish red sandy clay. The three most predominant soil types and those of interest for arable cropping are identified below:

- Ebini sandy loam - Typic Paleudult - Brown Sand - 26,300 ha
- Kasarama loamy sand - Arenic Paleudult - Brown Sand - 56,000 ha
- Tabela sand - Typic Quartzipsamment - Brown Sand - 27,440 ha
- Tiwiwid sand - Typic Quartzipsamment - White Sand - 40,480 ha.

Physical and chemical characteristics of these soils are presented in Table 1.

The dominant features of these soils in relation to arable cropping are as follows:

- Low cation exchange capacity
- Low exchangeable bases dominated by Al
- Low available P with a capacity to fix applied P fertilizer
- Low pH
- Generally free-draining with low water retention capacity
- Good physical structure

Agricultural development of the Intermediate Savannahs

The history of agricultural development of the Intermediate Savannahs is well catalogued. The early thrust was focused on livestock development in the 1940s when nutritional problems were encountered with cattle being recuperated in transit from the long trek from the South Savannahs along the Rupununi cattle trail. Subsequently a livestock research station and ranch was established at Ebini on the east bank and about 150 km up the Berbice river. Efforts at introduction of improved...
Table 1  Characteristics of the four dominant kinds of soil in the Intermediate Savannahs area of Guyana

<table>
<thead>
<tr>
<th>Depth</th>
<th>Particle size</th>
<th>Org.</th>
<th>Kjeld</th>
<th>Exch</th>
<th>Exchange bases</th>
<th>Base</th>
<th>Truog</th>
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</thead>
<tbody>
<tr>
<td>cm</td>
<td>Sand</td>
<td>Silt</td>
<td>Clay</td>
<td>pH</td>
<td>C</td>
<td>N</td>
<td>acid</td>
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<tr>
<td>0-10</td>
<td>98</td>
<td>2</td>
<td>0</td>
<td>4.6</td>
<td>2.5</td>
<td>0.04</td>
<td>0.1</td>
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<tr>
<td>10-17</td>
<td>98</td>
<td>2</td>
<td>0</td>
<td>4.5</td>
<td>1.7</td>
<td>0.02</td>
<td>0.2</td>
</tr>
<tr>
<td>17-36</td>
<td>98</td>
<td>2</td>
<td>0</td>
<td>5.4</td>
<td>0.1</td>
<td>0.01</td>
<td>0.0</td>
</tr>
<tr>
<td>36-86</td>
<td>97</td>
<td>3</td>
<td>0</td>
<td>5.6</td>
<td>0.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>86+</td>
<td>97</td>
<td>3</td>
<td>0</td>
<td>5.9</td>
<td>0.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Tiwiwi sand (Typic Quartzipsamment; map unit 700)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-20</td>
<td>94</td>
<td>1</td>
<td>5</td>
<td>5.1</td>
<td>0.7</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td>20-51</td>
<td>86</td>
<td>2</td>
<td>12</td>
<td>5.2</td>
<td>0.3</td>
<td>0.03</td>
<td>0.2</td>
</tr>
<tr>
<td>51-91</td>
<td>86</td>
<td>5</td>
<td>9</td>
<td>5.3</td>
<td>0.3</td>
<td>0.02</td>
<td>0.1</td>
</tr>
<tr>
<td>91-122</td>
<td>87</td>
<td>3</td>
<td>10</td>
<td>5.2</td>
<td>0.2</td>
<td>0.01</td>
<td>0.3</td>
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<tr>
<td>Tabela sand (Typic Quartzipsamment; map unit 800)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-25</td>
<td>80</td>
<td>3</td>
<td>17</td>
<td>4.8</td>
<td>1.2</td>
<td>0.05</td>
<td>0.6</td>
</tr>
<tr>
<td>25-41</td>
<td>90</td>
<td>0</td>
<td>10</td>
<td>4.7</td>
<td>0.9</td>
<td>0.04</td>
<td>0.9</td>
</tr>
<tr>
<td>41-56</td>
<td>93</td>
<td>0</td>
<td>7</td>
<td>4.7</td>
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<td>0.05</td>
<td>0.7</td>
</tr>
<tr>
<td>56-86</td>
<td>82</td>
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<td>18</td>
<td>4.7</td>
<td>0.2</td>
<td>0.02</td>
<td>0.5</td>
</tr>
<tr>
<td>86-158</td>
<td>79</td>
<td>1</td>
<td>18</td>
<td>4.7</td>
<td>0.1</td>
<td>0.02</td>
<td>0.4</td>
</tr>
<tr>
<td>158-193</td>
<td>76</td>
<td>1</td>
<td>22</td>
<td>4.9</td>
<td>0.1</td>
<td>0.02</td>
<td>0.3</td>
</tr>
<tr>
<td>193+</td>
<td>65</td>
<td>4</td>
<td>31</td>
<td>5.0</td>
<td>0.3</td>
<td>0.02</td>
<td>0.3</td>
</tr>
<tr>
<td>Kasarama loamy sand (Arenic Paleudult; map unit 810)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>0-25</td>
<td>80</td>
<td>3</td>
<td>17</td>
<td>4.8</td>
<td>1.2</td>
<td>0.05</td>
<td>0.6</td>
</tr>
<tr>
<td>25-41</td>
<td>90</td>
<td>0</td>
<td>10</td>
<td>4.7</td>
<td>0.9</td>
<td>0.04</td>
<td>0.9</td>
</tr>
<tr>
<td>41-56</td>
<td>93</td>
<td>0</td>
<td>7</td>
<td>4.7</td>
<td>0.8</td>
<td>0.05</td>
<td>0.7</td>
</tr>
<tr>
<td>56-86</td>
<td>82</td>
<td>0</td>
<td>18</td>
<td>4.7</td>
<td>0.2</td>
<td>0.02</td>
<td>0.5</td>
</tr>
<tr>
<td>86-158</td>
<td>79</td>
<td>1</td>
<td>18</td>
<td>4.7</td>
<td>0.1</td>
<td>0.02</td>
<td>0.4</td>
</tr>
<tr>
<td>158-193</td>
<td>76</td>
<td>1</td>
<td>22</td>
<td>4.9</td>
<td>0.1</td>
<td>0.02</td>
<td>0.3</td>
</tr>
<tr>
<td>193+</td>
<td>65</td>
<td>4</td>
<td>31</td>
<td>5.0</td>
<td>0.3</td>
<td>0.02</td>
<td>0.3</td>
</tr>
<tr>
<td>Ebini Sandy loam (typic Paleudult; map unit 820)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-8</td>
<td>57</td>
<td>6</td>
<td>37</td>
<td>4.3</td>
<td>2.8</td>
<td>0.16</td>
<td>1.6</td>
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<tr>
<td>8-31</td>
<td>56</td>
<td>6</td>
<td>38</td>
<td>4.4</td>
<td>2.2</td>
<td>0.11</td>
<td>1.7</td>
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<tr>
<td>31-41</td>
<td>48</td>
<td>6</td>
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<tr>
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<td>52</td>
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<td>0.06</td>
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<tr>
<td>76-91</td>
<td>43</td>
<td>8</td>
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<td>4.9</td>
<td>0.6</td>
<td>0.05</td>
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</tr>
<tr>
<td>91-122</td>
<td>44</td>
<td>12</td>
<td>44</td>
<td>4.9</td>
<td>0.7</td>
<td>0.03</td>
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</tr>
</tbody>
</table>

pasture species to replace the native Andropogons and Trachypogons met with initial success, but later on soil nutrient problems emerged as a major limiting factor to productivity.

Subsequent efforts at agricultural commercialization and diversification away from livestock production further emphasized the critical nature of the soil fertility status of these easily mechanizable brown sandy soils. The work of Chesney (1973; 1979), Downer (1972), Fletcher (1980) and Dookie (1981) laid the groundwork for the resolution of some of the more fundamental problems. Practical application of the technological packages generated to support agricultural commercialization made it clear that the heavy bias that was placed on soil fertility to the virtual exclusion of other critical factors like soil management proved detrimental. Table 2 presents a summary of commercial activities embarked on in the Intermediate Savannahs over the past two decades.

If a study is done on the history, evolution and subsequent fate of the development activities listed in Table 2, a very interesting trend develops.

- Activities that are livestock oriented or have a heavy livestock bias tend to persist and be sustained inspite of the prevailing adverse circumstances.

- Crop-specific development activities have had a high record of failures.

- There has been little effort at serious integration of crop and livestock enterprises, nor has there been any significant success in vertical integration of enterprises.

- Private enterprise occupies a low berth in the entire developmental scenario of the Intermediate Savannahs.

- Organizational, management and logistic factors have surfaced as major constraints to development and have also imposed considerable restriction on the application and use of new technology.

Soil fertility management

The technology currently being applied to soil fertility management of the Intermediate Savannah soils is based on the pioneering work done by Wagenaar, Chesney, Fletcher, Downer and others from the early 1960s and to the present (see Chesney and Gordon, 1973) The major considerations of inherently low soil pH with high levels of exchangeable Al and a propensity for rapid fixation of applied fertilizer P have dictated the character of the regimes currently in use. While there may be variations in levels, timing and source of nutrients in relation to the particular crop and production system (Table 3), the basic technological package can be summarized as follows:

Correction of soil pH

Both dolomitic and calcitic limestone have been used commercially. Dolomite was favoured initially because of its Mg content, however the cost-effectiveness of this ameliorant was shown to be negative when compared with standard grade calcitic limestone plus fertilizer Mg. It is now known that dolomitic limestone does not fully satisfy the Mg requirements and is too slowly available; especially for annual and orchard crops, when used at the recommended rate for correction of soil pH. Supplementary fertilization with more available forms of Mg is therefore necessary. Earlier recommendations that suggested rates of liming ranging from 1500 to 2000 kg per ha calcitic or dolomitic limestone have been
Table 2  Summary of commercial activity in the Intermediate Savannahs of Guyana from the 1960s to date

<table>
<thead>
<tr>
<th>Period</th>
<th>Project/Agency*</th>
<th>Description</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969/1976</td>
<td>Kibilibiri Project GOG - MOA</td>
<td>800 ha; corn, soya, legumes</td>
<td>Terminated mid-1970s</td>
</tr>
<tr>
<td>1973/1984</td>
<td>GNS Cotton Project GOG - GNS</td>
<td>Up to 1200 ha; cotton and cowpea</td>
<td>Scaled down, cotton out</td>
</tr>
<tr>
<td>1976/1981</td>
<td>CARICOM Corn and Soyabean Project GOG/CARICOM</td>
<td>Up to 800 ha; corn, sorghum, cowpea, pigeon pea</td>
<td>Terminated 1982</td>
</tr>
<tr>
<td>1960/1988</td>
<td>Ebini cattle ranch LIDCO/GOG</td>
<td>2000 ha; beef and dairy, semi-intensive</td>
<td>On-going, longest surviving</td>
</tr>
<tr>
<td>1975/ date</td>
<td>Mobilissa Project LIDCO/GOG</td>
<td>Diary farm</td>
<td>On-going since 1974</td>
</tr>
<tr>
<td>1986/ date</td>
<td>NEOCOL Soya Company GOG-GNS/GNTC /NEOCOL</td>
<td>120 ha in 1988, (1200 ha projected in 1990); soyabean, cowpea</td>
<td>Recently initiated</td>
</tr>
<tr>
<td>1983/1988</td>
<td>Cassava Dubulay. Private Company.</td>
<td>80 ha; cassava, soyabean for livestock</td>
<td>Scaled down—foreign exchange availability</td>
</tr>
<tr>
<td>1965/ date</td>
<td>Waranama ranch. Private</td>
<td>Beef, sheep</td>
<td>On-going, scaled down</td>
</tr>
</tbody>
</table>

* CARICOM  Caribbean Community  
GOG-MOA  Government of Guyana - Ministry of Agriculture  
GNS  Guyana National Service  
GNTC  Guyana National Trading Corporation  
NEOCOL  National Edible Oil Company Limited
Table 3  Recommended fertilizer practices for animal and crop production on the Intermediate Savannahs of Guyana

<table>
<thead>
<tr>
<th>Fertilizer practice</th>
<th>Animals/Crops</th>
<th>Pastures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial liming to pH 5.8/6.0</strong></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Split applications of limestone</strong></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Spot application of phosphate</strong></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Broadcasting high P compound fertilizer</strong></td>
<td>op</td>
<td>*</td>
</tr>
<tr>
<td><strong>Broadcasting trace element &quot;shot-gun&quot; mix</strong></td>
<td>op</td>
<td>op</td>
</tr>
<tr>
<td><strong>Spot application of compost or pen manure</strong></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Row drilling NPK Mg + trace element mix</strong></td>
<td>*</td>
<td>x</td>
</tr>
<tr>
<td><strong>Broadcasting of NPK Mg + trace element mix</strong></td>
<td>op</td>
<td>*</td>
</tr>
<tr>
<td><strong>Top-dressing of NPK Mg</strong></td>
<td>*</td>
<td>op</td>
</tr>
<tr>
<td><strong>Top-dressing of N only</strong></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Spot applications of trace element mix</strong></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Side-dressing of NPK Mg</strong></td>
<td>*</td>
<td>x</td>
</tr>
<tr>
<td><strong>Foliar applications of complete fertilizer</strong></td>
<td>*</td>
<td>x</td>
</tr>
</tbody>
</table>

* = recommended  x = not recommended  op = optional

Modified subsequently (Fletcher, 1981) based on more in-depth studies done in commercial fields representing the three major soil types.

Experience has shown that the normal period for reliming is 1.5 to 2 years or 3 to 4 cycles of annual cropping. It is now clear from field monitoring and analyses done at the CARICOM Corn and Soyabean Project site at Eberoabo that subsequent applications of limestone must be adjusted (reduced) in accordance with soil pH status, base saturation and K, Ca, Mg ratios. Overliming of commercial fields is highly probable in the absence of strict monitoring. Adverse consequences (not specifically demonstrated to date) include induced deficiencies of trace elements and dominance of Ca in the exchange complex resulting in K and Mg deficiencies.

Depth of placement of liming material is extremely important. Fletcher (1981) stressed the importance of deep incorporation of limestone down to at least 30 cm for equitable soil pH amelioration. This recommendation has implications for tillage and mechanization practices, however the consequences of poor lime incorporation and uneven distribution down the profile are seen as unthrifty and resulting in uneven growth of
plants, shallow rooting and as a consequence lower drought-tolerance. Bullen (personnel communication; circa 1985), subsequently designed a liming regime that required half of the total amount to be applied before ploughing and the balance prior to final harrowing. This would seem to adequately address the problem of irregular distribution, but it should be monitored over time especially in relation to reliming of previously limed and cultivated soils.

**K, Ca, Mg interactions**

A study of the secondary element status of soils under cultivation done by Fletcher (1980; 1981), at the CARICOM Corn and Soyabean Project at Eberoabo, showed that soils with good base saturation (90 - 100 per cent) tended to be dominated by Ca on the exchange complex. This condition results in imbalances which create disproportionate Ca/Mg and Mg/K ratios. Where Ca/Mg ratios are excessively high, there has been a tendency toward extraordinarily low Mg/K ratios; usually a danger signal for Mg deficiency. In Table 4 some actual secondary element values are presented to demonstrate the wide variability in these ratios.

A very delicate relationship exists between pH, exchangeable acidity and the secondary element ratios. The low CEC and buffering capacity of these soils justifies this relationship and suggests that any fertility management programme must have as a primary objective, the maintenance of an equitable balance between available Ca, Mg and K on the exchange sites. Just as essential is the design of a well-balanced fertilizer regime to supply adequate levels of the above elements. Such a regime must pay attention to the following:

- Thorough incorporation of lime down to at least 30 cm.
- Split applications of K and Mg during the crop cycle.
- Use of proper K and Mg ratios in the fertilizer regime.
- Use of dolomitic limestone only if cost effectiveness related to pH adjustment can be established.
- Preference for the use of potassium-magnesium sulphate (KMag) for both K and Mg fertilization.

**P fertilization**

Initial soil fertility investigations (Wagenaar, 1964) recognized P as a major limiting factor to crop production. P levels in the native soils rarely exceed 6 ppm. Generally however, P status of the heavier textured Ebini sandy loam tends to be higher. The soils are also known to be notorious fixers of applied fertilizer. This implies that applied P is held in the upper profile and can be released subsequently. Such a situation will not favour annual and short-term cropping in the same manner as it would long-term systems — e.g. pastures and orchard crops. The extent to which fertilizer P is fixed and made immobile is exemplified by soil test data from fields under sequential annual cropping at the CARICOM Corn and Soyabean Project. A full dossier of the cropping history on the fields under reference is not available for a more complete comparison, however the data in Table 5 suggest that the labile pool of P increases with fertilization and is available through a slow release mechanism to subsequent crops. Evidence also suggests (Chesney, 1979) that movement of applied fertilizer P down the soil profile is negligible. One can therefore logically assume that high levels of available P in the 15-30 cm horizon and lower must have come about as a result of mechanical soil manipulation.
Table 4  Soils analytical data from selected fields at the CARICOM Corn and Soyabean project, Eberoabo, illustrating the wide variability in secondary element ratios

<table>
<thead>
<tr>
<th>Field No.</th>
<th>Sampling depth (cm)</th>
<th>Ca/Mg</th>
<th>Mg/K</th>
<th>Base Satn.</th>
<th>Exch. Acidity</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline value</td>
<td></td>
<td>5.0</td>
<td>3.0</td>
<td>100</td>
<td>0</td>
<td>5.80</td>
</tr>
<tr>
<td>B 14/3</td>
<td>0-15</td>
<td>13.5</td>
<td>2.3</td>
<td>99</td>
<td>0.02</td>
<td>5.14</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>10.0</td>
<td>1.3</td>
<td>74</td>
<td>0.43</td>
<td>5.11</td>
</tr>
<tr>
<td>B 14/1</td>
<td>0-15</td>
<td>9.2</td>
<td>1.3</td>
<td>90</td>
<td>0.14</td>
<td>5.12</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>20.0</td>
<td>0.4</td>
<td>46</td>
<td>0.56</td>
<td>5.04</td>
</tr>
<tr>
<td>S4</td>
<td>0-15</td>
<td>25.7</td>
<td>1.8</td>
<td>95</td>
<td>0.11</td>
<td>5.49</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>22.5</td>
<td>1.3</td>
<td>84</td>
<td>0.19</td>
<td>5.14</td>
</tr>
<tr>
<td>C1</td>
<td>0-15</td>
<td>4.3</td>
<td>1.8</td>
<td>96</td>
<td>0.23</td>
<td>5.24</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>4.0</td>
<td>0.8</td>
<td>60</td>
<td>0.21</td>
<td>5.17</td>
</tr>
<tr>
<td>A/3</td>
<td>0-15</td>
<td>3.6</td>
<td>2.0</td>
<td>79</td>
<td>0.23</td>
<td>5.27</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>4.4</td>
<td>1.1</td>
<td>38</td>
<td>0.38</td>
<td>5.07</td>
</tr>
<tr>
<td>B 12</td>
<td>0-15</td>
<td>8.5</td>
<td>1.4</td>
<td>97</td>
<td>0.08</td>
<td>5.14</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>8.3</td>
<td>1.1</td>
<td>80</td>
<td>0.31</td>
<td>5.11</td>
</tr>
</tbody>
</table>

Table 5  Available P in selected cultivated fields at the CARICOM Corn and Soyabean Project (1979/1981)

<table>
<thead>
<tr>
<th>Field</th>
<th>Native soil</th>
<th>B14/3 Extractable P (Truog) in ppm.</th>
<th>B14/1</th>
<th>S4</th>
<th>C1</th>
<th>A13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-15 cm</td>
<td>6</td>
<td>29</td>
<td>40</td>
<td>14</td>
<td>5</td>
<td>27</td>
</tr>
<tr>
<td>15-30 cm</td>
<td>7</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

E.g. deep ploughing or chisel placement.

In another series of samplings in which limited information was available on previous soil and crop history, a general conclusion was drawn (Fletcher, 1981) that the labile P pool in certain fields had increased to the point of adequacy and that caution was necessary in further P fertilization, especially having regard to the possibility of P/Zn interaction and antagonism. Table 6 summarizes available P data obtained from two locations. The first location comprised six fields, five of which had had blackeye pea as the last crop; the last crop on the other one had been maize.
Table 6  Comparison of available P levels of selected fields under various cropping regimes at the CARICOM Corn and Soyabean Project - Eberoabo

<table>
<thead>
<tr>
<th>Field No.</th>
<th>1*</th>
<th>2*</th>
<th>3*</th>
<th>4*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extractable P (Truog) in ppm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sampling depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - 15 cm</td>
<td>6</td>
<td>27</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>15 - 30 cm</td>
<td>10</td>
<td>14</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

* Cropping regimes: 1 - Corn followed by 18 months fallow
2 - Blackeye pea followed by 12 months fallow
3 - Sorghum, main crop + ratoon (16 months)
4 - Pigeon pea, main crop + ratoon (15 months)

These fields were all fallow for a period of 12 - 15 months at which time they were ploughed and sampled. The second location comprised fields in which either sorghum or pigeon pea ratoon crops existed for a total duration of at least 12 months.

While fields under ratoon sorghum returned lower levels of available P than the fields with the blackeye/fallow rotation it was notable that CEC levels and base saturation were consistently higher under continuous sorghum cover. It is clear that fertility benefits must accrue from maintenance of a continuous cover on the land between seasons, and the role of such a cultural practice in the dynamics of P chemistry should be further investigated.

The recommended sources of P are Triple Superphosphate and Diammonium Phosphate. There is no conclusive evidence that Rock Phosphate has any advantage over the high analysis types. The slow release characteristic causes P to be made too slowly available for annual crops. Cost effectiveness per unit of P even when it is used for pastures and orchard crops is also questionable. The low analysis Single Superphosphate provides addition sulphur, however cost effectiveness per unit of P again comes into question. The primary source of sulphur would be KMag (potassium magnesium sulphate)

Micronutrients

Recommendations for trace element fertilization of the Intermediate Savannah soils have been developed by pooling the research information generated over the past 20 years with experiences derived from scientific work done in similar agro-ecosystems. Soil analytical data and field trials have confirmed that zinc, manganese and copper are acutely deficient in the native savannahs, and must be supplemented through fertilization. In the early days when beef ranching was the sole enterprise little attention was paid to micronutrient fertilization of pastures because of the availability and use of mineral licks. Subsequently it was demonstrated by Wagenaar (1964), and others that use of a micronutrient mix was essential in the production of all crops.

More recent work done by Walmsley (unpublished) has identified Zn as being deficient. Significant increases in leaf tissue concentrations of Zn were measured when zinc sulphate was added to microplots with maize as the test crop. This study also identified micronutrient interactions but fell short of determining and quantifying the effects of such interactions and antagonisms. The study also suggested that Cu may be a limiting factor to crop production. However in a subsequent field experiment at Ebini testing the effect of soil and foliar applications of B, Cu and Zn on maize, Cu depressed yields but both B and especially Zn,
increased yields. The difficulty of laboratory analysis of B leaves this element in doubt, however B is included in all micronutrient formulations applied to these soils.

A survey of micronutrient levels in soils under various crop regimes at the CARICOM Corn and Soyabean Project at Eberoabo shows a wide variation in extractable or available levels of Zn, Cu and Mn. Table 7 compares four scenarios:

- Unfertilized soil
- Midway in the crop (50 days - blackeye pea/maize)
- After 12 months of fallow following a blackeye pea crop
- After 6 months of fallow following a ratoon crop of sorghum.

It should be noted that the quantities of micronutrient fertilizer applied in each specific case would have depended on the number of cropping cycles and would probably have been based on a recommended dosage of 25 kg per ha FTE503.

The monitoring of micronutrient levels in the soil must be a routine prerequisite to micronutrient fertilization. While the FTE micronutrients have played a vital role in the soil fertility management programme, one should be aware of the probability of changes in status of the individual elements over time, and also the effect of heavy and repeated applications of primary fertilizer elements on the micronutrient balance. Consideration must also be given to the use of chelates and to foliar applications as an alternative or an adjunct to soil dressings.

**Nitrogen fertilization**

The technology for fertilization of crops with inorganic forms on N is well known and has been practised successfully over the years. Discussion on N fertilization will therefore be confined to addressing the prospects of legume seed inoculation with appropriate strains of *Rhizobium japonicum*.

<table>
<thead>
<tr>
<th>Cropping regime*</th>
<th>Sampling depth (cm)</th>
<th>Extractable micronutrients (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zn</td>
<td>Cu</td>
</tr>
<tr>
<td>1</td>
<td>0-15</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>0.1</td>
</tr>
<tr>
<td>2</td>
<td>0-15</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>0.9</td>
</tr>
<tr>
<td>3</td>
<td>0-15</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>1.1</td>
</tr>
<tr>
<td>4</td>
<td>0-15</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*1 unfertilized soil
2 midway in a crop of blackeye pea/maize
3 after 12 months of fallow following a crop of blackeye pea
4 after 6 months of fallow following a ratoon crop of sorghum
The intense interest in the use of commercial rhizobial cultures for legume (cowpea, soyabean, peanut) seed inoculation was sparked in the early and mid-1970s primarily by the involvement of the International Soyabean Programme (INTSOY) in soyabean work in the Intermediate Savannahs and other coastal and hinterland locations in the country. (INTSOY, 1975). Nodulation and nitrogen fixation have both been demonstrated in commercial plantings of both food and pasture legumes when inoculation was done. Native strains of inoculum specific to certain ecotypes have also been identified.

During the 1970s a semi-commercial facility to produce legume inoculant was developed within the Crop Science Division of the Ministry of Agriculture. Standard microbiological techniques were employed to culture and produce adaptable strains of Rhizobium. Peat obtained from deposits behind the coastal area is being used as a carrier. Currently the facility has the capacity to provide inoculant for 900 ha, based on a two-season year. Approximately half of this amount is allocated to cowpea and half to soyabean. If there is to be a significant expansion of the cultivated acreage of legumes on these inherently infertile soils, then it would be necessary to expand the capacity of this unit accordingly. It is anticipated that forage legumes will play a significant role in the synthesis and availability of nitrogen in cropping systems involving livestock.

An integrated approach to soil fertility management

After decades of research and commercial agricultural activity in the Intermediate Savannahs, it is now being slowly and grudgingly accepted that production systems oriented toward monoculture or straight crop or livestock systems is not the ideal approach to optimizing productivity and investment. The TAMS (1976) Intermediate Savannahs Report attempts to address the concept of an integrated development approach based on a crop/livestock enterprise model. In this proposal, the major agronomic considerations revolve around a beef/feedlot, grain and legume enterprise with the following features:

- A combination of open range and improved pastures with associations of grasses and legumes.
- A feedlot finishing programme linked to the cereal/legume crop enterprise.
- Long-term crop/livestock rotational systems to improve and sustain fertility status of the land.
- Contour farming and strip cropping.
- Use of green manure technology to enhance soil fertility.

The same group of consultants however proposed another enterprise — the Wiruni Cornsoyabean Farm which, in their conclusion, is deemed as not economically feasible without a livestock component. In these studies, as well as one done earlier by Hooker (1973) there seems to be only superficial consideration given to the technology of soil management. No bold or imaginative proposals have been put forward, rather, consideration was only given to technology being tested by local researchers at that point in time.

It is now patently obvious that when the main technological components of a feasible commercial enterprise are assembled, soil fertility management will be conditioned by the following:

- Systems and methods of land preparation.
- Soil conservation techniques.
- Enterprise components and types of crop and livestock.
- Proper use of rotations involving crops and livestock.
- More innovative weed control techniques and mechanisms.
- Appropriate sources of fertilizing materials and proper timing of applications.
- Close monitoring of changes in soil fertility status and concomitant adjustments in fertilizer regimes.
- Astute field management and decision making.

Some of these elements are gradually finding their way into existing commercial systems. For example, the Livestock Development Company (LIDCO) has attempted cropping of selected pastures at Ebini with maize or grain legumes prior to renovation. Satellite farmers at Mobilissa have also embarked on crop enterprises (peanut) to complement their milk production activities.

Conclusions and recommendations

Over the past five years it would appear that the emphasis on soil fertility research related to the Intermediate Savannah ecosystem has been gradually reduced. This situation may, among other reasons, have been caused by the organizational and logistic difficulties that have plagued developmental efforts and constrained technology applicability. Commercial activity is however on-going and it is only logical that scientific investigations should continue to support such development. Planners must also consider the vast array of information and technology available from other sources worldwide that may have some applicability to the current situation once the appropriate modifications have been made.

The past quarter of a century of research in the Intermediate Savannahs has increased substantially our knowledge of the nature and properties of these soils. Based on available information and on the current status of development activities it would seem that particular emphasis should continue to be placed in the following broad areas of research and development.

Soil management
- Contour cultivations, strip cropping and crop rotations.
- Tillage implements and depth of cultivation.
- Conservation tillage techniques.

Soil chemistry
- Further study of the major exchangeable bases (K, Ca, Mg) and their interactions on the exchange complex.
- Monitoring of P fixation, release and accumulation.
- More detailed studies on micronutrient fertilization.
- Studies on the efficiency of various fertilizer sources of plant nutrients, for example: P, K, Mg, N, micro-nutrients, liming agents.

Agronomy
- Effect of crop rotations on soil fertility - involving both crop and animal systems.
- Rooting depth of crops and soil moisture availability as it relates to depth of placement of fertilizers and depth of tillage.
- Use of foliar fertilizers.
- Weeds and their relation to fertility status.

Management and agro-economics
- Cost-effectiveness of using various fertilizing materials.
- A more comprehensive integration of soil fertility management techniques into the overall production system.
- Streamlining management of field operations to permit proper and timely application of technology.

- Proper record keeping.

References


Hooker, P.J. (1973) A preliminary study of the economic potential for beef, cattle, grain and legume seed production in the Intermediate Savannahs of Guyana using a linear programming model. IFAS, University of Florida, Gainesville, USA.


SOME ASPECTS OF SOIL PHYSICAL CHARACTERISTICS
AND THEIR MANAGEMENT IN THE INTERMEDIATE
SAVANNAHS OF GUYANA

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Guyana

Details of the soil physical characteristics of the major brown sand soils of the Intermediate Savannahs of Guyana along with the prevailing climatic regime of the area are presented. From these, the constraints to crop production are predicted and several criteria for the successful utilization of these soils are developed. Various soil management systems used in the humid tropics are then discussed in relation to their ability to meet the criteria for the Brown sands. In conclusion the utilization of the soil and climatic data for developing soil/crop management systems for the Intermediate Savannahs is discussed.

The Intermediate Savannahs are located in north-eastern Guyana immediately behind the Coastal Plains. They extend in a south-westerly direction on both sides of the Berbice River to the upland rain forest regions and cover a total area of approximately 270,000 ha. The meeting of meridian 58° West longitude and the line of latitude 5° 30' North approximates the geographical centre of the Intermediate Savannahs. The area is characterized by forests, scrub vegetation and grasslands with few scattered trees. This last is the true savannah. Aside from a number of small pockets of grassland, there are five main bodies of extensive savannah incuding 59,000 ha of true savannah with 38 different soil types, called both "White Sands" and "Brown Sands". There are about 42,000 ha of brown sand soils with a relatively high potential for agricultural development (Bullen et al., 1982). The White Sands are unsuitable for agricultural development.

The savannahs have a high potential for development due to the relatively low level of infra-structure needed to bring the land under cultivation. On the coast of Guyana, any land development scheme requires the implementation of intensive drainage and irrigation systems to ensure adequate water management for the lands which are below the level of the high tide. Even more important is the maintenance of these elaborate canals, sluices and drainage pumps which is extremely costly.

Such infra-structure is not necessary for the development of the lands of the Intermediate Savannahs. The major hindrances to the development of the area are its relative inaccessibility, the infertile soils compared to the more fertile coastal soils, the uneven and unpredictable rainfall pattern and the propensity of the soils to erosion.

The Government of Guyana views the Intermediate Savannahs as an important area in which large-scale agricultural production will be promoted. In pursuance of this policy three large-scale crop production projects were started during the last 20 years. In addition, there has been the continually expanding cattle operations of the Livestock Development Company (LIDCO).

All but one of the large-scale crop production projects have been discontinued. The reasons for the discontinuation have been varied—they have ranged from economic to technical. The technical or agronomic
reasons are unreliability of the rainfall, low soil fertility, high soil acidity, soil erosion and pest and disease problems including the influx of noxious weeds with continuous cultivation. The technical package available for the production of row crops in the ecozone can give technically acceptable yields. However, there needs to be a refining of this package to sustain the yields, while maintaining or enhancing soil fertility. To achieve this, various tillage, crop and land rotation systems have been considered, but these are still being assessed. This presentation seeks to detail some of the soil physical characteristics and related management practices that are likely to improve and sustain crop production in the savannahs.

Soils

The focus of this paper will be on the Brown Sands which are the most extensive, best suited for agricultural development and have been more extensively studied than the other soil types occurring in the ecozone. The Brown Sands include the Ebini sandy loam (Mapping unit 820), Kasarama loamy sand (Mapping unit 810) and the Tabela sand (Mapping unit 800). These soils have been classified by Granger and Khan (1983). The first two were classified as Typic Paleudults and the third as a Typic Quartzipsamment. Khan (personnel communication, 1988) in his survey of the Ebini Crop Station also recognized Kairuni loamy sand (Mapping unit 815) and Budharana loamy sand (Mapping unit 816). These two soil types which were formerly included with the Kasarama loamy sand, have been classified as Arenic Paleudult and Grosarenic Paleudult respectively.

Particle size distribution

Table 1 gives the particle size distribution of typical soil profiles of the five differentiated brown sand soils. These data show a range of clay content from 52 per cent in the 41-76 cm depth of the Ebini sandy loam to 4 per cent in the surface soil of the Tabela sand. The sand content ranged from 93 per cent in the 46-84 cm depth of the Tabela sand to 40 per cent in the 41-76 cm depth of the Ebini sandy loam. The silt content of the soils was more uniform with a range from 1 per cent in the top soil of Bukharana loamy sand to 20 per cent in the 135-203 cm depth of the Kasarama loamy sand. In general, clay content increased down the profile, while sand content decreased. The Ebini sandy loam showed the highest clay content of all the soils, an important factor in its productivity and management.

Water holding capacity

Table 2 gives water held in the three originally named brown sand soils at various soil water suction levels (Ah Chu, 1973). At the low suction of 3.5 cm of water, all the soils had adequate levels of soil moisture (>30 per cent volumetric soil moisture content). Natural drainage is considered to be equivalent to a water suction of approximately 330 cm depending on the soil type. The indications are that after natural drainage the Ebini sandy loam would have a mean soil moisture content of 27.03 per cent while the Tabela sand would have a mean moisture content of only 8.66 per cent. The mean moisture content of the Kasarama loamy sand would be 19.94 per cent. Available water is normally defined as the difference in the amount of water held by the soil against drainage and the water in the soil when plants wilt permanently.
### Table 1
Particle size distribution of the five soil types from the Intermediate Savannahs of Guyana

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ebini sandy loam</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - 8</td>
<td>57</td>
<td>6</td>
<td>37</td>
</tr>
<tr>
<td>8 - 31</td>
<td>56</td>
<td>6</td>
<td>38</td>
</tr>
<tr>
<td>31 - 41</td>
<td>48</td>
<td>6</td>
<td>46</td>
</tr>
<tr>
<td>41 - 76</td>
<td>40</td>
<td>8</td>
<td>52</td>
</tr>
<tr>
<td>76 - 91</td>
<td>43</td>
<td>8</td>
<td>49</td>
</tr>
<tr>
<td>91 - 122</td>
<td>44</td>
<td>12</td>
<td>44</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Kairuni loamy sand</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 18</td>
</tr>
<tr>
<td>18 - 30</td>
</tr>
<tr>
<td>30 - 57</td>
</tr>
<tr>
<td>57 - 70</td>
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<tr>
<td>70 - 97</td>
</tr>
<tr>
<td>97 - 127</td>
</tr>
<tr>
<td>127 - 193</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Bukharana loamy sand</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 23</td>
</tr>
<tr>
<td>23 - 53</td>
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<tr>
<td>53 - 67</td>
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<td>67 - 91</td>
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<td>91 - 124</td>
</tr>
<tr>
<td>124 - 178</td>
</tr>
<tr>
<td>178 - 203</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Kasarama loamy sand</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 13</td>
</tr>
<tr>
<td>13 - 25</td>
</tr>
<tr>
<td>25 - 48</td>
</tr>
<tr>
<td>48 - 71</td>
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<td>71 - 89</td>
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<td>89 - 112</td>
</tr>
<tr>
<td>112 - 135</td>
</tr>
<tr>
<td>135 - 203</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Tabela sand</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 28</td>
</tr>
<tr>
<td>28 - 46</td>
</tr>
<tr>
<td>46 - 61</td>
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<tr>
<td>61 - 84</td>
</tr>
<tr>
<td>84 - 145</td>
</tr>
<tr>
<td>145 - 203</td>
</tr>
</tbody>
</table>
Table 2  Percent moisture retained at different tensions, bulk density (BD), particle density (PD), total pore space, hydraulic conductivity and available water of brown sand soils.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Water suction (cm of water)</th>
<th>Available water (%)</th>
<th>B.D (g/cm³)</th>
<th>P.D (cm/h)</th>
<th>Total Hydraulic conductivity (cm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Moisture</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>36.92, 33.57, 30.23</td>
<td>27.57, 25.90, 24.70</td>
<td>10.14</td>
<td>12.71</td>
<td>1.56, 2.65, 41.13</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>23-58</td>
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<td></td>
</tr>
<tr>
<td>150</td>
<td>38.20, 33.76, 30.07</td>
<td>27.47, 25.92, 25.04</td>
<td>13.30</td>
<td>10.53</td>
<td>1.47, 2.53, 43.24</td>
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<tr>
<td>345</td>
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<tr>
<td>108-146</td>
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<td>146-188</td>
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<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38.78</td>
<td>35.50, 32.57, 30.46</td>
<td>29.13, 29.16, 27.03</td>
<td>15.47</td>
<td>11.60</td>
<td>1.47, 2.60, 43.64</td>
</tr>
</tbody>
</table>

Ebini sandy loam

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Water suction (cm of water)</th>
<th>Available water (%)</th>
<th>B.D (g/cm³)</th>
<th>P.D (cm/h)</th>
<th>Total Hydraulic conductivity (cm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9</td>
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<td></td>
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<tr>
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<td>25-36</td>
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<td>36-56</td>
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</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33.51</td>
<td>30.56, 26.12, 23.22, 23.69</td>
<td>21.05, 1.95, 9.03</td>
<td>10.91</td>
<td>1.57, 2.65</td>
<td>40.70, 3.86</td>
</tr>
</tbody>
</table>

Kasarama loamy sand

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Water suction (cm of water)</th>
<th>Available water (%)</th>
<th>B.D (g/cm³)</th>
<th>P.D (cm/h)</th>
<th>Total Hydraulic conductivity (cm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13-25</td>
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<td>25-36</td>
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<td>36-56</td>
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<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34.67</td>
<td>24.65, 15.89, 12.64, 10.60</td>
<td>9.73, 8.66, 3.55</td>
<td>5.11</td>
<td>1.52, 2.65</td>
<td>42.47, 38.62</td>
</tr>
</tbody>
</table>

Table 1a sand

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Water suction (cm of water)</th>
<th>Available water (%)</th>
<th>B.D (g/cm³)</th>
<th>P.D (cm/h)</th>
<th>Total Hydraulic conductivity (cm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-36</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>36-56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34.67</td>
<td>24.65, 15.89, 12.64, 10.60</td>
<td>9.73, 8.66, 3.55</td>
<td>5.11</td>
<td>1.52, 2.65</td>
<td>42.47, 38.62</td>
</tr>
</tbody>
</table>

Source: Ah Chu (1973)
The difference in percentage moisture between 345 cm and 1500 cm water suction is probably a good index of this available water and the values are presented in Table 2. Ebini sandy loam showed highest "available water" while Tabela sand showed the lowest. There was a marginal difference between the available water in Ebini sandy loam and the Kasarama loamy sand.

Fig 1 gives a graphic representation of the water holding capacity of the upper layers (0-20 cm and 20-50 cm) of the five soil types under consideration.

Hydraulic conductivity

The hydraulic conductivity data (Table 2) for the three soil types indicate a relatively lower level of 2.13 cm/h for the Ebini sandy loam compared to the other two soil types. Hydraulic conductivity was particularly high in the Tabela sands (34.62 cm/h). This indicates the free-draining nature of the Tabela sands and their inability to hold enough water for plant growth.

Porosity

Table 2 also gives the total pore space of the soils down the profile. These data indicate very little differences between the three soil types and the pore space is adequate for crop growth provided there is equal distribution between capillary and non-capillary pores. Table 3 gives the total capillary and non-capillary porosity for the upper horizons (0-20 cm and 20-50 cm) of the five soils. The non-capillary porosity, which is a measure of the soil aeration, indicated that the Tabela sand was the best aerated, while the Ebini sandy loam was the least aerated. The reverse is true for capillary porosity, which is a measure of the water holding capacity of the soils. These data confirm those previously given on the water holding capacity of these soils.

Bulk density

Bulk density measurements for three brown sand soils are given in Table 2. Bulk density is normally a measure of the soil structure or degree of compacting in clay soils. In the sandy soils of the Intermediate Savannahs, where compaction is not a big problem, there was no difference in total porosity measurements and similarly no differences in bulk density between the soils.

Topography

The topography of the Intermediate Savannahs is generally referred to as gently undulating (Bullen et al., 1982). This indicates that slopes are not steep and if water runoff occurs it is likely to be slow and not too erosive. The FAO (1965) report describes the soils as gently undulating to undulating with slopes of 1-3 per cent in the lower limit and 5-8 per cent in the higher limit.

Erodibility indices

In developing the universal soil loss equation Wischmeier related soil loss due to water erosion to various factors. Generally this equation is given as:

\[ A = R K L S C P \]

where:

A = Soil loss in tons/acre/yr.
R = Erosivity of the rainfall
K = Erodibility of the soil
L = Length of slope factor
S = Steepness of slope factor
C = Cultural practices factor
P = Physical practices factor
Fig. 1  Soil moisture content at two depths and various soil moisture tensions for five brown sand soils.
The erodibility of the soil has been measured (Olson and Wischmeier, 1963) directly from soil loss and rainfall erosivity values in the main, but this is a long and costly method. Attempts to simplify and hasten erodibility evaluations have resulted in the use of empirical indices. After exhaustive studies Wischmeier and Mannering (1969) proposed a complex erodibility equation utilizing 15 soil properties and their interactions. This equation was later superceded by the USDA Erodibility Nomograph of Wischmeier et al (1971) which utilizes four soil properties: percentage sand, percentage silt and very fine sand, percentage organic matter and soil permeability. This simple USDA Nomograph was adapted to temperate soils (Wischmeier et al., 1971), but Lindsay and Gumbs (1982) working on three Trinidad soils have found good correlation between this index and actual field measurements. The Nomograph was therefore used to develop erodibility indices for the soil types under discussion (Table 4). From the classification given by Lal (1980a) the erodibility indices (K) for the soils fall into the range 0.2-0.6. Soils with K values in this range are said to have a high propensity to erosion.

Table 3. Mean total, capillary and non-capillary porosity of the five brown sand soils of the Intermediate Savannahs of Guyana.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Total porosity (%)</th>
<th>Non-capillary porosity (%)</th>
<th>Capillary porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ebini sandy loam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-20</td>
<td>43.94</td>
<td>11.38</td>
<td>32.56</td>
</tr>
<tr>
<td>20-50</td>
<td>49.55</td>
<td>20.10</td>
<td>29.45</td>
</tr>
<tr>
<td>Kariruni loamy sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-20</td>
<td>38.39</td>
<td>8.85</td>
<td>29.54</td>
</tr>
<tr>
<td>20-50</td>
<td>38.49</td>
<td>17.80</td>
<td>20.69</td>
</tr>
<tr>
<td>Bukharana loamy sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-20</td>
<td>45.89</td>
<td>23.67</td>
<td>22.22</td>
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<tr>
<td>20-50</td>
<td>51.89</td>
<td>29.00</td>
<td>22.89</td>
</tr>
<tr>
<td>Kasarama loamy sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-20</td>
<td>35.38</td>
<td>13.10</td>
<td>22.28</td>
</tr>
<tr>
<td>20-50</td>
<td>36.18</td>
<td>14.79</td>
<td>21.39</td>
</tr>
<tr>
<td>Tabela sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-20</td>
<td>48.41</td>
<td>35.79</td>
<td>12.62</td>
</tr>
<tr>
<td>20-50</td>
<td>38.87</td>
<td>26.60</td>
<td>12.27</td>
</tr>
</tbody>
</table>
Table 4  Erodibility indices of three brown sand soils of the Intermediate Savannahs of Guyana

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Erodibility index value</th>
<th>Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ebini sandy loam</td>
<td>0.22</td>
<td>Serious</td>
</tr>
<tr>
<td>Kasarama loamy sand</td>
<td>0.30</td>
<td>Serious</td>
</tr>
<tr>
<td>Tabela sand</td>
<td>0.32</td>
<td>Serious</td>
</tr>
</tbody>
</table>

Related climatic factors

Climate has an important influence on the possible soil management and cropping systems in a particular area. In the Intermediate Savannahs the climate is described as "Tropical wet and dry" (TAMS, 1976). According to the classical system of climate classification, regions in which the minimum monthly rainfall is at least 60 mm can be termed tropical wet. The Intermediate Savannahs sometimes meet this condition but at other times do not. The ecozone is actually in a transition zone between the two types of tropical climate.

Rainfall

The Intermediate Savannahs receive an annual average rainfall of approximately 2000 mm (TAMS, 1976; Bullen et al, 1982). Rainfall is predominantly convectional in origin, falling in intense showers from cumulonimbus clouds (Fraser, 1981). The rainfall regime is typically equatorial, with two "wet" seasons and two "relatively dry" seasons. The "wet" seasons are due to an equatorial trough, the Inter-tropical Convergence Zone (ITCZ). The rainfall maximum from May to August is indicative of the trough's northward progression at that time of the year. A second peak occurs in December to January during the return of the trough. Rainfall however, is not only produced by the presence of the trough; a few major disturbances, particularly waves in the easterlies, are responsible for most of the rainfall in the "relatively dry" seasons.

Fraser (1981) gives some interesting rainfall data taken from the Ebini Meteorological station over the 10-year period, 1971-1980 (Table 5).

The large monthly ranges show that the rainfall at Ebini is highly variable and only in the months of July and August is the range less than both the average rainfall and the medium rainfall. This high variability of monthly rainfall places serious constraints on agricultural planning in the area. Programming of planting and harvesting activities are difficult because of this unpredictability. The agricultural potential of the area is seriously affected and controlled by this marked variability of rainfall.

Rainfall is also important in its contribution to soil water erosion. The intensity of rain showers is used to calculate an erosivity index R, for the rainfall of an area. This erosivity index is used in the universal soil loss equation mentioned above. The absence of recording rain gauges in the ecozone precludes the development of erosivity indices. Rainfall is loosely described as being "very intense". If this is true, this will increase the

<table>
<thead>
<tr>
<th>Month</th>
<th>Maximum rainfall (mm)</th>
<th>Minimum rainfall (mm)</th>
<th>Range (mm)</th>
<th>10-year average (mm)</th>
<th>Median (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>358.1</td>
<td>46.7</td>
<td>310.6</td>
<td>187.7</td>
<td>218.9</td>
</tr>
<tr>
<td>February</td>
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<td>12.2</td>
<td>210.3</td>
<td>76.7</td>
<td>61.5</td>
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<tr>
<td>March</td>
<td>330.5</td>
<td>12.4</td>
<td>318.0</td>
<td>144.8</td>
<td>124.0</td>
</tr>
<tr>
<td>April</td>
<td>318.3</td>
<td>54.6</td>
<td>263.7</td>
<td>157.2</td>
<td>132.6</td>
</tr>
<tr>
<td>May</td>
<td>380.5</td>
<td>74.4</td>
<td>306.1</td>
<td>269.0</td>
<td>274.6</td>
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<td>184.9</td>
<td>424.9</td>
<td>296.2</td>
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<tr>
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<td>178.8</td>
<td>264.2</td>
<td>322.6</td>
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<td>131.8</td>
<td>162.6</td>
<td>200.2</td>
<td>188.2</td>
</tr>
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<td>238.3</td>
<td>37.6</td>
<td>200.7</td>
<td>126.7</td>
<td>123.4</td>
</tr>
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<td>October</td>
<td>195.8</td>
<td>01.3</td>
<td>195.8</td>
<td>100.6</td>
<td>112.8</td>
</tr>
<tr>
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<td>64.3</td>
<td>159.5</td>
<td>112.3</td>
<td>112.3</td>
</tr>
<tr>
<td>December</td>
<td>326.6</td>
<td>104.1</td>
<td>222.5</td>
<td>184.9</td>
<td>159.0</td>
</tr>
</tbody>
</table>

Source: Fraser (1981)

Air temperature

The mean annual temperature for the region is 26°C. Diurnal fluctuations of up to 10°C are more pronounced than seasonal changes of 1.5°C (Bullen et al., 1982). The highest temperatures are recorded from August to November, a period corresponding to the long "relatively dry" season. Temperatures in excess of 34°C have been recorded during this period. January to March constitute the coolest months with a mean minimum of 20.8°C being normal.

Fraser (1981) states that high daytime temperatures put plants under high moisture stress as leaves transpire to cool. If soil moisture is limiting, plants would be damaged, as no moisture would be available during the nights to restore their water balance.

Wind

Despite the fact that the savannahs are about 160 km from the Atlantic, there is a daily cycle of winds induced by the North-East Trade Winds (TAMS, 1976). Wind speed increases gradually after about 07:00 h to a daily maximum of about 15-20 kph from noon to 16:00 h. The first 6 months of the year are usually marked by higher sustained winds. Gusts of 50-70 kph can occur in any month, and these are usually associated with rain squalls.

Relative humidity

The daily range of relative humidity is large. The maximum humidity occurs in the early morning with an annual average of about 92 per cent. The minimum occurs in the early afternoon with an average of about 65 per cent. The average difference of 27 percentage points is exceeded in the dry months of

erosion hazard in the Intermediate Savannahs.
September and October when differences may reach 40 percentage points. Minimum differences of about 16 per centage points occur in May and June. Average monthly minima of less than 50 per cent have been recorded and average monthly maxima of nearly 100 per cent are frequent. These large diurnal changes in relative humidity are due to the similarly large air temperature changes.

**Water surface evaporation and evapotranspiration**

Open pan evaporation measurements give a mean annual evaporation of 1803 mm (TAMS, 1976). This is really an estimate of the evaporative potential of the environment. Evaporation from natural bodies of water, which normally approximates to potential evapotranspiration (TAMS, 1976) can be taken as 80 per cent of open pan evaporation or approximately 1440 mm. This in itself is high when compared to the average annual rainfall of 2000 mm. There is therefore likely to be serious moisture deficits during certain times of the year.

**Soil physical constraints to crop production**

From the soil physical characteristics and the prevailing climate in the ecozone it is possible to predict some of the obvious limitations to crop production. Other limitations are a result of the total physical environment of the savannas and are not as obvious. From the soil physical data and personal experience of the area, the soil physical constraints to crop production could be detailed as follows:-

**Low capacity for water storage**

In terms of moisture holding capacity the soils can be ranked from high to low in the order, Ebini sandy loam > Kasarama loamy sand > Tabela sand. In addition to holding more water at field capacity, the Ebini sandy loam is also able to replenish the rooting zone with water from lower depths. This is due to the presence of a clay pan which at about 60 cm deep gives rise to a perched water table. For the other soil types, water replenishment is solely from rainfall. It is estimated that the Kasarama loamy sand can only store 7 days of water available for adequate plant growth. To maintain this level, requires approximately 20 mm of rainfall or irrigation water weekly. Lack of adequate moisture combined with shallow rooting depth can have an adverse effect on plant development, particularly if it occurs at critical times in the crop growing period.

**Soil crusting**

The brown sand soils tend to lose their organic matter content as soon as cultivation is carried out. The high rainfall and temperatures along with excessive drainage and aeration after tillage provides an intensely oxidizing environment which quickly breaks down all organic matter. This lack of adequate amounts of organic matter, along with the possibility of the development of a saturated solution of amorphous silica, contributes significantly to the crusting phenomenon that is manifested primarily on the Ebini sandy loam and the Kasarama loamy sand. This is also likely to be responsible for the hard, brick-like cementation that develops during dry periods in the Ebini sandy loam soils.

Crusting has a direct adverse influence on seedling emergence and water infiltration. The lower water infiltration in crusted soils increases water runoff and soil erosion.

**Propensity to erosion**

The Brown Sands can be classified as being highly susceptible to erosion, due mainly to their texture. Under virgin or natural vegetation in the uncultivated state this erosion hazard is not manifested due to the gentle slopes, the higher organic matter content and the protective vegetative cover. Soil disturbing activities enhance the erosion hazard by exposing the soil to high energy rainfall and by inducing crust
formation. Since these soil-disturbing activities are normally carried out immediately before the high rainfall periods, the soil is unable to regenerate a vegetative cover to protect itself from the direct impact of raindrops. The result can be very intense erosion on the cleared lands.

**High soil temperature**

The high air temperature and the observed hotness of the sand during the hottest time of the day have been used as indicators of high soil temperature. The supra-optimal temperature for plant growth has been given as 35°C by Maurya and Lal (1981). Soil temperatures above this have detrimental effects on plant growth. The same authors also indicated that the soil temperature for optimum plant growth is between 28 and 31°C. With air temperatures as high as 34°C during the day in the Intermediate Savannahs, it is likely that the soils attain temperatures higher than the optimum 31°C. Decreasing soil temperature is therefore likely to be beneficial to plant growth.

**Other soil constraints to crop production**

Although this presentation is particularly concerned with soil physical characteristics and management, no feasible management system is possible without knowledge of all the soil limitations to crop growth. Soil fertility constraints have been more frequently documented (Downer, 1972; Chesney, 1979; Dookie, 1981) than soil physical constraints. In general, the chemical constraints of the Brown Sands can be listed as follows:

- Acidity due to relatively high exchangeable Al
- Relatively low amounts of bases and micronutrients
- Low organic matter content
- Low nutrient holding capacity
- High leaching potential due to low cation exchange capacity

The biological constraints of these soils relate to the low organic matter content and the high soil temperature already mentioned. Alleviating these problems should therefore lead to enhanced biological activity in the soil.

**Requirements of the soil management system**

Van Doren and Triplett (1979) proposed that the method of soil management to be chosen in any particular area should have a beneficial effect on particular soil problems, as well as being suited to the crop, the prevailing climate and the socio-economic situation. In this presentation the socio-economic constraints for full development of the Intermediate Savannahs have not been comprehensively addressed. It is however important to note that these constraints are sufficiently serious to be ranked alongside the other, more technical, constraints.

The technical feasibility of a soil management system for the Intermediate Savannahs is evaluated in terms of how effectively it surmounts the physical, chemical and biological soil constraints under the prevailing climatic conditions. From the soil constraints already discussed a technically feasible management system will have to satisfy all or most of the following interrelated objectives:

- Increasing water-holding capacity or water use efficiency
- Lowering soil temperature
- Increasing soil structural stability and reducing surface sealing and crusting
- Decreasing runoff and soil erosion
- Increasing soil organic matter content
- Decreasing the trivalent Al saturation of the soil
- Enhancing soil chemical fertility

Present soil physical management practices

The present soil management system can be considered to be a conventional annual cropping system. It does not really satisfy the criteria necessary for successful soil management in the Intermediate Savannahs, but is more an adaptation of soil management systems used on the heavy clays soils on the coast of Guyana.

Land Preparation System

The savannah type vegetation of the ecozone is dominated by the grasses *Trachypogon plumosus* and *Andropogon leucostachyus* with scattered sand paper trees (*Curatella americana*). Traditionally, land is cleared by trampling methods which allow destruction of the vegetation without heavy soil movement. The trampling is mainly for the shrub vegetation. A heavy serrated roller called the Marden chopper (a rolling chopper) is normally used, followed by a bulldozer, or similar type of implement for the levelling of ant and bush hills.

Soil tillage normally consists of one ploughing operation followed by two passes of the harrow (heavy and light). Further operations such as cross harrowing or tining (spike-tooth harrow) may be necessary if the land is uneven after the initial operations.

Water management systems

Agricultural production in the Intermediate Savannahs is at present completely rainfed. Crops are planted to coincide with the two "wet periods" during the year. Fraser (1981) did limited analysis of rainfall data at Ebini for the period 1960-79 to determine confidence limits for the rainfall pattern. These data indicate that the high rainfall periods are more likely to be from mid-April to mid-August and mid-November to the end of January. Crops are therefore planted in this period with certain cut-off planting dates to ensure that they obtain adequate moisture throughout their growth period. No moisture conservation methods are employed.

Erosion control systems

Limited soil conservation techniques such as contouring and strip cropping are done on the more steep (5-8 per cent) slopes. These have showed limited success. Personal observations indicate that if intense rainfall is experienced very soon after tillage and planting there is serious erosion. This erosion risk slowly decreases as the crop becomes established, and a vegetative cover is restored to the soil.

Alternative soil management systems

To develop a feasible management system, the present management system will have to be modified to cater more to the requirements given above. Various soil management and cropping systems have been developed experimentally and are in use in the tropics. For the Intermediate Savannahs local adaptation of systems already in use under similar conditions in the humid tropics is likely to be of importance. These systems can be grouped under the following heads for convenience of explanation.

Conventional annual cropping systems

This group includes the present system now in use in the Intermediate Savannahs. The systems in this group range from sole cropping, sometimes in a two-crop rotation and using traditional tillage methods, to highly sophisticated inter-cropping systems. The sole crop system does not rank high in terms of
the seven criteria given above, but it is a very widespread system of soil management. Intercropping systems often increase cropping efficiency above that of the sole-crop system. This can lead to some improved characteristics particularly increased soil organic matter and its related benefits. Various systems namely sequential, relay, double and ratoon cropping have been tried with varying success. Their technical attractiveness may, however, be location specific, as logistical problems often upset the timeliness of required operations.

Non-conventional annual cropping systems

This group encompasses various interrelated management systems or practices. These range from reduced tillage systems to deep tillage systems. For the Intermediate Savannahs reduced tillage systems incorporating vegetative mulch may be the most appropriate. Lal (1980b) stated that reduced tillage systems should form an integral part of the improved cropping systems for adequate soil management in tropical regions. Some of the advantages of the system are improved soil structure, better water infiltration and soil and water conservation. The system benefits greatly from the generous return to the soil of plant residues which form a protective mulch on the soil. El-Swaify et al. (1984) found that surface mulching reduces the risk of serious soil erosion during the early wet season, allows the maintenance of higher infiltration rates, reduces surface sealing and provides protection against temperatures injurious to emergence and crop stand. Reduced tillage systems may however aggravate the incidence of diseases and may require complementary investments in crop protection and crop improvement.

Agro-forestry systems

In this system woody perennial species are grown in association with annual row crops. The system attempts to promote the beneficial effects of bush fallowing while an annual crop is still being grown on the land. Of importance in this group is the system of alley cropping (IITA, 1981), where fast growing woody perennial legume species are planted in wide rows (4-10 m). Annual crops are then planted between these rows. Prunings from the perennial species provide mulch, organic matter and nutrients to the soil for the benefit of the annual crop. It has been estimated in Hawaii under optimum soil and moisture conditions that 1 hectare of *Leucaena leucocephala* cut to a height of 1 m every 3 months can provide foliage containing 500-600 kg of N, 44 kg of P and 187 kg of K (Batson et al., 1987). Trials at IITA in Nigeria, produced dry matter yields of 7.4 t per ha per year from five cuttings of *Leucaena leucocephala* in an alley cropping trial. This dry matter provided a total of 247.2 kg N per ha per year among other nutrients (IITA, 1985). This system in combination with reduced tillage is now being tested on farms in Nigeria and several West and Central African countries.

Grass and legume/ley farming systems

As its name suggests in this group, short-term row crop production is alternated temporarily with grass or legume forages. The systems in this group are designed to increase the production of livestock products and improve physical and nutritional properties of the soil while carrying out the production of short-term food crops. The systems are particularly popular in India and in Africa's savannah zone, where the emphasis is on increasing the soil's organic matter content and on improving its structure through the use of animal manure, green manure and grass leys (El-Swaify et al., 1984). In the semi-arid tropics of Northern Australia, a legume ley no-till system gave encouraging results over a 5-year period (El-Swaify et al., 1984). This system has the following features:

- Cultivation of self-regenerating legume ley pastures, lasting 1-3 years in rotation with maize or sorghum.
- Cattle grazing on native grass pastures during the wet season and leguminous crop pastures and crop residues in the dry season.

- Crops planted directly on pasture which is chemically killed at, or shortly before, planting.

- Allowing a pasture legume sward that volunteers from hard seed to form an intercrop in the main crop.

The various systems given above all have their merits and demerits. Their ability to satisfy the seven interrelated criteria for a technically feasible management system is perhaps the best means of determining the most suitable system or systems. Table 6 attempts to summarize the effectiveness of the four soil/crop management systems discussed above. The non-conventional annual cropping system, agroforestry system and the grass and legume ley farming system all employing reduced tillage appear to be the most favourable systems. For all these systems, there is however, the very important requirement of liming the soil profile. Lal (1980b) reported that since lime does not move rapidly into the sub-surface layers broadcasting lime on the surface along with no-tillage can provide a serious limitation to crop growth. Simpson (1988) confirmed this for the Intermediate Savannahs. This means that there must be some initial soil disturbance to incorporate limestone into the profile. After this initial incorporation it is likely that crops can be grown for 3-4 years before limestone again has to be incorporated. No tillage can be included in the system after the initial incorporation of limestone.

Conclusions

The ultimate objective is to develop successful soil/crop management systems for increased agricultural production in the Intermediate Savannahs. From the foregoing, it is possible to look at adaptations to the systems in use on other parts of the tropical world. This will require conceptualization, utilizing the knowledge of soil properties and the prevailing climatic conditions. At present, this is the pathway which is being followed. Various soil/crop management systems are being assessed to determine their suitability to the ecozone. These systems utilize various tillage practices, mulching techniques, cropping sequences and land rotation systems in combination. Adequate assessment of these systems is time-consuming and the results tend to be inconclusive. The inconclusiveness is due mainly to an inability to fit the feasible soil/crop management systems into the entire production system.

More ideally, models of crop production systems should be developed incorporating the requirements for successful soil management under the prevailing climatic conditions. The development of these models is a complex process. For the Intermediate Savannahs successful soil management can be considered to be directly related to increased water holding capacity, structural stability, organic matter, pH and chemical fertility and inversely related to soil erosion and temperature. For improved agricultural production the model will have to include various other crop and animal production parameters.

It is perhaps possible to arrive at reasonable production models for the Intermediate Savannahs by logical deduction. The author has not attempted this here, but would prefer to utilize the more advanced technologies now available for model building. Although this pathway has not been tried at present, it is considered to be potentially useful for developing viable agricultural production systems for the Intermediate Savannahs. Assessment of models will ensure a quicker development of a viable production system.
Table 6  Potential benefits of alternative land management systems for the Intermediate Savannahs of Guyana

<table>
<thead>
<tr>
<th>Alternative land management system</th>
<th>Improvement of water holding capacity</th>
<th>Lowering of soil temperature</th>
<th>Increased soil structural stability and reduced surface sealing, crusting</th>
<th>Decreased runoff and soil erosion</th>
<th>Increased soil organic matter content</th>
<th>Allows soil profile liming</th>
<th>Maintenance or enhancement of soil fertility</th>
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<tr>
<td>Conventional annual cropping systems</td>
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<td>Sequential cropping</td>
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<td>Relay cropping</td>
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<td>Inter-cropping</td>
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<td>Non-conventional annual cropping systems</td>
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<td>Reduced tillage</td>
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<td>Deep tillage</td>
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<tr>
<td>Agroforestry systems</td>
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<tr>
<td>Grass and legume ley farming</td>
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</tbody>
</table>

+ = beneficial effect
- = no beneficial effect
? = doubtful effect
Acknowledgements

The author wishes to thank Drs. M. A. Granger and F. A. Gumbs for critically reviewing this paper, and Mss. Nazeema Bacchus, Alma Small and Anne Simpson for their help and support in the preparation of the manuscript.

References


PROSPECTS FOR MECHANIZED AGRICULTURAL PRODUCTION IN THE INTERMEDIATE SAVANNAHS

R. Power
Hydrogardens Ltd.
St. Paul, Barbados

Simplistically, the Savannahs comprise an area of land onto which one can put any sort of equipment to achieve a goal as far as going through the motions of crop production are concerned. However, first let us look at resources, and relate them to equipment, techniques, topography and climatic patterns, in order to determine whether an agriculturally viable goal can be achieved.

Resources/Requirements

Land
The land is there but in order to produce from it we further need capital, labour and managerial expertise, blended in such proportions as to achieve a desirable economic and viable product.

Capital
Adequate capital will provide the means of production; other than the basic land resource, capital availability is paramount. It is not the intention of this presentation to discuss this resource finitely, as this topic enters the area of economics and national development which at this stage is outside of this paper's scope. Despite this, capital requirements cannot be ignored.

Labour and managerial personnel
The Intermediate Savannahs are essentially unpopulated. To achieve any kind of production, people are needed. Generally, the more skilled a person, the greater the degree of sophistication he will demand for his living requirements. In this sense I am talking about community — not simply housing. Man is a social animal, and his needs are diverse. Aspects of housing, primary health care, recreation, amenities etc, must also be addressed if a population living in the savannahs is to move from the subsistence mode of production to economically viable forms of cash cropping — and surely that is why we are all here addressing the potentials of the Savannahs.

For agricultural production on the savannahs, a pre-requisite is a community. Historically, community development is based on the availability or close proximity to water. Here in Guyana many communities have evolved on the banks of rivers. Here a river is not only the source of an absolute basic necessity, but is also the common denominator as a reliable communication link with other communities. If an agrarian community is to develop on the Savannahs, abundant water supply is essential for human and agricultural uses (crop spraying).

Communications
Guyana is blessed with a network of naturally occurring highways — the rivers. Theoretically river transport is the most economical means of transport. However to utilize this "water highway" the costs of specialized carriers, and fixed installations such as docking, handling and storage facilities, may be high.

The prevailing means of access to the savannahs is by road vehicles. However the general cost of a sustained road link is horrific in terms of cost per unit ton of input/output largely due to severe wear and tear on vehicles because of the poor roads.
It is important to emphasize the absolute necessity of a balanced and integrated infrastructure if viable mechanized agricultural production is to be made feasible on the Savannahs.

The land and natural environment

The general reference of the Intermediate Savannahs of Guyana are defined within a triangle between Ebini, Kwakani and Ituni, covering an area of about 60,000 ha of actual savannah.

However each savannah is a relatively small, treeless area of anything between 40 and 2,000 ha, interspersed between the indigenous forest.

The topography is gently undulating and weathered in such a way that large (i.e. more than 50 ha) uniformly flat areas are uncommon. This is immediately detrimental to the existence of large fields for reasons that will be discussed later. Soil type varies, sometimes with quite rapid succession over a relatively short cross section of land. Soil types are identified essentially between the 730 and 820 series, with the Tabela (800), Kasarama (810) and Ebini (820) series predominating.

The natural flora of the indigenous savannah are generally limited to two or three bunch grass species and about four legumes, with a greater botanic diversity in the proximity of weathered ant-hills. Helaconia species are interspersed in areas of poor drainage.

Crop management

Once the virgin soil is modified by the application of lime and fertilizers (macro and micronutrients), colonization of cultivated areas by weeds becomes seriously debilitating to cultivated crops within a year.

It was found that the imported limestone introduced most of the species of weeds into the Savannahs. (So much so that the weed problem of the savannahs mirrored the principal weeds in Barbados, the source of the lime).

Nut sedge (Cyperus rotundus), Graminaceous weeds such as Cynodon dactylon, Crab grass and Panicum rapidly colonized. Some dicotyledenous weeds were also introduced.

In 1980 CARDI showed that yield losses of up to 60 per cent of potential production could be attributed to weed infestation.

These agronomic problems are quantifiable. Technology and expertise can limit weed pollution (at a cost); the problems of fertility in these podzols are not new either and there are existant recommendations for fertilizing highly acid, low CEC soils that even have a large percentage of free Al in them.

The major problems in the Savannahs have been of how to manage the application of material inputs considering the constraints of weather in relation to the chosen cropping mix.

Management problems - fertilizer handling

Management problems may be illustrated by looking at the aspect of fertilizer handling. Most fertilizers are hydroscopic to some degree. In the Savannahs, in the wet season even on bright days, the relative humidity would not drop below 100 per cent (wet bulb) until 9-10 a.m. and would be back to 100 per cent by 7 p.m.

This dampness caused extensive problems in achieving the application of consistant quantities when banding simultaneously with seeding. The problem was further aggravated since physical mixes of fertilizer were used with varying ratios of N, P and K according to the requirement of the crop and the dictate of the general analysis of the field being planted. Powdered trace elements were added to the blend.

On an ordinary working day, in order to start planting, the prerequisite
fertilizer blend was prepared early in the morning. A difficulty arose because at that time of day the machinery was very cold with considerable condensation on it. This invariably caused managerial problems because belts would slip, fertilizer would not flow, etc..

The timely availability of fertilizer mix limited the potential efficiency of the field application.

Attempting to pre-mix in advance of requirement caused problems, as the fertilizer would cake within hours of mixing.

Further, because of the size of the Savannahs, it may have been dry at the point where the fertilizer had been mixed, but be raining at the field site where it was to be applied.

These delays limited planting rates. So planting rates were essentially dependent on the weather. And the weather proved to be very unpredictable.

Weather conditions

There are two rainy seasons in the Savannahs. However forecasting when the rain would start was almost impossible.

From year to year, the beginning of the main rains varied by as much as ±18 days. Ideally, for the crops requiring the longest time to harvest (e.g. corn) the fastest planting rates should be achieved in the days prior to the onset of the first rain. However, if one started cultivating 35 days before adequate moisture for seed germination the probability of seed survival in the soils became very low. If the rains came very early, only a small percentage of the planned acreage was in and the stop-start panic of trying to plant between showers commenced with planting rate reduced to about 25 per cent of dry land planting. In this situation preparation costs increased because "time means money"

Machinery

Part of the Ebercabo project conception was that crops were to be planted conventionally. However, conventional machinery sometimes proved difficult to work. So when we looked at other crops, particularly Phaseolus beans and pigeon pea, we also looked at alternative planting techniques.

Broadcasting seed from an oscillating spreader proved to be successful on account of:

- the wide swath
- low power requirement
- wetness of the field at the time of application was not too important.
- cultivation to bury the seed could follow up to 48 hours later

Thus broadcasting facilitated planting because it was fast and low cost.

Another advantage was that a total canopy was achieved quite quickly which was good for weed control. A disadvantage was that with a total canopy there were problems with fungi and bacterial diseases because of the high humidity in the micro-environment below the canopy.

Harvesting with combines was no problem.

Other aspects of production: ploughing; spraying for insects and diseases; harvesting; drying and storage can involve similar difficulties as fertilizer handling problems

Concluding remarks

The scenario that I have tried to paint is that directly, mechanization of the Savannahs is not difficult – relatively low wear and tear on primary machines (tractor tyres that nearly last forever) – but high wear rates of cultivation equipment because the very abrasive nature of the soil. Enormous
transportation costs. These are qualifiable parameters.

The problem is to develop an integrated production system that is economic and the results of which are reasonably repeatable season after season, regardless of weather patterns etc. — that is the crux. And that is why we are here this week.

The prognosis for community development is poor. Even if a community existed on the Savannahs, the degree of technology being introduced must be adapted to the needs of the indigenous community and environment.

Finally, the main conclusion to be drawn is that mechanization is not the stumbling block to production — the weather is.
TECHNICAL SESSION I

DISCUSSION

Rapporteur: C. Bullen

H. Adams (CARDI, Guyana):
What is the chemical composition of the outcrops of rocks within the Zanderij Formation? Are there any possibilities of using such material as soil ameliorants?

P. Rellum (University of Suriname):
These outcrops are of Precambrian origin, acidic in nature and unlikely to be of value as soil ameliorants.

M. Holder (Ministry of Agriculture, Belize):
There are similarities between Belize and Suriname with respect to the issue of identifying alternative crops to be grown with rice on Coastal soils.

P. Rellum:
In the Suriname experience it was this problem that led, ultimately, to the research activities currently on-going within the Zanderij Belt.

S. Parasram (CARDI, Headquarters):
What would be the relevance of minimum and reduced tillage in managing these soils?

D. Walmsley (CARDI, Headquarters):
Would the use of more mobile sources of Ca such as Gypsum, be of help in ensuring a deeper rooting zone?

E. Lobato (EMBRAPA, Brazil):
This should be given serious consideration in the soil amendment programme.

R. Fletcher (CARDI, Montserrat):
Gypsum would not necessarily raise the soil pH; such pH changes are thought to be critical in the cultivation of certain crops.

E. Lobato:
Proper criteria should be identified as the basis for recommending lime applications. Further research is needed in this area.

M. Rasheed (Soyabean Co., Guyana):
The proper timing of land preparation is very important. The success of crop cultivation in the Intermediate Savannahs of Guyana is to a large extent dependent on (i) the availability of reliable and usable weather forecasts and (ii) the ability to complete crop production activities on schedule.

L. Daisley (Ministry of Agriculture, St. Vincent):
The presentations we have heard so far have not emphasized the importance of entomological problems encountered in large-scale farming such as in the cases of the Eberoba and Kilibiri Projects in Guyana.
Also there is a pressing need for economic and financial assessment of these projects.

M. Granger (NARI, Guyana):
Due recognition has been given to the problems posed by insect pests but those will be further elaborated in other Technical Sessions.

J. Browman (University of Guyana):
The problems encountered in the Eberoabo Project were largely of a financial nature arising from the restricted outflows of funds to the Project.
TECHNICAL SESSION II

Chairman: J. Browman, University of Guyana
Acid sandy soils, or Quartz Sands in Brazil, occupy an area of approximately 70.9 million hectares (Table 1). Although their area is large, very little is known about the true development potential of the Quartz Sands, mostly because Brazil possesses an even larger area of probably more productive and economically viable Latosols that have been the focal point of both agricultural research and development.

Because of significant physical and chemical constraints, the preferred development strategy for the Quartz Sands has been to leave them untouched. Nevertheless, as Brazil has expanded its agricultural frontier into the interior, many farmers have ended up on Quartz Sands that they must depend on to provide their living. Management alternatives for making these soils agriculturally productive need to be found.

Recognizing the paucity of data from research on the management of Quartz Sands in Brazil, this paper presents a review of the major constraints to production on these soils and the potential for their successful development.

General characteristics

Quartz Sands are soils with sandy or loamy sand texture at least 80 per cent sand and less than 15 per cent clay and A-C horizationation weakly defined. Their mineralogy is essentially all quartz as they developed primarily from siliceous parent materials. Most of the soils are deep, at least 2 m, and excessively well-drained (EMBRAPA, 1975). Their structure is single grain to very weak fine granular. Colour tones vary from reddish to yellowish depending on the type of iron oxide present (Adamoli et al., 1985). They are usually acid with very low nutrient and organic matter levels, low cation exchange capacity (CEC), and high aluminium (Al) saturation (Table 2). The major distinguishing feature between the A and C horizons is the colour difference due to a higher level of organic matter in the surface horizon. In some cases there may be a slight increase in clay with depth.

The Quartz Sands are widely distributed in Brazil, extending from areas with a long marked dry season to areas with little or no dry season (Fig. 1). Most of these soils are found in the Cerrado Region where they occur under savannah vegetation on flat to gently rolling relief. In the Amazon Region they may be found...
Table 1: Estimated area of the four predominant soil types in Brazil

<table>
<thead>
<tr>
<th>Brazilian system</th>
<th>Soil taxonomy</th>
<th>FAO/UNESCO</th>
<th>Million hectares</th>
<th>Percent of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latosols</td>
<td>Oxisols</td>
<td>Ferralsols</td>
<td>335.6</td>
<td>39.7</td>
</tr>
<tr>
<td>Red-yellow Podzolics</td>
<td>Ultisols</td>
<td>Acrisols</td>
<td>190.6</td>
<td>22.5</td>
</tr>
<tr>
<td>Quartz Sands</td>
<td>Entisols</td>
<td>Arenosols</td>
<td>70.9</td>
<td>8.4</td>
</tr>
<tr>
<td>Eutrophic Podzolics</td>
<td>Alfisols</td>
<td>Luvisols</td>
<td>64.7</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Source: Maderira Neto et al. (1982)

Table 2: Mean profile analysis of several Quartz Sands selected throughout Brazil

<table>
<thead>
<tr>
<th>Horiz</th>
<th>Clay (%)</th>
<th>Sand (%)</th>
<th>pH (water)</th>
<th>Org C (%)</th>
<th>Exch cations (meq/100g)</th>
<th>Avail P (ppm)</th>
<th>Al sat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Al</td>
<td>Ca+Mg</td>
<td>K</td>
</tr>
<tr>
<td>A</td>
<td>8</td>
<td>82</td>
<td>4.8</td>
<td>0.77</td>
<td>0.7</td>
<td>0.3</td>
<td>0.06</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>82</td>
<td>5.0</td>
<td>0.21</td>
<td>0.5</td>
<td>0.2</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Sources: Camargo and Falesi, 1975; Maderira Neto et al. (1982)
Fig. 1 Approximate distribution of Quartz Sands within Brazil (EMBRAPA 1981)
under either savannah-type or forest vegetation with soils under forest vegetation generally containing more organic matter (Falesi, 1972; Camargo and Falesi, 1975). In both regions, the Quartz Sands are commonly found associated with Latosols and Red-Yellow Podzolics.

**Major constraints**

Due to their textural and mineralogical properties, the Quartz Sands are inherently poor soils for agricultural production. Their sandy texture and deep profile development indicate infiltration rates will be high and permeability extreme, hence water deficits may occur during short periods without rainfall and applied nutrients may be easily leached during periods of heavy rainfall. Among the Quartz Sands, however, it has been shown that the water retention capacity increases as the fine sand proportion of the total sand increases (Manfredini et al., 1984). Where located on sloping land, the Quartz Sands, because of their weak structure, are also susceptible to erosion by water if no plant cover is maintained.

Dominated by quartz with the near absence of a clay fraction, the Quartz Sands have very little capacity to retain and supply necessary nutrients for crop production. Essentially all of the CEC that exists is due to the organic matter, most of which is in the surface horizon. Agricultural production on these soils will therefore require careful fertilizer management and implementation of practices that maintain or increase organic matter levels.

**Production potential**

**Pastures**

The predominant agricultural activity today on Quartz Sands in Brazil is their use for native pasture, particularly in the Cerrado Region. These are mainly extensive cow-calf operations with Zebu cattle at low carrying capacities of 0.2 to 0.6 animal units per ha per year (Kornelius et al., 1979). The nutritive value of the native vegetation is generally poor and live weight gains are low, especially during the dry season when less than 60 per cent of the nutritional needs for grazing animals are met (Grof, 1985).

A significant research effort in Brazil has been aimed at increasing animal production through the cultivation of improved pasture. Much of the emphasis has been on identifying suitable legume species that can be planted into native pasture or in association with an improved grass. The more promising legumes until now have been *Stylosanthes guianensis*, *S. capitata*, *S. macrocephala*, *Centrosema macrocarpum*, *C. brasilianum*, and *Zornia brasiliensis* (Thomas et al., 1988), although *Z. brasiliensis* has not always scored well on animal acceptance. In non-grazing trials, dry matter yields following modest fertilizer application of P, K and micronutrients have been as high as 9.9 tonnes per ha during the wet season at two different Cerrado sites dominated by Quartz Sands (Alencar, 1985; Penteado, 1985). During the dry season maximum dry matter yields were only 1.2 tonnes per ha. In general, these legumes have shown excellent tolerance to high Al saturation, low P, and drought; the *S. capitata* lines should be well adapted since they were collected from the acid sandy infertile soils of the savannahs in Brazil and Venezuela (Thomas et al., 1987).

The grasses usually used for improved pasture have been *Andropogon gayanus*, *Brachiaria decumbens*, *B. ruziziensis*, *B. humidicola*, and *Panicum maximum*. In a 3-year grazing trial conducted in the Cerrado, *A. gayanus* showed significantly greater persistence and productivity than the other grasses (Thomas and Andrade, 1984). More recently, several *Paspalum* species have shown promise because of their vigorous growth in poor soils, good seed production, and resistance to spittle bug attacks. At a Quartz Sand site in northern Goias State, *Paspalum*
*maritimum* has been one of the better grasses (Drudi, personal communication).

Comparative studies of degraded *P. maximum* pastures on Quartz Sands and clayey Latosols in the Amazon Region indicated that P deficiency was the major cause of productivity decline on both soils (Serrao et al., 1979). As illustrated in Fig 2, a missing-element fertilizer trial in a 12-year old degraded *P. maximum* pasture on a Quartz Sand showed yields to be most limited by the lack of applied P. At the same site, *P. maximum* dry matter yields (four cuts total) were increased from 2.7 to 10.4 tonnes per ha following the application of only Simple Superphosphate fertilizer at the rate of 22 kg P per ha (Serrao et al., 1979). The overall poor fertility of the Quartz Sand, however, was demonstrated by the fact that leaving out any of the tested nutrients resulted in reduced yield when compared to complete fertilization (Fig. 2).

The potential importance of S and micronutrient fertilization for forage production on Quartz Sands was shown in another missing-element trial by Casagrande et al. (1982). In this greenhouse study the growth of perennial soyabean (*Neotonia wightii*), after application of lime and P-K fertilizer, was most limited by the lack of applied S followed by B and Mo.

The development of Quartz Sand soils for pasture production might prove to be a viable sustainable alternative to leaving them untouched. Well-adapted species of perennial grasses and legumes, through proper management of fertility needs and grazing pressures, should provide the permanent ground cover, deep rooting, and continuous input of organic matter so crucial to sustained production on these poor sandy soils.

**Tree crops**

Certain perennial tree crops, whether grown for wood or fruit, are capable of producing well on sandy soils. Of particular note in Brazil are silvicultural species of *Eucalyptus* and *Pinus* and fruit trees such as cashew (*Anacardium occidentale* L.) and citrus (*Citrus sinensis* and other spp.). Since these trees do best on deep well-drained soils, Quartz Sands might provide suitable sites for their cultivation. Poor fertility and the potential for water deficits, however, are intrinsic constraints on these soils that can limit the production of even tree crops.

In an evaluation of 10 provenances of *E. camaldulensis* at five different sites within the Cerrado, one of which was a Quartz Sand, Moura (1986) obtained the smallest height and diameter means for 3-year old trees in the Quartz Sand. The means for height and diameter of trees at the Quartz Sand site were 5.9 m and 5.4 cm respectively, while the means at the other sites ranged from 6.8 to 7.6 m (height) and 6.2 to 7.4 cm (diameter). Much of this difference in growth was probably due to the lower water holding capacity of the Quartz Sand; the other sites were on soils with higher clay content.

Research conducted mostly in the Cerrado Region has demonstrated that initial applications of N, P, K, lime, and the micronutrients B and Zn are important for the establishment of both *Eucalyptus* and *Pinus* forests (Moura and Giumaraes, 1988). In a fertilizer trial on a Quartz Sand, Simoes et al. (1970) showed that *Pinus caribaea* growth increased significantly following the application of N, P, and K with the greatest response due to P. Based on this response, the authors recommend these nutrients be applied at rates of 60 kg N per ha, 44 kg P per ha, and 20 kg K per ha. At the same site, Simoes et al. (1970) also showed that *P. caribaea* responded to an initial limestone application of 3 tonnes per ha.

With its centre of origin along the north-northeast coast of Brazil, cashew is a nut and fruit crop that does well in sandy soils, particularly those with a water table depth of 2-6 m (Guilherme et al., 1986). Although much of the area planted to cashew includes Quartz
Fig. 2 Relative yield of *Panicum maximum* in a missing element fertilizer trial on a Quartz Sand soil; 100% = 8.3 t/ha in four cuts (Adapted from Serrao *et al.*, 1979).
Sands, it is a crop that seldom receives chemical fertilizer; usually only animal manure is applied at the time of tree establishment. Nutrient solution studies in the greenhouse have demonstrated the importance of macronutrients (Haag et al., 1975) and micronutrients (Sarruge et al., 1975) for the healthy development of the cashew plant, but very little work has been done at the field level to determine optimum fertility levels and fertilizer response on Quartz Sands. Nevertheless, based on the results of these nutrient solution studies and the poor fertility of Quartz Sands, one would assume that cashew would respond economically to most nutrient applications.

Citrus has become an important export crop for Brazil during the past two decades. Although sometimes found in Quartz Sand areas, it is preferably cultivated on sandy Latosols and Red-Yellow Podzolics that have been limed and fertilized. Best yields are obtained where irrigation is available. Because of its export value and demonstrated response to added nutrients (Malavolta, 1983), it is common for citrus producers to sample their soils and plants to determine nutritional status on a regular basis (Sanches, 1983). Of the tree crops mentioned in this section, citrus would be the more demanding in terms of management of lime and fertilizer inputs and supplemental irrigation for production on Quartz Sands.

**Annual crops**

Of all the cropping alternatives, annual crops such as maize, soyabean, and rice are perhaps the least suitable for agricultural production on Quartz Sands. Even so, there are areas of Quartz Sands in Brazil where such crops, particularly soyabean, are being cultivated on a continuous basis. With these crops the element of risk is great since short periods of only a few days without rainfall can result in yield reduction or crop failure, a consequence of the low water holding capacity of these soils and the likelihood of shallow rooting due to subsoil acidity. Because of their low CEC and high permeability, Quartz Sands will require frequent nutrient applications and, to minimize the risk of crop failure, supplemental irrigation during unpredictable dry spells.

Although very little research has been conducted on Quartz Sands, there exists a large volume of work carried out on other acid soils, mostly Latosols, of central Brazil (Goedert, 1983; Goedert, 1985) that should provide reasonable guidelines for the management of annual crops on Quartz Sands. This work has demonstrated marked yield responses to lime (Sousa et al., 1985; Gonzalez-Erico et al., 1979), to P (Goedert et al., 1985; Yost et al., 1979), to N (Subet et al., 1985; Grove et al., 1980), to K (Vilela et al., 1985), to S (Couto and Ritchey, 1985), to micronutrients, particularly Zn (Galrao, 1985), and to organic matter additions (Pereira and Peres, 1985).

For Quartz Sands, the lime recommendation should be based on the amount of exchangeable Al where CaCO$_3$ (tonnes per ha) needed is determined by multiplying the milliequivalents of exchangeable Al per 100 g of soil by 1.5-2. This method should furnish sufficient lime to neutralize exchangeable Al and to provide Ca as a nutrient. How often lime would need to be reapplied could best be determined through experimentation and periodic monitoring of soil test levels. N and probably K would need to be applied for each crop with best results obtained through split applications, thus minimizing leaching losses by providing these nutrients as close to the time of uptake as possible. P fertilization should be based on soil test levels recognizing that Quartz Sands have a higher critical level for soil P than more clayey soils (Lins et al., 1985). Following an initial broadcast application of P when the area is first cultivated, best results for subsequent crops would most likely be obtained through band placement of P at the time each crop is sown.
Quartz Sands cultivated for continuous annual crop production could rapidly reach a degraded state if management does not include the addition of organic matter to the soil. This can be accomplished through the return of all crop residues to the soil after grain harvest and the addition of animal manure or the use of rotation systems based on a green manure, cover crop, or pasture ley. Annual crop production on these soils might also benefit greatly from the use of minimum tillage systems. If annual crops must be grown on Quartz Sands, the importance of organic matter, because of its ability to increase CEC and water holding capacity, cannot be over-emphasized.

Conclusions
Quartz Sands are acid sandy soils with serious chemical and physical constraints to agricultural production. Their textural and mineralogical properties make these soils nutrient poor, leachy, and potentially droughty during short periods without rainfall. Where better soils exist, the preferred development strategy would be to leave the Quartz Sands untouched. If they must be developed, then deep rooting perennial crops such as trees and improved pasture probably stand the best chance of being economically and ecologically successful. The large extent of Quartz Sands in Brazil and the ever increasing expansion of agricultural lands demand that alternative management practices for these soils be more thoroughly researched.

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A REVIEW OF ANNUAL CROP PRODUCTION SYSTEMS IN THE INTERMEDIATE SAVANNAHS OF GUYANA

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A comprehensive survey of Guyana's soil resources was completed in 1965 and 99 different kinds of soil were identified and classified using the USDA (1938) system with tentative placements in the 7th Approximation (FAO, 1965). Apart from the coastal plains where marine deposition, of recent vintage, has been a dominant factor in soil formation, the other physiographic regions possess soils that have been formed through the weathering of rocks and variously deposited through the activity of rivers. As a consequence most of the soils of the hinterland are acid and possess relatively low fertility.

The concentration of population and economic activity on Guyana's coastland, over the years, has been accompanied by a relative paucity of resources directed at agricultural research and development in the hinterland. In the case of the Intermediate Savannahs, however, the region has for sometime, been regarded as the second frontier for agricultural development. A significant quantum of research has been done on soil characterization, soil fertility, soil-plant-fertilizer interactions and fertilizer requirements for annual crops and forage grasses. This research has led to and has been supportive of several efforts in large-scale production of a number of annual crops. These efforts have, for a variety of reasons, been sporadic and not sustained. The 1983-1991 Agricultural Development Plan has targeted the Intermediate Savannahs for, among other activities, commercial production of such annual crops as cotton, cowpea, soyabean, peanut, sorghum, and industrial cassava. This paper seeks to review and highlight the problems and constraints associated with annual cropping systems in the Intermediate Savannahs and to provide some basis for the direction of future research work.

The Intermediate Savannahs

Geography, geology and geomorphology

Located in the north-eastern quadrant of Guyana, the Intermediate Savannahs lie immediately south of the coastal plains, extending east and west of the Berbice River (Fig.1). The region covers an area of approximately 2,700 km². Access from the coast is by river, road and air. The Berbice River provides the main avenue for the movement of people and supplies. Road links to the capital city, Georgetown, are in the form of a paved, all-weather road to Linden and loose surface all-weather road to Ituni. Access from Ituni to other parts of the Savannahs is by tracks and roads of variable quality. River crossings are made possible through the use of pontoons. A number of airstrips in the area, permit the use of light and medium aircraft which are mainly used to transport personnel.

The Intermediate Savannahs have developed on the "white sand plateau" which occupies the greater part of north-eastern Guyana. Geologically, this plateau corresponds to the Berbice Formation (Pliocene to Pleistocene) and
Fig. 1  The "Intermediate Savannahs".
consists of sub-continental and old deltaic deposits of sands and clays with occurrences of bauxite, laterite and kaolinitic clay. The surface is characterized by a predominance of white sand with brown loamy and sandy clay (Brown Sands) sediments irregularly dispersed. The entire plateau covers an area of approximately 64,000 km² with altitudes varying from 16 m near the coast to more than 150 m further inland (TAMS, 1976).

**Topography, climate and vegetation**

The area is of generally low elevation and relief. Low undulating hills rise to about 50 m from their bases. The homogeneity of the sands has given rise to a simple dendritic drainage pattern which in itself is an expression of the existing topography. With very few steep slopes, natural erosion is minimal despite the sparse vegetation. However, as noted in the TAMS (1976) report, where man has disturbed the natural environment, erosion commences with surprising speed. One significant feature of the landscape is the presence of abandoned termite hills which constitute the only serious obstruction to land clearing since these have to be levelled prior to land preparation.

A tropical humid climate has been described for the Intermediate Savannahs where annual rainfall has a bimodal distribution; 40-60 per cent of annual precipitation is usually experienced in the long rainy season of mid-April to mid-August with less than 20 per cent being associated with the often unpredictable short wet season of mid-November to January. The long dry season of mid-August to mid-November is associated with soil moisture deficit (Fig. 2).

The region's mean temperature is 26°C with diurnal fluctuations of up to 10°C being more pronounced than seasonal fluctuations of 1.5°C (Hydrometeorological Service, 1971) Mean relative humidity is 80 per cent but daily variations are quite large — 92 per cent in the early morning periods and 65 per cent in the early afternoons.

Although not classified as a rain-forest climate, the region's daily sunshine hours average only 6 per annum. This is mainly due to a significant amount of cloud cover, especially during the rainy months. The climatic pattern, on the whole, facilitates two rainfed crop seasons with the second, coinciding with the short rainy season, being devoted to crops of shorter growing period.

The term "savannah" as applied to this ecozone is in many respects a misnomer since about 70 per cent of the natural vegetation consists of forest and shrub with only 25 per cent being grassland type vegetation in association with marsh and swamp plants. Forests are found mainly on the finer textured soils and include a number of hardwood species such as greenheart (Lecythis radiata), bullethead (Manilkara bidentata), wallaba (Eperua falcata) and dakama (Dimorphandra conjugata). In the true savannahs, two grass species dominate — Andropogon spp. and Trachypogon plumosus. Sand-paper trees (Curatella americana) typically dot the landscape while along the river levees a number of palms such as the kokerite (Maximiliana regia), manicole (Euterpe edulis) and corkwood (Pterocarpus officinalis) are found. Cultivation of annual crops has traditionally been carried out on the "savannah lands" mainly because of the minimal land clearing required, while a number of the hardwood species occurring in the forests are harvested for timber.

**Dominant kinds of soil**

The soils of the "white sand plateau" include well drained Oxisols, Entisols and Ultisols. They range in texture from the coarse white sands to the medium sandy clays. The most extensively occurring soils are the Ebina sandy loam (Typic Paleudult), the Kasarama loamy sand (Arenic Paleudult), the Bukurana loamy sand (Grossarenic Paleudult), the Tabela sand (Typic Quartzipsamment) and the
Fig. 2 Average monthly rainfall, potential evapotranspiration and monthly number of crop rainy days for Ebini, Guyana.
Tiwiwid sand (Typic Quartzipsamment). The last named is usually referred to as "White Sand" while the former four are commonly known as the "Brown Sands".

A common feature of these soils is their relatively low pH, ranging from 4.3 to 5.9 within profiles and among types (Bullen et al., 1982; C. Bullen, M. Granger and J. Piggott, unpublished data). They are almost devoid of inherent fertility in both surface and subsoil. CEC and base saturation are typically low and extractable P is conspicuously lacking and this is considered a major limiting factor. Except for the surface soil in the Tiwiwid sand and the Ebini sandy loam, organic matter content of these soils is negligible. Thus, coupled with the peculiarity of texture, the high intensity of rainfall and the topography, creates a potential erosion hazard which is readily manifested upon the commencement of soil tillage activities. Some of the soils have exhibited a tendency towards surface encrustment—a phenomena which is potentially hazardous to seedling emergence.

The authors quoted above also noted that the general tendency of lower base saturation values in subsoils implies the existence of a chemical barrier which may inhibit root penetration and consequently retard effective use of both moisture and nutrients, particularly in the Brown Sands.

Land utilization in the Intermediate Savannahs

Historical review

It has been estimated that about 70 per cent of the land area is under forest type vegetation with slightly less than 25 per cent under savannah type vegetation (TAMS, 1976). As noted earlier, annual crop production has been entirely devoted to the "savannah" areas and this holds true for other kinds of agriculture that has been practised. On the other hand, timber extraction is carried out by several privately or co-operatively owned enterprises in the forested areas.

The "Brown Sand" savannahs first came under scrutiny for agricultural purposes in the 1930s. The Takama area (Fig. 1) had been used as a resting ground for cattle brought from the Rupununi along a long and tortuous trail. Follet-Smith (1930) described the area as being "unsuitable for cattle" noting that cattle became emaciated and developed "a pica for bones". Analysis showed that the soils were deficient in P and K while the grasses were significantly deficient in P and had low percentages of Ca and K.

These early studies ultimately led to the establishment of a research station at Ebini in 1941. Initially, this facility focused on the problems associated with economic beef cattle production in the Intermediate Savannahs. This was expanded in the 1950s with the inclusion of crop oriented research.

Ebini, over the years, has remained the centre for research activities both in livestock and crop production. In other areas within the region, commercial annual crop production has been attempted but the efforts were not sustained. The Kibilibiri savannahs with an area of over 4,400 ha, saw the first such effort, commencing with soya bean and maize cultivation in 1970 (Fletcher, 1977). This project in later years found it more economical to produce other annuals such as peanut and cowpea. In similar fashion, a joint venture involving the Governments of Guyana, Trinidad and Tobago and St. Kitts/Nevis, commenced in 1975 in the Eboroabo savannah. Here again, corn and soya were the initial crops of choice but in the ensuing years other crops such as pigeon pea were also planted. In 1974, the Government of Guyana established the Guyana National Service (GNS) — a paramilitary organization which had a responsibility for hinterland settlement among other objectives. The GNS established, and still operates, a centre at Kimbia in the Intermediate Savannahs. From 1975 until recently cotton (annual) was the crop of emphasis at this location with
cowpea, peanut and to a lesser extent sorghum being planted in rotation.

Each of the above-mentioned enterprises initially envisaged large-scale cultivation of the crops of interest. Each was constrained by a number of factors, not the least of which centred around the acquisition of agricultural inputs which required foreign exchange. But the experiences of these ventures also highlighted a range of technical constraints. Fletcher (1977) in reviewing commercial soyabean production in Guyana noted that several instances of crop failures or low yields were attributable to climatic or management problems. The research effort, although not as consistent as might be expected, has largely been fuelled by the experiences of these attempts at commercial production which at the present time are again placing emphasis on soyabean.

**Development of livestock enterprises**

Following the early investigations on animal survival in the savannahs and the establishment of the Ebini Research Station in 1941, a considerable and largely sustained effort in livestock research has led to a successful commercial cattle enterprise at Ebini. Mineral deficiencies in soil and plant were recognized as a major limiting factor which caused deaths in cattle (N. Holder, unpublished data, 1974). To some extent the feeding of bone meal ameliorated this situation but in later years, commercial preparations of mineral supplements were designed and used.

Low conception rates were improved through several practices. The assignment of range management and livestock experts to the station in 1953 ensured continuity of the research effort and saw calving percentages increase from 23 to 52 by 1955. Calving intervals were reduced from 32 months to 18 months by 1957. During this time also, considerable research was conducted on the performances of a number of breeds of beef cattle as well as the establishment and performance of a range of improved pasture grasses. Dumont (1963) in reviewing the achievements of the research unit expressed the opinion that a viable economic enterprise was already in the making.

In the period 1969 - 1975 livestock research at Ebini was further intensified. Valuable information was garnered on such phenomena as:-

(i) yields of different grass species in the Intermediate Savannahs

(ii) the effects of different feeding programmes on liveweight

(iii) the results of molasses-urea feeding on liveweight

(iv) the reproductive behaviour of cross-bred cattle.

(v) the evaluation of different types of fences for cattle (Holder, 1982).

Based on the advances made at Ebini, the Government of Guyana determined that the station had reached a level of sophistication justifying its conversion to a commercial enterprise. The Livestock Development Company Limited (LIDCO) took over theEbini herd in 1975 after which the entity was run on a commercial basis. The farm now consists of a beef ranch with over 3,200 heads of cattle as well as a 200-cow dairy unit. The Company proposes further expansion of the beef enterprise while the dairy farm has already achieved stabilization (LIDCO, 1987).

The feasibility of sheep and goat production on the Intermediate Savannahs has been receiving attention since 1973. The technical coefficients obtained over the years have not been as encouraging as in the case of cattle. Indeed, disease problems such as foot rot as well as low reproductive rates have combined to determine a relatively static flock. The research effort has also been discontinuous and inconsistent.
Current status of agriculture

From the foregoing, it may be readily appreciated that the major success in agriculture in the Intermediate Savannahs, has been in the area of cattle production. The sporadic ventures into large-scale annual crop production have, by and large, either terminated or have been downgraded due to an inability to acquire the inputs required. However, for a variety of reasons, commercial crop production on the Intermediate Savannahs remains a desirable and, to some, an attainable goal. Firstly, it has been recognized that a number of annual crops, even though cultivable on the coastal plains, albeit with extreme difficulty, would be better suited for the lighter textured soils of the savannahs. Secondly, the pressure for land space on the coast forces active consideration of the savannahs where the land resources are much greater. Thirdly, the commercial ventures referred to above have yielded singular but significant successes which are thought to be repeatable.

Based mainly on these premises, crop production activity continues to be an important part of the region's agriculture. Private farmers along the Berbice River who have traditionally practiced "slash and burn" methods for maize cultivation in the forested areas, have in recent years exploited, at a growing rate, the soil resources in the savannahs for peanut production. While little information is available with respect to yields obtained, the continuing trend in this area, certainly suggests that the financial gains are attractive.

A newly formed Soyabean Company has harvested, in 1988, close to 120 ha of soya and is planning to gradually increase the acreage under cultivation while diversifying its operations with the use of rotational cropping. The GNS centre at Kimbia is still engaged in commercial peanut production even though the effort has been scaled down, largely because of difficulties in acquiring inputs.

In support of these efforts, the National Agricultural Research Institute (NARI) has established a field research unit at Ebini. The purview of this unit includes, but is not restricted to, soil management studies, soil-plant-fertilizer interactions, testing the development of suitable and adaptable varieties of cowpea, peanut and soyabean and the maintenance of germplasm of selected crop varieties. The unit works in close collaboration with the commercial production entities with a view towards informing its own efforts while disseminating information.

Constraints to crop production

Climate

The effects of climatic factors on the crop growing environment may be discerned both directly and indirectly. While the direct impact of rainfall is readily manifested in terms of sheet and gully erosion in soils, it is not always appreciated that relative humidity is of importance in the development of pests and diseases which affect crops.

Although formal research on the erosion problem has been lacking, field observations point to significant losses in both soil and crop yields because of this phenomenon. It is not uncommon to experience in excess of 150 mm of rainfall within a 24-hour period during the wet seasons. This coupled with the peculiarities of soil texture, the lack of organic matter and the topography of the land, combines to present a formidable problem in terms of the crop-growing environment. Contour farming has been attempted on a limited scale at Kimbia and Ebeorabo and this approach, while holding some promise as a combative measure, requires accurate field surveys to facilitate field layout. The use of grass strips and grassed waterways to slow down the rate of run-off has been suggested but not actively promoted.

From another aspect, rainfall has been identified as a limiting factor especially
in regard to the shorter crop season referred to earlier. The short wet season is quite often unpredictable; both in terms of its duration and total precipitation. Soil-moisture relations which are already aggravated by the sandy nature and low organic matter content of soils are therefore further affected in this period. The Brown Sands, on the average, will hold about 25 mm of available water per 30 cm of soil and water stress will be readily manifested after about half this amount has been used. The use of irrigation, on the other hand, presents its own problems which range from identification of adequate water resources to the economic viability of using this practice. The general consensus appears to be that irrigation for commercial crop production would not be economically justifiable. However, in the case of seed production the use of irrigation would be vital to ensuring the output of good quality material.

As in many other parts of the tropics, relative humidity plays an important role in many aspects of the crop production cycle. As noted earlier, the diurnal changes in relative humidity are, by far, more pronounced than any seasonal fluctuations. The morning periods are usually characterized by high humidity with comparatively low values in the afternoons sometimes accompanied by winds. The environmental conditions associated with high humidity are particularly conducive to the growth and development of range of fungi including *Cercospora*, *Choanephora* and *Collectotrichum* (Singh and Allen, 1979) all of which have been observed to attack cowpea varieties grown in the savannahs. Chemical control of these fungi is currently regarded as a standard practice although some successes have been achieved in the search for resistant varieties. For example, Minica I cowpea is presently recommended over the California No.5 variety partially due to its resistance to Lamb's tail pod rot (*Choanephora* spp.)

The changes in humidity are more pronounced in the long dry season which usually coincides with the main harvesting period. Cowpea harvesting in particular, and to a lesser extent cotton, are affected by the atmospheric conditions prevailing. The early morning period is often not available for harvesting since the pods and bolls may be too wet to allow proper mechanical harvesting. On the other hand, the heat and low humidity of early afternoon can lead to shattering of pods in some cowpea varieties. This implies a constriction of the time period available for harvesting, and depending on the scale of commercial cropping, may necessitate the use of additional harvesters in order to ensure timeliness of operations. Again, both chemical and genetic methods have been used to combat the problem. The use of drying agents such as Grammoxone has been successful but is considered costly. On the other hand, varieties with low potential for shattering have been identified and used e.g. Minica I cowpea.

**Soil fertility**

A considerable segment of the total research effort so far has been dedicated to studies on various aspects of soil fertility in the Intermediate Savannas. As is shown in Table 1, the dominant soils are severely deficient in all major and most minor nutrient elements.

For most crops, Ca, P, K and Mg appear to be the main limiting elements but there are indications that micronutrients will probably decrease yields as the major elements become non-limiting (Bullen et al., 1981b). The work of Downer (1972) and Chesney (1979) support the contention that these major elements are critical to the nutrition of crops grown on the Brown Sands. Several studies on the responses of various crops to fertilizer applications of the major elements have generally concluded positive responses at varying levels of application (Chesney, 1973; Chesney 1975; Kazim, 1979).

The cation exchange capacity of the soils, in both surface and sub-surface horizons, is dominated by exchangeable
## Table 1  Chemical characteristics of the "Brown Sands" of the Intermediate Savannahs of Guyana

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>pH</th>
<th>Org.C (%)</th>
<th>Kjel. N (%)</th>
<th>Exch. Acid</th>
<th>Ca</th>
<th>Mg</th>
<th>K</th>
<th>Na</th>
<th>Total</th>
<th>CEC</th>
<th>Base Satn. (%)</th>
<th>Truog P (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tabela Sand (Typic Quartzipsamment)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - 20</td>
<td>5.1</td>
<td>0.7</td>
<td>0.05</td>
<td>0.2</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.3</td>
<td>0.5</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>20 - 51</td>
<td>5.2</td>
<td>0.3</td>
<td>0.03</td>
<td>0.2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
<td>33</td>
<td>4</td>
</tr>
<tr>
<td>51 - 91</td>
<td>5.3</td>
<td>0.3</td>
<td>0.02</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>9 - 122</td>
<td>5.2</td>
<td>0.2</td>
<td>0.01</td>
<td>0.3</td>
<td>0.0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>0.6</td>
<td>50</td>
<td>4</td>
</tr>
<tr>
<td><strong>Kasarama loamy sand (Arenic Palendult)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - 25</td>
<td>4.8</td>
<td>1.2</td>
<td>0.05</td>
<td>0.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>25 - 41</td>
<td>4.7</td>
<td>0.9</td>
<td>0.04</td>
<td>0.9</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>41 - 56</td>
<td>4.7</td>
<td>0.8</td>
<td>0.05</td>
<td>0.7</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>56 - 86</td>
<td>4.7</td>
<td>0.2</td>
<td>0.02</td>
<td>0.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.3</td>
<td>0.8</td>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td><strong>Ebini Sandy Loam (Typic Palendult)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - 8</td>
<td>4.3</td>
<td>2.8</td>
<td>0.16</td>
<td>1.6</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
<td>0.2</td>
<td>1.4</td>
<td>3.0</td>
<td>47</td>
<td>7</td>
</tr>
<tr>
<td>8 - 31</td>
<td>4.4</td>
<td>2.2</td>
<td>0.11</td>
<td>1.7</td>
<td>0.0</td>
<td>0.5</td>
<td>0.1</td>
<td>0.1</td>
<td>0.7</td>
<td>2.4</td>
<td>29</td>
<td>10</td>
</tr>
<tr>
<td>31 - 41</td>
<td>4.7</td>
<td>1.6</td>
<td>0.08</td>
<td>1.3</td>
<td>0.0</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>0.5</td>
<td>1.8</td>
<td>28</td>
<td>6</td>
</tr>
<tr>
<td>41 - 76</td>
<td>4.9</td>
<td>0.8</td>
<td>0.06</td>
<td>0.7</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.9</td>
<td>22</td>
<td>5</td>
</tr>
</tbody>
</table>

Source: Bullen et al. (1982)
acidity, mainly from Al. This condition is more pronounced in the subsoil (Downer, 1972; Chesney, 1979; Bullen et al. (unpublished data). Soil acidity, especially in the subsoil, has been identified as a major chemical limitation to effective root development (Ritchey et al., 1980; Foy et al., 1980). The detrimental effects of low subsoil pH on root growth has been demonstrated to be intimately associated with exchangeable or solution Al. This problem of Al toxicity is usually prevalent below pH 5.5 and more so below pH 5.0. In the savannas of Brazil and Guyana it has been noted that most soils have more than 40 per cent Al saturation in both surface and sub-surface horizons (Lopes and Cox, 1977; Bullen et al., 1982; C. Bullen, M. Granger and J. Piggott, unpublished data).

Over time, it has become standard practice to apply limestone to the Brown Sands in order to reduce soil acidity, increase pH as well as to provide a source of Ca. Research has led to the development and use of recommended levels of limestone for the range of crops grown. Other soil ameliorants such as "low grade Rock Phosphate" which is an admixture of Rock Phosphate and Ca CO₃ have also been used, but it should be noted here that formal research on the use of alternative soil ameliorants has been lacking.

Crops grown with apparently adequate levels of fertilization on the Brown Sands tended to have poorly developed root systems (Bullen et al., 1982; C. Bullen, M. Granger and J. Piggott, unpublished data) This, it was felt, led to inefficient exploration of the rooting zone and ultimately to inefficient use of nutrients and water. While the specific causes of shallow rooting are not always easily identifiable, it was thought that the high level of sub-soil acidity in these soils may have constituted a chemical barrier to root penetration.

Experiments on deep incorporation of limestone (Bullen et al., 1983) indicated that this practice may have been of some importance in the amelioration of the observed condition in cotton.

Soil physical factors

The physical make-up of the Brown Sands is generally regarded as favouring tillage operations and rooting activity. However, a number of physical factors can adversely affect both tillage and rooting under special circumstances. In the case of the Ebini sandy loam, for example, where particle size distribution shows a higher clay content than in other brown sand soils, it has been observed that on drying, the surface soil tends to harden to the extent of impeding mechanical tillage. On the other hand, this soil has a higher moisture holding capacity which, in the rainy season, often results in puddling and also limits tillage activity. The soil is thus characterized by a relatively narrow moisture regime for tillage operations.

Physical factors that may limit root development include mechanical impedance and soil-water relationships. In the Intermediate Savannahs, bulk densities are relatively high (Bullen et al., 1982; C. Bullen, M. Granger and J. Piggott, unpublished data). This may have some undesirable effects on root penetration. Dookie (1984) found that deep tillage reduced mechanical impedance to root growth in cowpea and resulted in increased crop yields. The effects were, however, temporary and did not carry over from one crop season to another. This observation is seen as having some importance in view of arguments raised on the utility of no-tillage or reduced tillage systems in the Intermediate Savannahs. This latter approach has been seen as one way of combating the serious problem of soil erosion associated with currently used tillage practices.

Another soil physical phenomenon of importance in the Brown Sands is an observed tendency towards surface encrustment when the natural vegetation has been removed. It is particularly more relevant to the Kasarama loamy sand and the Ebini sandy loam — soils with higher clay contents in the surface
horizon. The phenomenon has not been thoroughly investigated but field observations in respect of cotton grown at Kimbia, have shown that a potential hindrance to seedling emergence is created by the encrustment (Bullen et al., 1982).

**Weed infestation and succession**

This aspect of the crop growing environment has been largely unresearched except for field observations and the conduct of a limited number of herbicide trials. Thus the economic consequences of weed infestation have not been quantitatively established. However, it is generally accepted that significant yield losses in a number of open-row crops are attributable to the presence of weeds.

Across the savannahs, interesting observations have been made on the changes in vegetation which take place with the onset of mechanized commercial crop farming. The native vegetation consisting mainly of grasses is seen as reflective of the poor inherent fertility of the soils. On the other hand, abandoned crop fields are observed to have entirely different species of plants (both mono- and dicotyledonous) growing with a vigour that apparently reflects an enhancement of the soil fertility status as a result of cropping.

The possible method(s) of introduction of weed species into the savannahs have not been determined by any thorough study. It is thought that one possible means is through the liming materials which are used. However, it is accepted that weeds are spread from one field to another through improper tillage practices. Field observations have shown that one of the first weed species to appear (usually after a field has been cultivated once) is nut-grass (*Cyperus rotundus*). This grass is known to have a low tolerance for shade (Hammerton, 1974). As such it is soon overpowered by other species such as *Eleusine indica*, *Digitaria horizontalis*, *Echinocloa colonum*, *Emilia sonchifolia* and *Portulaca oleracea*. It is noticeable that the broad-leaved species are usually less competitive. Chemical control of a number of these species has been largely successful but in the case of nut-grass in particular this approach is known to be very costly.

The succession of weeds ultimately leads to a predominance of broad-leaved species in association with some of the latter grasses. However, it has been noted that even in cases where fields have been left to fallow for years, upon cultivation the nut-grass usually emerges first. Some consideration has been given to researching biological methods of weed control. The use of a pasture grass as a fallow in the cultivation system is seen as a possible approach. *Brachiaria humidicola* which is extensively used in pastures for cattle in the area is known to be very aggressive and competitive, to the extent of eliminating most other plant species. On the other hand, the grass is very slow in establishing and has low tolerance for shade. A possible approach can therefore involve initial cropping of fields for two or four seasons, followed by a grass fallow after which fields are again planted to open-row crops. Apart from weed control, this system appears to promise additional advantages in terms of soil organic matter enhancement and erosion control, as well as the possibility of combining both crop and livestock production systems.

**Problems associated with mechanized crop production**

In general, it may be argued that a technological package for large-scale open-row cropping on the Brown Sands already exists. However, in the course of application of this package, several problems are encountered. Of greatest significance here, is the scheduling of operations having regard for the vagaries of weather, texture of soil, the strength of the available machinery and equipment fleet, and the need to harvest crops at the best possible time. These factors impact heavily on the planning of the crop cultivation operations.
The agro-meteorological services in the area generate data that are of use in characterizing past weather patterns. But there is need for additional capability in terms of predicting, with a fair degree of accuracy, monthly and even daily weather patterns (Bullen et al., 1982). Such a service can be of immense advantage to operatives in the field who would be in a position to deploy resources much more efficiently. A case in point is the issue of dealing with tillage operations on the Ebini sandy loam soil which, as noted earlier, has a relatively narrow moisture regime for tillage. On numerous occasions, tillage operations have been seriously hampered because unexpected showers have come at a time when this soil type was being prepared. On the other hand, harvesting operations have also been affected by showers of relatively short duration which if predicted might have also determined a deployment of resources to cope with the situation.

Deployment of machinery and equipment often poses serious problems to the field manager. An example of this is seen where, with relatively large acreages under cultivation, a particular type of tractor might be needed to carry out two kinds of activity such as planting and inter-row cultivation. This often raises the question of the optimum size of the machinery pool required for the particular unit. But more fundamentally, there exists a need for a refinement of the agricultural mechanization technology for crop production with emphasis being placed on matching machine and equipment capability with the environment and the required operations.

One approach to scheduling crop production activities, adopted for some time at Kimbia, has been a reverse approach when activities are planned from the harvesting of the crop backwards to land preparation (Piggott, personal communication, 1983). This approach emphasizes the importance that should be attached to harvesting and was derived out of a number of experiences of crop failures due to ill-timed harvesting operations. Fletcher and Gordon (1977) referred to the inter-relationships of several agronomic, environmental and mechanical factors which contributed to the feasibility of mechanical harvesting of cowpea at Kibilibiri. This study, recommended two periods of day as ideal for harvesting of this crop but also emphasized that crop scheduling had important implications for the final yield and quality of the crop.

Proposals for further research

Enhancement of rooting activity

Recent research (Bullen et al., 1983; Dookie, 1984) in this area has pointed to the importance of rooting zone activity in improving crop yields. Bullen et al. (1983) reported substantial yield increases in cotton, soyabean and cowpea on the Ebini sandy loam, Kasarama loamy sand and Tabela sand soils when the roots of these crops penetrated between 10 and 50 per cent deeper. These observations were made when two methods of limestone application — surface and deep incorporation — were being compared. Dookie (1984) studied the effects of deep incorporation of limestone as well as deep tillage on cowpea growth and yield. The results indicated significantly better yields with these practices compared with the traditional methods were limestone is applied to the soil surface and incorporated in the top 10cm of soil.

These findings require further refinement. It is necessary, for example, to establish field methods of ensuring uniform distribution of limestone throughout the entire rooting zone. A possible approach would be through the use of split applications in combination with appropriate tillage practices. Of some importance here is the issue of determination of the depth of rooting zone that may be considered optimal for the respective crops. This, in turn, can have ramifications for the types of tillage implements to be used.
Such studies will also have to take into consideration the texture of the soils and their propensity for compaction. Thus, ultimately a balance will have to be struck between the depth of tillage desirable and the use of implements that may result in unfavorable soil physical characteristics.

The use of alternative soil ameliorants also requires adequate investigation. In this regard, it should be noted that some commercial operations have opted for ameliorants other than the traditionally used limestone, mainly on the basis of cost and availability. The activity of low-grade rock phosphate — the mainly used alternative — needs to be thoroughly determined both in greenhouse and field studies. Similarly, work on the development of other alternative soil ameliorants, based on locally available resources, appears to be necessary from the point of view of the economic implications.

Past research efforts have devoted great attention to this area and have, over the years, led to a determination of the fertilizer requirements for most crops grown on the brown sand soils (Table 2).

While the recommendations in Table 2 can be, and are being, used in commercial production, further refinements are necessary with a view of optimizing the use of added nutrients. The interactions of soil, plant and fertilizer should be examined to determine (a) existing soil nutrient status, (b) levels of nutrient sufficiency and/or toxicity, (c) chemical behaviour of added nutrients, (d) responses to added nutrients through missing element and critical level techniques, (e) fate of added nutrients, residual effects, leaching characteristics and modifications of soil behaviour and (f) suitable nutrient sources, placement, timing and rates of application of fertilizers for the range of crops to be grown. These objectives can be achieved through a programme of regular soil testing along with greenhouse and field studies.

### Soil management

It has been established that the fragility of the brown sand soils demands that careful attention be paid to the development and use of adequate management systems. Such systems must encompass (a) proper methods of erosion control, (b) organic matter enhancement and maintenance, (c) suitable rotation systems and (d) appropriate soil tillage systems.

Reference has already been made in this paper, to the utility of pasture grasses in achieving some of the above objectives. Indeed, a system of land rotation involving both crop and livestock production, is ultimately envisaged for the Intermediate Savannas. Such a system will feature:

(i) Initial cultivation of virgin lands for annual crops for two or four seasons.

(ii) Pasture and establishment and use for livestock production, for a period to be determined.

(iii) Reversion to annual crop production, for a period to be determined.

This approach, it is felt, can have several technical as well as economic advantages. The inclusion of grass leys in the rotation sequence can significantly reduce soil degradation caused by erosion and can also lead to enhancement of soil organic matter content. The utility of *B. humidicola* in terms of weed control has been discussed but a scientific approach should be taken to further determine the efficacy of this grass as a means of weed control. From the economic standpoint, the amalgamation of crop and livestock enterprises is seen not only as a means of spreading risk but also as a method of generating increased income while reducing overall production cost.

The role of reduced tillage systems in the context of this approach would have to be carefully determined. On the one
Table 2 Fertilizer requirements of some crops grown on the Brown Sands of the Intermediate Savannahs of Guyana

<table>
<thead>
<tr>
<th>Crop</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Mg</th>
<th>Micronutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/ha</td>
<td></td>
<td>kg/ha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legumes</td>
<td>34-56</td>
<td>34-44</td>
<td>83-112</td>
<td>20-34</td>
<td>34-56</td>
</tr>
<tr>
<td>Peanut</td>
<td>34-56</td>
<td>44-59</td>
<td>112-139</td>
<td>27-41</td>
<td>34-56</td>
</tr>
<tr>
<td>Maize/sorghum</td>
<td>112-170</td>
<td>37-44</td>
<td>91-112</td>
<td>27-41</td>
<td>34-56</td>
</tr>
<tr>
<td>Cotton</td>
<td>84-120</td>
<td>47-56</td>
<td>66-89</td>
<td>9-20</td>
<td>34-56</td>
</tr>
</tbody>
</table>

Source: Bullen et al. (1983)

hand a ensure the availability of nutrients throughout the rooting zone.

It therefore appears to be necessary to determine the optimum intervals for maximum tillage operations and the effects on soil and plant of reduced tillage systems.

Other research activities

Although soil-related research has occupied centre stage for some time and is likely to remain the main focus of research for the immediate future, serious attention will also have to be paid to other areas:-

- Climatological data gathering and analysis with a view towards developing a weather prediction capability.
- Pest management programme development having regard for both chemical and biological control.
- Crop varietal selections in order that more adaptive crop varieties may be identified.
- Studies on the economics of large-scale commercial operations as an integral part of the research.

References


An account is given of research work on crop cultivation on the sandy loams of the Zanderij belt performed since the late 1960s. These soils are characterized by good physical properties, high acidity, large amounts of exchangeable Al and small quantities of nutrients.

Emphasis was on developing mechanized arable farming systems for major food crops. Although that part of the work had to be terminated before it was completed, important information on the individual crops was gathered. Maize, sorghum, groundnut, soybean, cowpea and mungbean grew well, provided rainfall distribution did not deviate too much from the many years' average for the area and large quantities of lime and fertilizer were applied. Fully-mechanized cultivation, from soil tillage through to harvest, was comparatively easy to realize, but expensive. On the other hand yields were relatively low. As a result production costs per ha as well as per kg grain were (too) high.

Other work included oil palm (at present, next to grasses, the only commercially grown crop in the Zanderij region), sugar cane, pineapple, citrus, banana, cassava, sweet potato, pigeon pea, cover crops, crops producing mulch or green manure, and leucaena.

Recorded systematic work with crops in Suriname's Zanderij Belt started in the late 1960s and early 1970s, when roads built for the Forestry Service opened up the sparsely populated area.

First the experimental farm at Coebiti (60 ha) was established, followed several years later by the experimental farm at Kabo (30 ha). Before clearing, both sites were covered with moderately heavy rain forest. The land is mostly flat and the soils are predominantly unbleached sandy loams. In general natural drainage is good. Average annual rainfall at the farms is approximately 2200 mm and shows a bimodal distribution: a long rainy season from mid-April to mid-August as well as a short rainy season from early December to early February are characterized by a mean monthly precipitation of 200-300 mm, while during the long and short dry seasons in between, the average rainfall per month does not exceed 100-150 mm (Table 1).

### Table 1. Average monthly rainfall at Zanderij Airport in the period 1958-1982

<table>
<thead>
<tr>
<th>Month</th>
<th>Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>200</td>
</tr>
<tr>
<td>February</td>
<td>136</td>
</tr>
<tr>
<td>March</td>
<td>146</td>
</tr>
<tr>
<td>April</td>
<td>223</td>
</tr>
<tr>
<td>May</td>
<td>286</td>
</tr>
<tr>
<td>June</td>
<td>309</td>
</tr>
<tr>
<td>July</td>
<td>251</td>
</tr>
<tr>
<td>August</td>
<td>181</td>
</tr>
<tr>
<td>September</td>
<td>103</td>
</tr>
<tr>
<td>October</td>
<td>95</td>
</tr>
<tr>
<td>November</td>
<td>117</td>
</tr>
<tr>
<td>December</td>
<td>187</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2234</strong></td>
</tr>
</tbody>
</table>

The mean sunshine duration is highest in the long dry season (approximately 9 hours per day in September and October) and lowest in the period January through June (approximately 6 hours per day or even less). Under
normal circumstances air movement is hardly noticeable; strong winds rarely occur.

Many experiments were conducted and many studies begun in the years up to 1981/82, almost all of them at the farms mentioned above. The great majority dealt with annual food crops; grasses and tree crops received less attention from the scientists working in the area. It is regrettable that the radical changes in the political scene and the collapse of country's economy in the early 1980s ruined these comprehensive research projects. Very little work has been done since.

Commercial crop production has not yet started in the Zanderij area. Private and government farms are still absent. So far crop growing for food and feed has been restricted to small subsistence farms of the scattered inhabitants of the region where shifting cultivation is practised, and to some cash cropping between young Pinus caribaea plants when, in the 1960s and 1970s, the Forestry Service replaced hundreds of hectares of natural forest by pure stands of this tree species.

In the following chapters emphasis is on the investigations carried out at the Coebiti and Kabo farms. The author wishes to state that he, although being one of the founders of the projects, was only indirectly concerned in the design and execution of most of the research programmes.

Objectives of the investigations

Almost 90 per cent of Suriname's population is living near the coast on land consisting of heavy clays and loams with a high water holding capacity and bad internal drainage. Consequently agriculture always has been, and still is, concentrated in the coastal area.

Labour being expensive in Suriname, any farming system involving the large-scale cultivation of annual crops will require a high degree of mechanization to have a fair chance of being remunerative. Modern rice growing has been shown to be such a system. Each year approximately 75,000 ha of rice is harvested producing some 300,000 tonnes of grain. However, the humid climate in combination with the peculiar characteristics of the coastal soils seriously hinders mechanized operations if annual crops other than paddy rice are grown. Even putting up cambered beds and digging an extensive open drainage system do not solve these problems.

Yet the country needs such other crops. For instance, the animal feeds industry alone requires annually 30,000 tonnes of maize and 20,000 tonnes of soyabean press cake. Therefore it became necessary to look for more suitable soils. Self-evidently the Zanderij region, with its vast areas of unused flat land and lying reasonably near the towns and villages of the coastal plain, was the first to catch the eye. Most of its soils are chemically less fertile but physically much better than those of the coastal region. Their sandy nature and higher infiltration rate do not as a rule require cambered beds, open drains or other facilities to cope with the excess water during and after heavy rain. Consequently the obstacles for mechanized farming seemed significantly less than on the coastal clays and loams.

The final objective of most investigations conducted in the Zanderij belt was the development of mechanized farming systems involving annual food crops other than paddy rice. This required, amongst other things; analyses of the chemical, physical and biological changes that occur in and above the soil when the natural forest is replaced by such crops; studies of the effects of tillage and other agricultural practices on various soil types and crops; observations on the growth and yield of crops under different external conditions; and comparisons of costs and benefits.
In addition some, though little, research was concerned with the performance of important perennial crops on the soils of the Zanderij Belt. Of course, pasture and fodder grasses were not overlooked. However, that part of the work is reported on in another paper (Alvares, 1989).

**Annual food crops**

**Cropping season**

Rainfall is the main factor limiting annual crop production in the humid tropical lowlands, especially if the soil has a low water holding capacity and supplementary irrigation is not available, as is the case in the Zanderij area. Thus in theory one might for each annual crop at any locality determine the optimal cropping season by projecting the crop's water requirements throughout its life cycle on existing tables or graphs showing the average rainfall over many years in each successive period (e.g. day, week, month) of the calendar year. On the basis of those data the optimal cropping seasons for the major food crops grown in the trials at Coebiti and Kabo would be:

- for maize, sorghum, groundnut and soyabean: early May to late August
- for cowpea and mungbean: late December to late February.

Likewise it can be explained that cowpea and mungbean, having a growing cycle of approximately 2 months, can best be sown in the last week of December and harvested in the last week of February.

That much for the theory. Unfortunately, however, in the case of the Zanderij Belt the long-term average monthly rainfall data are unreliable in the sense that commencement and termination of the seasons as well as the amount and distribution of the precipitation show considerable variation from year to year. This is particularly true for the short rainy and the short dry seasons: the possibility of a water shortage in the former is large and often the latter is a relatively wet, instead of a dry period.

The research groups have coped with these anomalies by adjusting themselves to the actual weather pattern in any given season. As a result three planting periods per year have evolved:

- from late March to early May for maize, groundnut and soyabean
- the second half of June for sorghum, groundnut, cowpea and mungbean
- from early November to mid-December for sorghum, groundnut, soyabean, cowpea and mungbean.

**Soil**

Because of their extremely poor chemical and physical soil properties, the agricultural possibilities of the white and brown sands of the Zanderij belt are very limited. All attention was therefore directed to the brown loams. It is estimated that approximately 150,000 ha of these consist of gently sloping, well-drained loamy soil where arable cropping could be possible. However, much of this soil occurs in small patches of several square kilometers or less bordered by sands, creeks or steeper slopes.
In their natural state, i.e. under rain forest, the physical condition of the brown loams is excellent. The infiltration rate is high, permeability is good, and there generally is sufficient air during wet periods. After clearing and burning, however, one is left with a soil low in organic matter and with a mineral fraction largely consisting of low activity kaolinite and quartz sand. Except for organic matter, structure forming agents that bond soil particles together are nearly absent. This general lack of structure-forming agents results in soils with a low structural stability. Forces like heavy rainfall and soil tillage can easily destroy the soil structure, resulting in a reduced infiltration rate, a decrease in macro-porosity, increased resistance to root penetration, and erosion caused by surface runoff. The reasonable amount of available water that is present under forest because of deep rooting, changes to a small amount after clearing.

Chemically the brown loams under rain forest are characterized by a high acidity, high contents of exchangeable Al, low contents of all major plant nutrients except N, and a low CEC. Deforestation followed by arable cropping abruptly breaks the nutrient cycle responsible for the fertility of the rain forest ecosystem. The large amounts of nutrients released within a short time upon burning and decomposition of the felled vegetation cannot be retained by these soils and are rapidly leached beyond the reach of most annual crops. Moreover, in contrast to the natural vegetation that is adapted to the acid soil, high in exchangeable Al, arable crops generally grow badly when the cation exchange complex is mainly occupied by Al ions in amounts toxic for them.

It follows that to alleviate the soil physical and chemical constraints rooting depth has to be increased; the soil has to be protected by a vegetation cover as long as possible; organic matter contents should be maintained at levels as high as practical; tillage should only be performed when the soil is not too wet; lime must be applied to raise the pH and to reduce the amount of exchangeable Al; and regular fertilizer applications are necessary to cancel the shortage of nutrients.

In liming, best results were obtained when quantities were given sufficient to raise the pH(KCl) to 4.3 or higher (from about 3.8). The long dry season turned out to be the best period for liming, since leaching losses in the subsequent short rainy season were limited, leaving sufficient residual effects for the crops in the long rainy season. In trials, rates varying from 0 to 2 tonnes Ca per ha were tested, applied in liming materials as diverse as Emkal (with 95 per cent CaCO$_3$) and Curaphos (with 75 per cent CaCO$_3$ and 5 per cent P). In general 1 tonne of CaCO$_3$ per ha every year gave satisfactory results, and at the same time increased the amounts of Ca on the absorption complex to levels needed to meet the requirements for Ca as a nutrient.

Data obtained from a large number of fertilizer trials involving N, P, K, Mg and minor elements justify the tentative recommendations presented in Table 2.

Mechanized field operations

As stated earlier arable farming systems to be developed for the Zanderij area have to be mechanized systems. Manual labour should be limited to a minimum. Of course machine capacity needs to be correctly adapted to the size and nature of the farm. Over-mechanization leads to an unnecessary increase in production costs, whereas in the case of a shortage of machine capacity favourable tillage or planting periods may be missed or harvests postponed with the penalty of losses. As important as knowing the correct machine capacity is a knowledge of the
Table 2. Tentative fertilizer recommendations (kg per ha per crop) for the Zanderij brown loams

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Maize</th>
<th>Sorghum</th>
<th>Grain legumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>In long rainy season:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>250 *</td>
<td>120</td>
<td>20</td>
</tr>
<tr>
<td>P</td>
<td>40</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>K</td>
<td>80</td>
<td>40</td>
<td>60 *</td>
</tr>
<tr>
<td>Mg</td>
<td>50</td>
<td>30</td>
<td>40 *</td>
</tr>
<tr>
<td>Outside long rainy season:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>120</td>
<td>120</td>
<td>20</td>
</tr>
<tr>
<td>P</td>
<td>40</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>K</td>
<td>80</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Mg</td>
<td>50</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

Minor elements: 25 kg fritted trace elements every 2 years

* Split dose, except when giving K to groundnut.

workability of every mechanized field operation.¹

There are strong indications also that on the Zanderij loams standard tillage practice is paying off. This comprises several steps. First, all weeds and crop rest are cut with a rotary slasher, which is necessary to obtain a good cover of the weeds. Slashing is followed by disc ploughing to a depth of 25 cm, harrowing and seedbed preparation. Less thorough tillage, such as rotavating to depths of 7 or 15 cm only, or no-tillage resulted in the long run in considerable yield reductions. Subsoiling, i.e. deep tillage whereby the soil is loosened at depths below the plough layer (in this case the working depth of the subsoiler was about 50 cm), did not always have positive effects on crop growth.

Conditions for ploughing were found to be workable if the moisture content of the 0-20 cm soil layer was between 18 and 26 per cent by volume. It was never too dry for harrowing with a rotary power harrow, but with a moisture content of the 0-20 cm soil layer of 24 per cent or more conditions became non-workable.

Mechanized planting was generally and successfully done with a 4-row pneumatic precision planter, which can handle all types and sizes of seed and is equipped with special fertilizing attachments². The workability criterion of 24 per cent moisture in the 0-20 cm soil layer for harrowing was proven to apply to planting too; at that moisture content soil started to clog the furrow openers of the planter.

In most experiments fertilizers were either applied at planting, or before or after planting using a pendulum

¹ If weather, soil and/or crop conditions during a certain period are such that a mechanized field operations can be carried out properly, this period is called workable. Soils can be too wet or too dry for tillage, mature crops can be too wet for harvesting, etc.; then conditions are called non-workable.

² Precision planting was essential for the experimental work, but for farmers a planter not as complicated and expensive would seem adequate.
broadcaster that can also be rigged for side-dressing.

Granular pesticides were applied in one operation simultaneous with planting by means of an applicator mounted on the planter. For other pesticides (including weedicides) a tractor-mounted sprayer was used.

Maize, sorghum, soyabean, cowpea and mungbean were harvested with a small self-propelled combine harvester, one of the smallest commercially available machines, whose mowing platform can be replaced by a 3-row picking table to enable maize harvesting.

Combining cowpea and mungbean directly from the stem posed problems due to their uneven ripening, mainly because green leaves and pods give the seeds a green coating in the threshing process. Mowing the crop and leaving it in the field to dry in a swath eliminated this problem, provided the combine was equipped with a pick-up attachment and mowing was followed by a few dry days since rain quickly leads to seed deterioration.

Workability studies showed that combining conditions were 100 per cent workable if the harvest day itself was dry and rainfall on the preceding day had not exceeded 4 mm. On the other hand conditions were found to be 0 per cent workable on a day with as little as 2 mm precipitation if it followed a day with more than 4 mm rainfall.

Mechanized groundnut harvesting was found difficult and time-consuming until machinery used for harvesting groundnut in the U.S.A. became available. After lifting, the crop was left a few days in the field for drying, resulting in considerably less damaged pods than when lifting was immediately followed by combining.

In general maximum yields are reached when a crop is physiologically mature. In the period between physiological maturity and harvest, losses may be experienced for various reasons. Nevertheless on farms there will often be several days or even weeks between the ideal and the actual harvesting date as a consequence of bad weather or insufficient machine capacity. In the projects on hand it was found that for maize a harvesting delay of up to approximately 1 month was not harmful provided the weather was dry, but led to yield losses of at least 200-300 kg grain per week in periods with heavy rainfall. Sorghum showed similar effects.

Maize

Maize cultivars used comprised locally grown land varieties, synthetic varieties composed of imported and locally developed inbred lines, and open pollinated varieties from CIMMYT, Mexico. The latter often slightly outyielded the former. Under favourable growing conditions the yield level was approximately 4 tonnes per ha (dry grain). The average yield in all experiments over a 10-year period of the treatments representing current cultural practice was 2.78 tonnes per ha, which is about 50 per cent less than yields normally reached in trials with the same cultivars and under similar weather conditions in the coastal area.

Planting date experiments, in which maize was sown twice a month for a period of over a year, suggested that available soil moisture is an important production determinant. Dry spells leading to drought stress often caused yield depressions, especially if coinciding with the period of flowering and grain filling.

Several plant density and spacing experiments were carried out. Usually yields were highest at densities of about 60,000 plants per ha, using a distance between rows of 75 cm and in rows between plants of 20-25 cm.

The prevalent disease and insect problems in the Zanderij area are leaf blight, different ear and kernel rots, fall army worm, corn earworm and stalkborers. Control of some of these pests with insecticides was possible,
though not considered economically feasible.

Weed control was completely chemical: a pre-emergence application of alachlor at 2.4 kg a.i. per ha. When maize was grown after groundnut the spraying of alachlor was followed by a post-emergence application of atrazine at 2.5 kg a.i. per ha, primarily to control volunteer groundnut.

**Sorghum**

Though in Suriname farmers do not grow sorghum, the crop was included in the research programmes for Coebiti and Kabo because of its drought resistance. The cereal's possible utilization was clear: a substitute for maize (and rice) in animal feeds.

The cultivars used were Martin, from the U.S.A., which had been cultivated at experimental sites in the coastal region for many years, and IS 2745 originating from ICRISAT, India. Both cultivars are of the semi-dwarf type. Tall cultivars are unsuitable for mechanized harvesting and have therefore not been considered. The average yield in all experiments over a 10-year period obtained with the current methods was 1.99 tonnes per ha (dry grain). Under favourable growing conditions the yield level was 2.5 tonnes per ha.

As ripening sorghum is extremely vulnerable to grain moulds capable of causing complete crop failures, it is essential that dry weather prevails during the maturing period.

The crop was always planted in rows 50 cm apart at a distance between plants in the rows of 12-15 cm, corresponding with densities of about 150,000 plants per ha.

Insects presented hardly a problem, whereas diseases often developed into serious calamities. Among these were grain moulds and head blight, for which cultivars with closed panicles (such as the ones in the trials) that do not dry quickly after rain (in contrast to open panicles) in particular are very susceptible. Unfortunately the fungi responsible for these diseases survive on the grains after harvest. Seedlings from such infected planting material showed delayed growth and often died soon after emergence. Full-grown plants were often attacked by other fungi, causing necrotic spots and red-brown stripes on leaves which as a result died prematurely.

As in maize, weeds were controlled by herbicide application only: post-emergence spraying of atrazine at 2.5 kg a.i. per ha, 10-14 days after emergence.

**Groundnut**

The groundnut cultivar generally used in the experiments was Matjan, a representative of the Spanish type and introduced from Indonesia. Matjan is the recommended cultivar for the sandy ridges in the coastal area where farmers grow it on a small scale. Various other Spanish type cultivars were introduced, among them Altika which was developed for acid, infertile soils in Guyana, but none of these proved to be better than Matjan. If growing conditions were favourable Matjan's yield level was 3 tonnes per ha (dry unshelled nuts). Averaged over all trials in the 10-year period the yield obtained with standard cultivation methods was 2.46 tonnes per ha.

Planting date experiments have shown groundnut to be more drought resistant than any other food crop grown in the area except cassava. Following a period of prolonged drought the production may be reduced, but the crop does not die and is still able to give a reasonable yield.

A total of approximately 150,000 plants per ha appeared to be the optimal density. To facilitate spraying and harvesting equipment the crop was planted in 150 cm wide strips between 50 cm wide wheel tracks. Each strip contained four rows 35, 50 and 35 cm respectively apart. The distance between plants in the rows was 12-15 cm.
Insect pests of economic importance have not been reported. Diseases, however, are very harmful. In fact leaf spot and leaf rust are the main factors limiting groundnut production in the Zanderij Belt. If not controlled properly they cause premature leaf drop which necessitates the harvesting of Matjan 3-4 weeks too soon, resulting in low quality seed and low production. Satisfactory control was obtained by application at 14-day intervals of chlorothalonil, starting 3 weeks after planting.

Serious weed infestation of the young plantings was adequately prevented by pre-emergence application of alachlor at 2.4 kg a.i. per ha.

Soyabean

Soyabean cultivars used were the local ones known as Laris and Vada (both introduced from Indonesia) Jupiter which performs well on acid, infertile soils in Guyana, and several cultivars provided by the University of Illinois under its international soyabean programme. Many others were tested. The average yield obtained in all trials over a 10-year period of the treatments with standard cultivation methods was 1.71 tonnes per ha (dry grain). Under favourable conditions, however, the yield level was almost 2.5 tonnes per ha.

Ripening seeds of soyabean are an easy prey for fungi and bacteria during rainy weather with little sunshine and high air humidity. It is therefore necessary to time planting such that the crop will mature in a dry period. On the other hand soyabean is very susceptible to drought during the pod-filling stage.

Planting was usually done in rows 50 cm apart at a distance between plants in the rows of 12-15 cm, that is at a density of approximately 150,000 plants per ha. There are, so far, no serious pests and diseases that limit soyabean production in the Zanderij region. Weed control was the same as for groundnut.

Cowpea

In the research programmes defined for the Zanderij Belt cowpea was seen as a catch crop. Having a short growing cycle and not requiring much soil moisture, it can be planted late in the season when the main crop has failed or could not be timely planted.

A large number of cultivars was obtained from IITA, Nigeria, and their performance measured against that of African Red, which is sometimes grown in the coastal area and is characterized by an upright growth habit, a fairly even ripening and pods that are held well above the ground. In most cases the introductions did not outyield the reference cultivar, but some of them showed attractive properties such as a more even ripening, an upright determinate growth habit and pods held above the foliage. If growing conditions were favourable the yield level was 1.2 tonnes per ha (dry grain). Standard treatments in all trials over a 10-year period gave an average yield of 0.97 tonnes per ha.

Usually the crop was planted in rows 50 cm apart with an average spacing between plants of 13.5 cm, corresponding to a density of about 150,000 plants per ha.

No serious insect pests and diseases were observed, except fungi that attack and destroy pods and seeds when the crop matures during a wet period.

Weed control was the same as in groundnut.

Mungbean

Like cowpea and for the same reasons mungbean was seen as a catchcrop. The cultivar used in the field trials is a locally grown type known as Katjang Idju. Various other cultivars were introduced from Taiwan but, although some of them performed well in observation plots, they were not as yet included in the large-scale experiments. The average yield of the local cultivar over a 10-year period obtained with standard cultivation methods was 0.77
tonnes per ha (dry grain). Under favourable growing conditions a yield level of 1.0 tonne per ha was reached.

In all plantings the distance between rows was 50 cm and in the rows between plants an average of 13.5 cm, resulting in a density of approximately 150,000 plants per ha.

Insects pests and diseases were not a problem. Fungi affected pods and seeds when ripening occurred in a rainy period, but caused not so heavy losses as in cowpea.

Weed control was the same as in groundnut.

Other food crops

Only a little work has been done on other food crops which might grow well on the Zanderij loams, mainly because it was obvious that they could not, or would not, easily meet the requirements of fully mechanized farming systems.

The performance of cassava, sweet potato and pigeon pea was studied in various observation plots. All three grew reasonably well. The yield level for cassava was 25-30 and for sweet potato 10-20 tonnes fresh tubers per ha. Pigeon pea reached yields of 1-2 tonnes dry seed per ha.

Supplementary irrigation

In many instances yields of maize, sorghum or soyabean were much lower than expected because of the occurrence of periods of drought stress in the months between planting and the onset of ripening. Experiments were carried out to ascertain the effect on yield of supplementary sprinkler irrigation during such periods. The results were remarkable. It was shown that irrigation has a strong positive influence on growth and yield when applied to avoid drought stress.

This is particularly important if the soils could be tilled and maize, sorghum or soyabean planted in the second half of the long dry season about one month before the heavy rains of the short rainy season are expected, ensuring that little artificially supplied water is needed (evapotranspiration of the crops in the first month of their growing cycle is considerably lower than in the second and third month) and ripening and harvesting will fall in the first weeks of the short dry season.

As cost/benefit analyses have not yet been made, it remains to be seen whether it would be economically feasible to buy, install and operate a supplementary irrigation system at arable farms in the Zanderij region. Moreover it is a fact that irrigation water is not readily available in that area.

Crop management and farming systems

Researchers working on annual food crops at Coebiti and Kabo have attempted to synthesize available experimental results into mechanized crop management systems for each major crop studied. They were the first, however, to admit that these systems are still more or less hypothetical and leave much room for improvement. In the systems, cropping seasons are defined, taking the requirements of the different crops and the climate-related workability problems with soil preparation, planting and harvesting into account. The total number of field operations and crop husbandry measures including amounts of fertilizers and pesticides is presented per crop. Eventually the cost per hectare of labour, machine use and other inputs is given.

They did not yet succeed in defining complete farming systems of which those major food crops would be constituents. There is not sufficient basic information for that. To mention just one example: as yet virtually nothing has been done to resolve the question as to which rotations are required to keep the soil physically and chemically in good shape and prevent weeds from becoming unmanageable.
About the only thing that can be said in this respect is that, as expected, some findings point to a strong positive effect of grass leys and leguminous cover crops.

**Economic feasibility**

Starting from the production costs included in the above-mentioned crop management systems the research team responsible for that part of the study composed Table 3.

To calculate the production costs a farm of approximately 30 ha and growing two crops per year was assumed. The off-farm costs as presented in Table 3 cover only the use of farm machinery (including labour) and the purchase of lime, fertilizers, pesticides, inoculum and seed. Farm machinery use amounts to $239 (maize) - $318 (groundnut), lime and fertilizers to $209 (groundnut) - $397 (maize), and pesticides, inoculum and seed to $52 (maize) - $407 (groundnut).

It follows that those off-farm costs are far from complete. Not included are miscellaneous but yet substantial cost components such as interest on investment and loans, housing, taxes, insurance, storage, transport, artificial drying of the freshly harvested grain, packing and packing material, the farmer's remuneration, and the commission/profit of the various middlemen.

For various reasons it would not be sensible to draw far-reaching conclusions from the above financial exercise, one of them being that prices of agricultural produce are much influenced by government policy. However, two things are clear: a) the costs of mechanized production of major annual food crops in the Zanderij region are relatively high, and b) a disproportionately large part of these costs has to be paid in foreign currency because almost everything has to be imported.

**Table 3. Prices, costs and yield levels of maize, sorghum, groundnut and soybean grown in the Zanderij Belt of Suriname**

<table>
<thead>
<tr>
<th>Crop</th>
<th>World market price c.i.f North Sea ports in 1980/81 (US$/tonne)</th>
<th>Off-farm production costs in 1980/81 (US$/ha)</th>
<th>Yield required to recover off-farm costs (kg/ha)</th>
<th>Average experimental yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>152</td>
<td>687.76</td>
<td>4525</td>
<td>2780</td>
</tr>
<tr>
<td>Sorghum</td>
<td>159</td>
<td>548.52</td>
<td>3450</td>
<td>1990</td>
</tr>
<tr>
<td>Groundnut</td>
<td>399</td>
<td>934.32</td>
<td>2344</td>
<td>2460</td>
</tr>
<tr>
<td>Soybean</td>
<td>292</td>
<td>543.14</td>
<td>1860</td>
<td>1710</td>
</tr>
</tbody>
</table>

**Oil palm**

The African oil palm is considered to be one of the most promising crops for large-scale cultivation in the Zanderij belt.

A part of the oil palm estate Phedra consists of loams and sandy loams of the Zanderij formation. The palms planted in these fields show excellent growth and production, notwithstanding the low to moderate fertilizer application and the absence of liming. Apparently oil palm, just as the original forest vegetation, does not experience ill effects from the high acidity of the soil and its large quantities of exchangeable Al.
Likewise an observation plot at Coebiti which was recently destroyed by fire proved that oil palm is a crop with a future in the Zanderij region.

Other crops

Work on other crops has been far less comprehensive and searching. Yet some of it is certainly worth mentioning.

Sugar cane

Looking for an alternative for the soil type on which sugar cane is traditionally grown — the heavy coastal clays which do not allow mechanized harvesting and various other mechanized operations — the clone D 141/46 was tested in several observation plots at Coebiti. The outcome was hopeful. Cuttings were planted early in the short rainy season in rows 1.5 m apart. The crop grew well if the soil was properly limed and fertilized. The roots appeared to penetrate the soil to a depth of 2 m, which may explain why in the records no mention was made of drought stress during the long dry season. At the age of 12 months the crop yielded on the average 130 tonnes net millable cane per ha containing 15 per cent recoverable sugar in its juice.

Fruits

Of the major fruit crops so far only pineapple, citrus and banana have been tried out in the Zanderij region, again on a small scale and solely at Coebiti.

Growth and yield of pineapple were such that eventually the crop might prove to be a suitable one for the area.

Contrary to expectations citrus did not grow well. Also yields were very poor. However, the few trees planted at spots where, after removal the forest, debris had been burnt did much better. This could indicate that by improving upon fertilizer use citrus might be given a better chance. Banana turned out to be a failure.

Cover crops

In most farming systems there may be a role for cover crops, either in the rotation or otherwise. With a view to that the following have been planted at Coebiti for observation:

a) Kudzu, Pueraria phaseoloides — for the Zanderij soils the best of the lot. On recently cleared, unfertilized land its growth is poor because of lack of P, but once the soil has been cropped a few times, Kudzu is established easily and forms a dense cover which is little affected by drought. However seed production is poor.

b) Calopogonium mucunoides — covers the soil well during wet periods, but loses most of its leaves in dry seasons so that little soil cover is left.

c) Centrosema pubescens — like Calopogonium.

d) Indigofera endecaphylla — like Calopogonium and Centrosema, but much less vegetative growth during the rainy seasons.

e) Mimosa invisa — like Indigofera.

f) Flemingia fruticulosa and F. vestita — produce very little vegetative material, remain small and flower early.

g) Psophocarpus palustris — appeared not to be adapted to the conditions; the seedlings stopped growing soon after emergence and their leaves were small and yellow.

Crops producing mulch or green manure

Canavalia ensiformis, several Crotalarias, Flemingia congesta, several Tephrosias and Gliricidia sepium were planted at Coebiti for the purpose of observation.

The Crotalarias are annuals, so that the amount of organic material (green
manure) they produce very much depends on the height they reach before the end of their life cycle. In that respect C. anagyroides, C. falcataria and C. striata performed best. Canavalia ensiformis and the Tephrosias appeared unsuitable for mulch production because of too little vegetative growth. Flemingia congesta had a slow start, but once established showed a steady growth and could be regularly cut back without the risk of dying. Gliricidia sepium was the one that excelled. Growth stagnation was never observed, not even in very dry periods, and after cutting back — usually twice a year — regrowth was always quick to appear and profuse. Dry matter in the clippings amounted to approximately 20 tonnes per ha per year.

Leuceana

Suriname participates in the regional OAS-project 'Leuceana as a source of feed, fuel and erosion control'. One of the field trials is situated at Coebiti. It was planted in April 1986, using approximately 4-months-old nursery plants of the local cultivar, some of the so-called giant cultivars (K8, K28 and K67) and two leafy cultivars (Cunningham and CF95) of Leuceana leucocephala. Liming preceded soil tillage. In the beginning growth was satisfactory. Unfortunately the armed struggle in the interior part of the country interfered with the accessibility of the experimental site. As a result maintenance has not been as good as it should be, and growth (wood production) and yield (feed production) were not regularly measured. In the course of 1988 conditions improved. A programme of periodic thinning coupled with height and girth measurements in the wood production plots, and of frequently harvesting the foliage in the feed production plots is now underway.

References


MECHANIZED CASSAVA PRODUCTION IN THE INTERMEDIATE SAVANNAHS OF GUYANA

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Georgetown, Guyana

Cassava (*Manihot esculenta*) has for too long been a "Cinderella" amongst the crops of Guyana. Like so many others of prime economic value (rubber, oil palm, solanum potato, sweet potato, sugar cane, cacao) it had to be transported from its area of development. Now, along with potato, the two must be the most important of root vegetable crops in the world. Not the least of its attributes is the ability to survive and produce on soils which would starve other crops and the Intermediate Savannahs of Guyana are totally suited to each other and together can be of major economic importance.

Work described here was carried out from 1967 to 1985 but with some breaks. The Intermediate Savannahs of Guyana and cassava are totally suited to each other and together can be of major economic importance.

The area lies east of the Demerara River, some 80 km inland and are traversed on a North/South axis by the Berbice and Canje Rivers.

This paper takes in both engineering and agronomic aspects of cassava production; an engineering approach alone would leave too many unanswered questions.

The soils

The agronomic textbooks enjoin us to seek the classic well-drained, deep and fertile loams for a wide variety of crops. Such soils exist only in small parcels throughout the world and for the great majority of cases the opposite is the rule. While cassava soils must have the best possible drainage, this valuable crop can live and produce on soils where others would die of malnutrition. Without doubt the freely draining sandy loams are ideal and, typically, the Intermediate Savannahs of the near hinterland of Guyana are of this classification as regards both drainage and lack of nutrients. Near to the forested areas soil colour changes from light brown to dark and very dark — for fertility, the darker the better.

Topography

The general elevation of the savannahs is around 30-35m and gently undulating. Defunct, mounded earthworm or ant hills, varying in size from 4-15m³, are a feature of the area and appear in numbers from 12-40 per ha. The hills are of markedly superior fertility than the basic soils and the highest population is found closer to the forested zones. The better fertility is evidenced by the vegetation, strong shrubs and even trees are seen where the immediately adjacent savannah is sparsely grass covered.

Vegetation

Two features are dominant, the "Bush Island", aptly named for its appearance in well defined clusters of from 0.5 to 2 ha and larger, and the shrub Sandpaper, (*Curatella americana*). Well-named for the abrasive nature of the leaf surface it is said to have reached the nadir of uselessness by refusing to burn. This is not true. In fact, once dry it burns with a good and smokeless heat.
Land development

Reclamation

The term land reclamation can be defined as bringing land from a natural state into one suitable for the organized and geometric business of crop growing. Here the first prerequisite is a hot and clean burn. Pre-treatment using a flexible spike tooth harrow ensures that all vegetation, including Sandpaper, is laid low following which fire applied at about 13 00hrs on a correctly chosen day will result in the cleanest land surface.

Reduction of the ant-hills is essential. The operation may be performed before or after primary cultivation and the question is which of the two? Prima facie post-tillage appears more suitable, the land is relieved of compaction thus making spreading easier and most of the vegetation has been soil-incorporated. In fact, and without any doubt, hill reduction is best carried out before any tillage. Following the burn the hills are loosened by a field cultivator or chisel plough. The tractor reverses to the hill and lowers the implement as near as possible to the apex and then moves forward with the implement at full depth. This has a general loosening effect and several passes around the circumference ensure that all soil is relieved and roots cut. Following upon this the actual distribution is carried out using the rear mounted blade. Working in a radial pattern using the centre point of the hill as the start position, work commences by reversing onto the hill and lowering the blade and then moving forward carrying the spoil to be deposited as evenly as possible. With training and practice operators quickly achieve skill at the work and produce good results. The higher fertility contained in these soils makes it important to carry out the best possible form of spreading. The next operation will probably be a further pass with the spike-tooth harrow to carry out further levelling and to shake the roots free of soil. A side-effect here is to expose all broken Sandpaper roots making the following operation, hand collection of the roots, an easy one. Machines are available for the task, two examples being the Australian bush-type finger-wheel rake and the American rear-mounted dump rake. Both work but, unfortunately, are not available in Guyana.

A point which needs stressing is the fact that the jobs described above are carried out only once; correctly the definition is reclamation, after which all cultivations are of the on-going type. Another point which may be mentioned is that all land-forming should be carried before the application of any form of soil ameliorants.

Primary cultivation

Next comes primary cultivation. This may be carried out using either the mouldboard or disc-type plough. If the former is chosen then it should be of trip beam design to avoid undue strain and possibly damage caused by contact with oversized Curate/la roots. A wide furrow width should be selected, not less than 40 cm but 45 cm is preferable. One class which would have performed well was the North American prairie plough. Designated "Sodbuster" (John Deere) "Prairie Buster" (Massey Harris) and similar trade names by other makers, the type was developed to deal with the tough, springy and root-filled grasslands of the North American Middle West. Its main features were a 60 cm furrow width at a depth of 15-20 cm, a mouldboard of around 1.2m in length, and the share tip and the coulter point were made integral. In working, the extra-long mouldboard ensured the slow turning of the furrow slice and its complete inversion in an unbroken state. Due to the width/depth ratio no possibility existed of the slice reverting to its original position, a problem frequently occurring when more conventional ploughs were used. The disc plough can perform good work but skill and patience are required to produce the best results. Ultra-sharp discs make work easier but this, unfortunately, is a counsel of perfection since no sharpening facilities are now available. The type cannot completely bury all vegetation and this makes all
the more important a clean burn at the outset. However, in the context of equipment available in Guyana at this time the disc plough remains the best choice. Following ploughing comes discing and then the all important land planing. Machine agriculture demands precision and in a like manner so does agronomy.

Machine design has permitted field operations to take place over a wide range of soil surface conditions but one rule remains. The more correct the surface the better the results. Water control, in surplus or deficit, is better managed on surfaces properly arranged to suit terrain and crop. Best agriculture permits no compromise. The land plane shaves the high spots to fill the "lows" and makes the final distribution of the soil from the earthworm hills. Depending on the severity of the height differences, as many passes are given as required to correct the inaccuracies. Usually this will be three or four but exceptionally more may be required. Each pass should be at an angle, usually about 90° to the previous one. Roots left lying on the land surface cause an enormous waste of time in this operation and so the clearing should be carried out properly.

Marking and planting

Machine and agronomic considerations seldom completely agree and an element of compromise generally results in many situations. Seeking and deciding on a course of action may create field problems in such areas as row width and plant spacing. Fortunately cassava presents no problems in this direction and a 75 cm row width and plant space serves well. An added advantage is the facility to carry out inter-row cultivations in two directions at 90° apart.

This permits the best of weed control. To achieve the degree of accuracy required, the whole field needs to be marked before planting commences. This is quickly and easily carried out using a marking device bolted to the frame of a field cultivator. Six rows may be marked at one time and the marking device consists of a length of 10 cm x 10 cm timber drilled at 75 cm intervals to accept stout pegs which are the actual row markers. Marking six rows at one time results in a production of 2 ha, and generally more, per hour. Once the field has been marked in the two directions planting may commence. Staff are instructed to insert a seed piece at every intersection and when carried out with reasonable care this results in a high degree of accuracy. This can best be appreciated some 3 weeks after planting when the young plants present a pretty picture of geometric precision, and, if the operator is a good one, a practical demonstration of how straight lines make work easier. This system presents the strongest case for staying with hand planting. Machine planting is the simplest of operations and was carried out very successfully in 1967. Better machines exist today and work extremely well but cannot produce the accurate effects of the "cross blocking" method described. Without doubt, provided labour is available, this method is the best. It is fast, also, since there is no time lost in estimating planting distance. Recently CIAT have advised that plant material be cut with a square end as opposed to the traditional sniped or chisel-shaped end.

The claim, well supported by work here, is improved root development. The square-cut end also makes for more difficult insertion of the seed piece into the soil, and thus harder planting work. The cure is to carry out one direction of marking using reasonably deep chisels or spring shank cultivators. This results in well-relieved soil and makes the planting operation an easy one.

Varieties

In the review period eight varieties were examined for fertilizer response, growth characteristics (i.e. whether straight or branching), yield and by a rudimentary test, dry matter content
Of the eight, four were exotic, Iracema and Tacana (Brazil), Del Pais (Puerto Rico) and M Col. 673 (Colombia). The balance consisted of three from coastland Guyana and one Berbice River specific. With the exception of M Col. 673 and the Berbice River selection all exhibited straight growing characteristics. M Col. 673 is heavily branched and the Berbice River selection, moderately so. From the machine harvesting point of view, all except in Col. 673 could be machine harvested without stalk cutting should the need arise. It was not possible to test fertilizer response or yield on the three selections from coastal Guyana. Results for the others were based on harvesting representative amounts from 0.012 ha. At all stages these latter exhibited boom growth and this condition continued through periods of minimal rain. Two outstanding yields were recorded, Iracema and the Berbice River selection, the latter slightly topping the former at around 28.7 tonnes per ha.

The DM figures were calculated (for all except the coastland selections) on the basis of percentage of farine produced. With the exception of the Berbice River variety all yielded 23-24.5 per cent farine. A gratifying 32 per cent resulted from this exception. Another point in favour of the Berbice River selection is its thin white and smooth skin as opposed to those of the exotics which are deeply reticulated and brown. More waste is present and this is possibly one reason for the higher DM content of the Berbice River type.

**Fertilizer application**

The application and placement of fertilizer has been carried out using two types of equipment, one as an attachment to the Lilliston Rolling Cultivator and the other (Cole Mfg Co.) a double toolbar mount. In the former the mixture is deposited on the surface and on each side of the row and then incorporated by the rolling spider gangs. Placement by this method is not as deep as desirable but at least the slight ridging effect of the rolling cultivator does ensure a minimum loss of nutrients through surface runoff in rainfall.

With the Cole fertilizer unit the situation is quite different. Here each hopper has two outlets for each row and each outlet feeds a separate placement shank. The result is that fertilizer may be applied at two depths at the same time. This facility has the beneficial effect of distribution throughout the depth of the rooting zone and almost assuredly is the reason why boom growth continued through periods of no rainfall. Another valuable feature of the Cole unit is the facility to vary the amounts fed to each shank.

For example the shank set at 7.5 cm deep receives about one-third of the total dose while the 17.5 cm placement takes two-thirds. It is perhaps not necessary to add that this work must be carried out before serious root development takes place usually immediately following planting or within 1 week. The writer cannot recall ever seeing better placement than that provided by the Cole. All fertilizer used was applied as a home-made mix because of the non-availability of compounds.

**Inter-row cultivations**

Some years ago when minimum tillage had assumed the proportions of a cult in the eyes and minds of many the prestigious *Implement & Tractor* magazine ran articles entitled, "Do not throw away the cultivator, yet". Whatever the reason may be, the facts are that in periods of dry weather inter-row cultivation of the crop produces accelerated growth and this effect is particularly noticeable on areas receiving no fertilizer. A comment from an experienced person: "it not only looks good but it is good".
Harvesting

Whether the roots are lifted by hand, by the rudimentary share-type lifter or by the power driven deep reaching chain-type digger, cassava harvesting is an easy task on the soils of the Intermediate Savannahs. Little soil adheres to the roots and this quickly falls off after a few minutes in the sun. A feature of at least three of the selections is the growth pattern of the roots. In these, root initiation commences at the terminal portion of the seed piece and continues horizontally and slightly downward. If, for example, root initiation commences at say 15 cm deep then a root of 40 cm in length will be 25 cm deep at the distal end. Later it will be seen how advantageous this is. Mention has already been made of the fact that most varieties grown could be harvested by machine without the need to remove the top growth. Occasions will arise when this facility can save another operation by either hand or by tractor. The basic share-type lifter can be made quickly and easily in any workshop possessing cutting, drilling and arc welding facilities and if a toolbar is available on to which it may be bolted the job is yet easier. To operate this unit cassava tops and the heaviest weed growth must be removed beforehand to prevent blockages. It requires a 50 P.T.O. horse-power tractor but since the pitch of the lifting share is fairly severe, thus producing large draft forces, wheel slip is practically non-existent.

There are several makes of machine lifters/harvesters. At least two are of the type mentioned above whilst a third resembles a strengthened groundnut digger. Standing on it's own by way of design and construction is the Bomford & Evershed machine.

The basic details are:

- a three-point linkage unit, category II
- chain-type cleaning and conveying,
- throat width of 100 cm
- depth capability of 40 cm
- unit may be offset to suit row width and tractor wheel track
- very sturdy rolling coulters slice all weed growth ahead of the lifting share
- requires 75 P.T.O. horsepower on the savannah soils.

Previous mention has been made of the 25 cm rooting depth of certain selections. It is fortunate that these are the most useful varieties for yield and dry matter content and thus fall well within the depth reach of 40 cm. The throat dimension is 25 cm greater than the crop row width. In this there is an advantage in that there is no possibility of any portion of the crop being left unharvested, in other words the harvester over-reaches the row width by 25 cm, or put another way, in harvesting 1ha the machine treats 1.3 ha.

The offset facility. The 75 cm row requires a 150 cm tractor wheel track and it follows that a centrally mounted harvester unit cannot function. Most operators, given the choice, prefer to guide a tractor from the right hand side and so the headstock is offset to a point where the righthand side of the harvester throat and the righthand rolling coulter are precisely lined up with the centre of the prime movers, the rear and front wheels. Set properly for lateral and longitudinal balances no side draft results. Should any roots have developed from one row to the next and thus cut by the rolling coulter, the next pass, utilizing the 25 cm over-reach will ensure clean harvesting. A side-effect and genuine advantage of this feature is the total removal of all weeds including the roots, which are then shaken free of soil and ready for in situ burning at the right time — some will be woody and others tufted grasses.

The 75 P.T.O. horsepower is adequate to utilize the harvester's performance
properly. For preference this class of tractor should be fitted with 7.50 x 16 F2 front tyres and 13 x 38 R1 rears, not larger.

Tractor sizes

The criteria governing the choice of tractor sizes are several but the most important is the size of holding. While there is no practical limit at the upper end of the scale there is certainly one at the lower. Any operation in this relatively remote area must be of sufficient size, and therefore productive capacity, to support the necessary infrastructural needs vital to the operations. Electricity, water, radio transmitter, roads, possible field telephone and suitable transport are amongst these needs.

Since it is obvious that machine harvesting will be necessary it follows that tractors of a size suitable for this machinery are needed. A good case exists for using one model of tractor only — the 75 P.T.O. horse power unit. It is of a good size for row marking, inter-row cultivation, harvesting and certainly not too large for transport. On the contrary, there may be a long distance transport need of perhaps 60-80 km. In this event it could take an 8 tonne load, or perhaps more, and be economical. Such a choice makes repair parts keeping a simple operation and this is of particular importance with tyres. Damage will occur in the early stages of development and one size of rear tyre greatly simplifies problems. For the work, the 13.6-12/38 R1 is ideal and in 8 ply rating. This size of tractor is large enough to support the two operator approach. In this system the two operators are required to keep the unit working from first light to last twilight, an operating day of 13 hours.

No 4-wheel drive or front wheel assist is necessary but spaced dual rear wheels are advantageous when using wide inter-row cultivators, for example the Lilliston 6 row Rolling Cultivator. Cabs are not required but the sun canopy is essential. The general dimensions of the original equipment type are inadequate. The width should be equal to the out-to-out measurements of the base rear tyres while the length should be of the order of 2.5 - 3m; such a size gives good protection. The "flat deck" configuration is preferred to the straddle mount — it puts the operator a little higher and thus less affected by dust.

At times, dust is a very major problem so much so that consideration must always be given to the installation of a vertical shaft axial flow roof-mounted fan which performed so well on combine harvesters before the introduction of the controlled environment cab. This fan produces a gentle down draft above the operators head and keeps him completely free of dust. It is a low cost item. Dry type air cleaners are essential to give the necessary engine protection.

Tyres should be of the F2 class for the front axle and R1 for the rear. Under no circumstances should the R2 type be considered. Certainly there is no need for the more obese tyre sizes on any unit. These are a distinct disadvantage and their price prohibitive. Table 1 shows horse power consumptions in land reclamation and on-going cultivation of cassava. These production figures are achievable easily but may vary according to conditions.

Equipment

The regular disc plough is very satisfactory but the normal types available do not offer a feature which is essential. This is depth control by a land wheel. Fortunately this is available on the Brazilian-made Massey-Ferguson 200 series ploughs. The addition of the wheel does away with the need to use the
### Table 1: Horse power consumption in reclamation and on-going cultivation of cassava on the Intermediate Savannahs of Guyana

<table>
<thead>
<tr>
<th>Reclamation</th>
<th>hp-hours per ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chain harrowing</td>
<td>29</td>
</tr>
<tr>
<td>Breaking hills</td>
<td>38</td>
</tr>
<tr>
<td>Levelling hills</td>
<td>76</td>
</tr>
<tr>
<td>Ploughing</td>
<td>58</td>
</tr>
<tr>
<td>Plane (3 passes)</td>
<td>114</td>
</tr>
<tr>
<td></td>
<td>315</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>On-going cultivation</th>
<th>hp-hours per ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disc harrowing after harvest</td>
<td>29</td>
</tr>
<tr>
<td>Ploughing</td>
<td>43</td>
</tr>
<tr>
<td>Marking out (two days)</td>
<td>15</td>
</tr>
<tr>
<td>Applying fertilizer/lime</td>
<td>19</td>
</tr>
<tr>
<td>Inter-row cultivation (twice)</td>
<td>29</td>
</tr>
<tr>
<td>Harvest</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>205</td>
</tr>
</tbody>
</table>

* P.T.O. horse power-hours per ha.

Tractors' Draft Control feature which, no matter how good its condition, simply cannot control depth over the widely varying soil conditions. Using the Draft Control it is true to say that the operator's right hand must be on the control at all times. Using the land wheel results in the best work.

All normal disc harrows are satisfactory but should be of the tandem configuration. A new and very unusual type is the M-F 280. This unit may be used on the linkage or drawbar. The latter is much preferred and more effective. Land planing usually requires tractors larger than 75 P.T.O. horse power, for most operations 120 horse power is the lower limit.

Perfectly satisfactory results can be achieved using the Eversman TM10 unit behind, for example, the M-F 290 tractor of 74 horse power. The TM series through ingenious linkages uses the tractor's rear wheels for height sensing so that the tractor becomes an integral part of the whole unit. Unlike most land planes it is easily transportable.

For inter-row cultivation the standard of comparison is the Lilliston Rolling Cultivator. It is ideal for weed control, soil mulching, ridging where required, offtaring, fertilizer application and incorporation, and used in conjunction with the "cross blocking" planting method already mentioned makes weed prevention almost 100 per cent. It will not damage root systems and, most important of all, can be operated at high speed.
It is of the soundest design and construction. For best field performance the unit (6 rows) should always be fitted with gauge wheels and double disc guide fin.

Conclusions

There can be few easier areas in which to develop machine agriculture than the savannahs described here. Similarly with the crop, cassava is among the easy crops to accept modern equipment.

For success the probable key factor is management of the type that accepts as a fact that procedures must be followed in the correct manner, time and sequence.

Given that these are in order, few problems will be encountered. Certainly the soils, topography and weather lend themselves to the best production per unit of time.

Some stress has been laid on operator comfort. This is as it should be, for example to ask a man to work without protection from sun when the answer is so simple highlights serious inefficiencies. With dust control the same applies.

Cassava has a large contribution to make but not as a backyard crop. Given its correct place in the scheme of affairs there will come a new form of agriculture on the savannahs.
H. Adams (CARDI, Guyana):  
No comment was made of acouchei ant problems in the presentations. Have any of the presenters experienced problems with ants?

J. Ruinard (University of Suriname):  
Acouchei ants have been encountered. Mirex® is used as a bait and also applied by mist blowers.

W. Bowen (EMBRAPA, Brazil):  
In Brazil similar problems exist. Mirex® is used. Usually more damage is done in small experimental plots than in commercial fields.

H. Adams:  
What calcium source is used to achieve good peanut yields in Suriname?

J. Ruinard:  
CaCO₃ is the only source of Ca. There is no need for supplemental gypsum.

L. Smith (Ministry of Agriculture, Barbados):  
(1) Professor Ahmad alluded to the inclusions of brown sands. His suggestion is that lateral water movement can create this situation. Is it feasible to correct differences between White and Brown Sands and then treat them similarly?  
(2) Farming systems research seems to be towards large-scale operations rather than small farmers.

W. Bowen:  
White Sands do not have iron oxide. It is advisable to leave them alone.

R. Power (Hydorgardens Ltd., Barbados):  
Re small farming communities: infrastructural developments and social amenities are necessary before small farmers can survive in the savannahs.

J. Ruinard:  
In Suriname there are no inhabitants in the savannahs. The basic intention is that medium-scale farmers could be settled when technical coefficients are worked out and a package of practices is available.

J. Cropper (Consultant, Guyana):  
What comes first, the farmer or the agricultural and infrastructural development.

W. Bowen:  
In Brazil it was due to research results that farmers were attracted to farm the quartz sands.  
It is felt generally that research and development work must precede any attempt to settle farmers in a new environment.

N. Holder (LIDCO, Guyana):  
This matter can be more adequately addressed, perhaps in the workshop sessions, after presentation of papers on livestock.
TECHNICAL SESSION III

Chairman: P. Osuji, CARDI
Physiographic features of the Intermediate Savannahs

The Intermediate Savannahs are located in the northeastern quadrant of Guyana and cover an area of about 2,700 km², extending both east and west of the Berbice River. The term "intermediate" derives from the fact that these savannahs lie south of the coastal savannahs and north of the southwestern (Rupununi) savannahs. The ecozone is regarded as part of the country's hinterland and in a sense represents the second major frontier for agricultural development with approximately 122,000 ha of cultivable land. Agricultural production efforts have so far been directed at beef and dairy enterprises as well as the production of a number of annual crops including cowpea, soyabean, peanut, cotton, maize and sorghum.

Approximately 90 per cent of Guyana's population is resident on the narrow coastal strip abutting onto the Atlantic Ocean. This ecozone also supports the major areas of economic activity including rice and sugar cane cultivation as well as other agricultural pursuits. On the other hand, the population of the Intermediate Savannahs has been largely induced through state run projects and schemes such as the Ebini Livestock Station which started operations in the early 1940s. Access from the coastal region can be accomplished by rail, river and by air. The Berbice river provides the main avenue for the transport of supplies as well as people. From the capital city, Georgetown, paved, all-weather roads eventually lead to the mining town of Linden from where a loose-surface all-weather road provides access to various parts of the savannahs. There are also a number of airstrips utilizable by light and medium aircraft.

Geologically, the Intermediate Savannahs have developed on the "white sand plateau" which corresponds to the Berbice Formation and consists of sub-continental and old deltaic deposits of sands and clays with recurrences of bauxite, laterite and kaolinitic clay. On the surface, the white sand predominates and is interspersed with brown loamy sands and sandy clays ("Brown Sands") sediments. The plateau varies in altitude from about 16 m above sea level in the north to 150 m further inland.

Topographically, the Savannahs are characterized by low elevation and relief. Undulating hills rise to about 50 m from their bases to give the effect of a gently rolling pattern. There are very few steep slopes and consequently natural erosion is minimal. However, as noted in the TAMS (1976) report soil-disturbing activities, often lead to soil erosion with surprising speed. The landscape, in parts of the Savannahs, is dotted with abandoned termite hills which constitute the major obstruction to land clearing.

Rainfall in the Intermediate Savannahs is characterized by a bimodal distribution pattern. A long rainy season from mid-April to mid-August is
experienced annually and is usually dependable with 40-60 per cent of annual precipitation occurring in this period. On the other hand, the short rainy season of mid-November to January is often unpredictable in terms of its duration and total precipitation. Consequently, most agricultural activities are planned and executed with due consideration to this pattern. The dry seasons are often quite harsh with consequential adverse effects on pasture quality. Periods of soil moisture stress are frequently experienced in the months of February to April and September to November.

The natural vegetation of the ecozone comprises about 70 per cent forest and shrub-type species with only 25 per cent being grassland-type vegetation in association with marsh and swamp plants (TAMS, 1976). In the true savannas, two grass species predominate — Andropogon spp. and Trachypogon plumosus. These occur in association with other grasses and sand-paper trees (Curatella americana) while in the swampy areas along streams and river levels, a number of palms are to be found.

The soils of the Intermediate Savannahs include well-drained Entisols, Oxisols and Udisols. While a number of soil types have been identified and characterized, the most extensively occurring are the Ebini sandy loam (Typic Paleudult) the Kasarama loamy sand (Arenic Paleudult), the Tabela sand (Typic Quartzipsamment) and the Tiwiwid sand (Typic Quartzipsamment). The soils are characterized by relatively low pH, ranging from 4.3 to 5.9 within profiles and among types (Bullen et al., 1982). Natural fertility is almost consistently lacking in both top and sub-soil. CEC and base saturation are typically low while extractable phosphorus is conspicuously lacking. Phosphorus is considered the most limiting nutrient element in these soils but deficiency symptoms for almost all other elements may be exhibited as they become limiting.

**Historical review**

**The Rupununi cattle trail**

It is interesting to note that the low fertility acid sandy soils, largely found in the Intermediate Savannahs of Guyana, derived their importance from cattle production efforts taking place far away in what is now known as the South West or Rupununi Savannahs. It is, therefore, necessary to briefly trace these historical linkages.

The Rupununi Savannahs are divided into two parts by the Konaku Mountains which run east to west, 5km from the Brazilian border. In the early nineteenth century the southern half of the Savannahs was entirely in the hands of the aboriginal indians, while the northern half was controlled by the Brazilians.

No attempt was made by the Dutch to settle the savannahs of the Rupununi. A few men did tour the savannahs periodically in search of minerals and scientific exploration, but the many difficulties experienced discouraged permanent settlement. The indians by the middle of the nineteenth century were in sole possession of the savannahs with little or no external influence.

In the Rio Branch District of Brazil and the smaller savannahs on the southern side of the Kanaku mountains, the Brazilians were involved in a crude system of cattle rearing for the purpose of feeding prisoners who were sent to these savannahs. These cattle formed the nucleus from which large herds have sprung.

DeRoy, a Dutch trader settled in the upper Rupununi Savannahs near Dada­nawa between 1860 and 1870 and he was the first to introduce cattle into the Rupununi by purchasing a few heads from Brazil for milking purposes, but since cattle rearing was not his main economic activity, his holding remained small. It was not until the arrival of Melville 20 years later that any expansion of the cattle industry in the
Rupununi District occurred. Melville played a great part in the development of the Rupununi District. On his arrival he bought some more heads of cattle from Brazil which together with DeRoy's estate and cattle totalled about 300 heads. The majority of the cattle now in the Rupununi come from this one small herd of scrub stock without little or no introduction of fresh or improved blood.

Melville knew little about cattle husbandry and management, but his animals thrived on the natural open ranges since, being under-stocked, these were able to provide ample feed and kept the animals free from diseases. His animals roamed the ranges entirely without care. No castrations were done under 5 years of age, hence there was little selection of bulls. In-breeding was rampant and progressive and the methods of handling extremely crude, and a large number of the cattle became wild strays.

During this time there was no overland communication with the coast — all trade was to Brazil and so at the beginning of the twentieth century Melville was exporting a few steers there. At that time, Rupununi steers had a reputation for good size and quality, which was directly attributable to the fact that the savannah was still under-stocked. But, since this trade was illegal and with the sales becoming increasingly difficult, Melville approached the Government of British Guiana in 1917 with a project of cutting a trail to connect the savannahs with the steamer terminus on the Berbice River. This proposal was opportune since the 3-year-old war had inflated the price of food. Thus approval was obtained and Melville was responsible for the construction of the trail, which was officially opened at the end of 1919.

Actually, the trail at that time was just a clearing or underbushing of the forest, with the large trees left standing. Clearings for grazing and holding paddocks or corrals were non-existent. So also were rest houses for the cattle drivers. The banks of the creeks were high and ungraded, and the swamps were nearly impassable. The trail lacked every facility for driving stock and could be said to have been a trail in name only, so that for the first 2 years heavy losses were incurred in attempts to drive cattle through.

The opening of the cattle trail also resulted in the establishment of the Rupununi Development Company, Ltd. which acquired all of Melville’s holdings. However, by the end of 1921 the Company’s position seemed hopeless due to losses incurred by the cattle trail.

**Early livestock research at Ebini**

The few animals that survived the cattle trail were staged on the savannahs near the Berbice River, prior to being shipped to the coast. Those steers which had survived the trail initially regained the condition they had lost in transit, but they subsequently deteriorated. Also, attempts to keep breeding stock in these areas resulted in the majority of the calves and cows wasting and dying. Some of the cows failed to breed and became unthrifty. The mortality rate was quite high.

Preliminary investigations conducted on the savannahs indicated that there were mineral deficiencies in the soil. Animals fed mineral supplement improved physically and this indicated that there was a need for intensive research in order to determine the most economic methods of satisfactory cattle rearing on the savannahs. These findings resulted in the establishment of the Ebini Livestock station in 1941 to carry out further investigations into the rearing of cattle on the savannah soils. A detailed soil survey (1955-1957), supported the findings of Follet-Smith (1930), who on investigating the conditions of the Waranama ranch of the Rupununi Development Company attributed the troubles to poor soil and low nutritive value of the savannah grasses which were all deficient in essential minerals. The early experiences with cattle in the Rupununi were a repetition of those at Waranuni.
Follet-Smith (1930) had recommended the feeding of bone meal to alleviate the mineral deficiencies, but this was not possible because of the war. Later when the bone meal was fed along with trace elements, the growth rates and reproductive performance did not improve even though the stocking rate was low. Thus the question of establishing improved pastures arose and in 1952 fertilized, planted pastures were used with a stocking rate of 2.5 cows per ha.

In the early 1960s, there was approximately 600 ha of pastures planted with Pangola grass, but this species was affected by a virus disease (stunt virus), which resulted in its dying out. In June of 1962, a different strain of Pangola grass provided by USAID was planted. Other introduced grasses tried were Coastal Bermuda, Suivance Bermuda, S947 Giant Bahama and Giant Star grass. Two strains of Bahia tried grew well with excellent ground cover to suppress weeds, but they were not highly productive. Molasses grass proved quite useful, except that it was not very productive or palatable.

**Pasture establishment**

Since 1954 highly productive pastures have been developed on the Brown Sands. These included common self-propagating species of legumes such as Desmodium adscendens (Tick clover), Alysicarpus vaginalis (Alyce clover) and Zornia diphylla. To further assist grass establishment, Stylosanthes gracilis and Vigna sinensis were also seeded into the pastures. Some grass species such as Paspalum notatum (Bahia grass) Axonopus compressus (Carpet grass) Melinis minutiflora (Molasses grass) and Hyparrhenia rufa (Jaragua grass) did show some promise under improved pasture management, especially in their response to fertilizer and to grazing. Other promising grass species were Ischaemum timorense (Locuntu grass) and Digitaria decumbens (Pangola grass).

These grasses have been capable of carrying one adult animal per 0.8 ha over 2 years.

Other pasture management and improvement strategies have included controlled grazing of the ranges by having periodic heavy grazing and spelling. This eliminated the necessity to burn which used to result in an annual loss of herbage. This controlled grazing resulted in an increase in fertility and development of endemic sward-forming grass species of Axonopus, Mesosetum and Paspalum at the expense of some tufted tall-growing and less nutritive species such as Trachypogon plumosus, Andropogon lencostachyus etc. This method of range management could have increased the carrying capacity to four cattle per km².

Fertilizer trials also showed that the application of 125 kg of basic slag per ha on selected areas will ensure production during a dry spell of one and a half times as much forage as that produced on an unfertilized range.

During this period, trials were also conducted on mineral deficiencies. One such was the *ad lib* feeding of "churns" (trace-elemented bone flour supplement) to 2 and 3-year-old steers grazing unimproved pastures. These animals made a weight gain of 0.3 kg per day. Animals grazed on a phosphate fertilized pasture without being fed mineral supplement gained 0.65 kg per day.

Results of soil samples tested at Rothamsted Experimental Station in England, indicated that there were deficiencies of trace elements such as Cu, Co and Mo.

During the period 1957-59 symptoms similar to those obtained in rats fed a Zn deficient diet were observed in cattle on the Berbice savannahs. These symptoms occurred seasonally (March-June) and increased from six cases in 1958 to over 20 cases in 1959. The stock affected were mostly those born
and reared under range conditions and the symptoms were more pronounced in older stock than calves.

During April and May 1959 some affected animals were treated by administering zinc sulfate while others were left untreated in a simple trial. The responses of the treated animals were favourable.

In pot trials with the tomato, responses were obtained when Zn was applied. Radio-chemical balance studies indicated that the absorption of Zn from the alimentary tract in steers was not more than 50 per cent. There was also a low Zn content in the Trachypogon grasses.

It was thus concluded that an adequate supply of Zn was not always available to animals reared on natural range pasture.

**Beef cattle breeding and management systems**

The importance of beef production in order to meet the protein needs of the country's population was recognized in the 1970s. The Ebini savannah with its potential of producing a large quantity of forage was therefore identified as the location for beef cattle production. At that time, the main objectives of the project were:

- To determine the effect of two systems of rearing replacement heifers on subsequent performance as cows on native range.

At the station in 1969, the animals in stock were in a poor physical condition. There were many old, non-productive animals in the herd. Inbreeding was common and year-round breeding and apparently no culling for production performance, was practiced. The poor condition of the animals was also a result of over-stocking of the pastures.

The animal population at this time consisted of about 1000 females (mostly Creole, Zebu and Santa Gertrudis) and their descendants which had been mated mostly to Zebu and Santa Gertrudis sires. The Zebu bulls were of Sahiwal or Brahman origin with the Creoles being sired principally to Zebu stock of Brazilian origin. The Santa Gertrudis bulls had included King Ranch bulls from USA and grade or pure Santa Gertrudis bulls raised at the station. A number of Santa Gertrudis cows had also been imported from USA. Thus at the beginning of the project the cow herd was classified on breed composition into:

- pure or high grade Zebu
- pure or high grade Santa Gertrudis
- those sired by dairy bulls
- those sired by British beef breeds
- Zebu-Creole
- Santa Gertrudis-Creole
- Creole

The bulls on the station were inadequate in number, of a poor quality, and only a few Zebu and Santa Gertrudis bulls were available. Thus six Brahman, five Santa Gertrudis, two Charolais and two Holstein bulls were imported.

The Committee responsible for this project decided to utilize the cattle already on the station and practice a system of cross-breeding and upgrading. Zebu or Zebu crossbred foundation breeds were considered for the upgrading system due to their adaptability to tropical conditions and as
Santa Gertrudis cattle were already present, it was decided to include them in the breeding programme.

The data collected after the first year of the trial, showed that there was an advantage for improved pastures over native pastures, and that the response to molasses-urea on native pastures was favourable.

Generally, body weight of cattle and pregnancy rates were satisfactory and the weaning weights were just a little below that expected. But, there were still heavy losses from death of the calves.

**Pasture management studies**

A trial conducted at Ebini to evaluate the performance of the cow herd on four pasture management programmes was prompted by the prevalence of mineral deficiencies, low conception rates, and high calf mortality between birth and weaning. A brief study of reproductive performance at Ebini showed that there was considerable seasonal variation in the calf crop on an all-year-round breeding system and the calves born during November-December had higher birth weights, a lower mortality and higher weaning weights than those born at other times of the year. This was attributed to the heavier milk production of dams due to the availability of more nutritious pasture forage.

The protein supplement used in Programme No. 3 (native pasture) was a mixture of 97 per cent molasses and 3 per cent urea fed at the rate of 2.25 kg per cow per day for the entire year.

In Programme No. 4 the animals were grazed on the native range for 6 months (March 15 to September 15) and on improved pasture from September 16 to March 14 so as to secure a high rate of fertility and productive performance during the calving and mating seasons. This also helped to reduce cost.

A complete mineral mixture was used across all the pasture programmes. After a trial period of 2 years, the animals on Programme No. 1 (improved pasture) showed a considerable increase in weight under good management and a stocking rate of 0.6 ha per animal. There was also some improvement in the calving percentage and weaning weights of the calves.

The animals on Programme No. 2 (native pasture) appeared to be more responsive to seasonal changes in the weather. Initially, for the mature animals there was a loss in weight followed by weight gains in the wet season then losses in weight again in the dry season. There was also a lower calving percentage throughout the year. This was probably due to the poor quality of the range pasture which was not nutritious enough to allow the cows to become pregnant while they were still suckling young calves. This resulted in a biennial system of calving.

The animals on Programme No. 3 also exhibited this biennial system of calving but to a lesser extent. Their weight remained relatively constant (after an initial drop) throughout the year, and this may have been due to the protein supplement being able to fill the nutritional gap caused by the lowering of forage quality in the dry season.

There was a satisfactory calving percentage for the animals on Programme No. 4 over both years, but the weights of the mature animals decreased and increased as they were moved to range and improved pastures respectively.

There was little difference in weaning weights and survival ratings between calves on Programmes No.1 and No.4, but there was a noticeable difference between Programme No.2 and No.3, with Programme No.3 having a higher weaning weight percentage.

There was no considerable difference in birth weights between programmes but the difference between the range in Programmes No.2 and No.3 and those including improved pastures (No.1 and No.4) were significant. Weaning
weights were substantially lower and calf mortality considerably higher in Programmes No.2 and No.3.

Supplemental feeding of beef cattle

In a feeding trial (Holder, 1972), mixtures of rice bran, copra meal and sugar cane molasses (with or without urea) were investigated as possible protein-energy supplements for growing/fattening beef cattle grazing Pangola grass pastures at Ebini. Weaners, bulls and heifers were weaned off of both native and improved pastures and were fed for 280 days.

The results showed that:

- on the basis of average daily gains, the best performance was obtained with copra meal and the rice bran/copra meal/molasses-urea supplement. The rice bran/copra meal mixture performed equally well; but the molasses-urea supplement was less effective.

- there was a highly significant sex difference (P<.01) in growth rate; bulls growing faster on all supplements tested except the pure molasses-urea.

- cattle weaned from native pastures gained more weight (P<.05) than those weaned from improved pastures.

Establishment of legumes and Guinea grass


Plant density counts were made in May, June, July and September 1972, and the data showed that legumes in pure stand established best on the burn and disc treatment with P fertilizer. Guinea grass established best with the same land preparation. Addition of both N and P fertilizers gave the best results for establishing native grass-legume mixtures.

Commercial beef operations

Commercial beef operations began at Ebini in 1972 (December). The decision was taken to establish such an operation after favourable reports were obtained from earlier research work done on this location to investigate the problems pertaining to economic beef cattle production and the development of cattle farming systems that would realize the beef cattle potential of the Intermediate Savannahs.

These studies established that:

- Mineral mixes can be used to alleviate mineral deficiencies in the forage offered, hence reducing the possibility of low conception rates in cow herds and mature animal mortality.

- The introduction and proper management of improved pasture grasses can increase production rates considerably when compared with native pastures.

- The seasonal system of breeding could improve calving rates, reduce calf mortality, increase the weaning weights and hence reduce the operating cost by the general improved system of management.

- The use of locally available agricultural by-products as energy-protein feeds for grazing beef animals could result in an increased post-weaning production, which reduced the quantity of inorganic fertilizer required for the improved pastures.
The commercial beef operation was aimed at:

- Demonstrating the profitability of commercial beef operations on the Intermediate Savannahs

- Providing beef for local consumption so as to improve the protein diet of the population and also to earn foreign exchange by exports.

- Providing a source of heifers for farmers

- Acting as a demonstration unit where research findings could be tried out before being released to farmers.

- Serving as a model institution at which trainee managers, cattle producers and others could have a first hand look at a commercial beef cattle operation.

The Livestock Development Co. Ltd (LIDCO)

Since 1975, the Livestock Development Company Limited (LIDCO) a parastatal organization, has operated beef and dairy cattle production enterprises at Ebini. In many respects, the evolution of management systems practised at these units, was informed by the wealth of research data generated in the years prior to 1975. However, over time, there have been modifications to these systems, mainly dictated by economic considerations. To the extent that after 12 years of operation, the beef unit has expanded, in total herd size, by over 79 per cent and the dairy-unit has attained stabilization, it may be argued that the efforts in these pursuits have been successful. The process of evolution in management of the cattle, however, is a continuous one that is still being informed by continuing research activity and the exigencies of the national economic situation.

In the beef herds, the current management system is characterized by a seasonal breeding programme — a tool used only at Ebini. The rationale for the use of seasonal breeding was derived from the need to ensure that calves were born at a time of year when the on-the-ground conditions were favourable and forage availability and quantity were reasonably good. Thus the breeding season extends from mid-December to mid-March with calving taking place from mid-September to December. In terms of the weather pattern, the calving season coincides with the long dry season but extends into the short wet season when rainfall is usually enough to bring about a resurgence in pasture quality and quantity.

No formal studies have been done on the effectiveness of seasonal breeding vis-a-vis the all-year-round system. However each is recognized to have distinct advantages and disadvantages. For example, statistics derived from the LIDCO Annual Performance reports have shown a tendency towards increased calf mortality in the long rainy season of mid-April to August. Thus the implementation of the seasonal breeding system is one way of combating this problem. On the other hand, seasonal breeding is associated with a so-called "alternate year" effect in terms of calving percentages in that a fluctuation in calving is often observed. Indeed, within the Ebini cow herd it has been observed that older cows tend to calve in alternate years.

All-year-round breeding is practised at the dairy unit but attempts at a comparison of the two systems would not be applicable in view of (a) the disparity in cow herd sizes and (b) the system of artificial calf rearing practised at this unit. Additionally, the breeding programme within the dairy unit is designed to ensure that cows are bred within 3 months after calving. Heifers are raised separately and exposed to bulls on the attainment of live weight of 250-275 kg.

In both units the main forage species utilized is *Brachiaria humidicola* which currently is planted in over 95 per cent of the improved pastures at Ebini. The
choice of this species has been influenced by a number of factors including the adaptability of the grass to the acid soil conditions. Prior to 1980, several other grasses including *Digitaria* species, *Panicum maximum* and *Brachiaria aerea* (Tanner) had been utilized. Pasture maintenance with some of these grasses required regular fertilization. The relatively high cost of fertilizer and, in later years, the difficulties experienced in obtaining supplies, eventually influenced the move towards the use of *B. humidicola*. Minimal fertilizer applications are done at the time of establishment but thereafter no fertilizer is used.

Currently, the stocking rate employed in the two units varies from 1 animal unit to 0.6 ha in the beef herd to 1 animal unit to 0.8 ha in the dairy herd. For most of the year cattle enjoy a reasonable forage availability. However, shortages are often experienced in the short dry season of February to mid-April. During this period it is customary to remove a sizeable part of the beef herd to the surrounding range-land where stocking rates of the order of 1 animal unit per 4 ha are used. In conjunction with this system of deferred grazing, a standard practice is the burning of range-land prior to grazing. The native species, *Trachypogon plumosus*, is noted for its resurgence after burning even in dry conditions and the system ensures that animals are exposed to young, soft and palatable vegetative material as against the hard and less nutritious material prior to burning.

Deferred grazing is not practised in the dairy unit since this is not usually deemed to be necessary. Apart from the greater forage availability afforded by the lower stocking rate, supplemental feeding is normally increased during the drier months. The programme of supplemental feeding in the dairy herd is regarded as an essential part of the overall management system in recognition of the relatively low nutrient status of the forage on offer. A high phosphate molasses-urea mixture is fed, *ad lib*, along with other available protein energy feeds derived from local industries. The latter include rice bran, wheat middlings, copra meal and cotton seed. The use of these by-products depends on their availability on the local market and consequently each has been used from time to time. While all categories of stock within the dairy herd are given supplemental feed, priority is given to the lactating cow first and secondly to the pregnant cow in the last trimester.

From the foregoing it would be recognized that forage conservation would be applicable in the Ebini situation. However, this practice has not been attempted on a large scale. Nevertheless, the need for development of applicable systems of forage conservation is currently seen as a research priority. Recent work at Mobilissa under the IDRC-sponsored Milk Production Systems Project has demonstrated the technology and feasibility of ensiling grasses utilized for pasture purposes. Transference of these systems to Ebini would be dependent on the urgency with which management of LIDCO views the issue. An important and vital aspect of the management of cattle in the Intermediate Savannahs concerns mineral nutrition. This arises out of the known mineral deficiencies inherent in the soil and consequently in plants. Research has demonstrated that pasture forages grown in the area do not contain several essential mineral elements to meet the dietary requirements of cattle and therefore supplemental minerals are a standard requirement. Over a number of years the composition of the mineral mix used has been worked out and refined. Table 1 gives information on the composition of the product in use in 1980.

The consequences of non-use or limitations in the use of mineral supplementation are well known in the context of the Ebini herds. During the period 1978-1981, the enterprise was faced with frequent mineral shortages brought about by actual shortages of foreign exchange facing the country. Inadequate levels of mineral supplementation during this period
Table 1  Chemical composition of the commercial mineral mixture used at Ebini, Intermediate Savannahs, Guyana

<table>
<thead>
<tr>
<th>Ingredient/Element</th>
<th>Unit</th>
<th>Desired minimum level</th>
<th>Exporter's analysis</th>
<th>TPF analysis</th>
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<tbody>
<tr>
<td>Phosphorus</td>
<td>%</td>
<td>8.4</td>
<td>18.4</td>
<td>14.9</td>
</tr>
<tr>
<td>Calcium</td>
<td>%</td>
<td>18.8</td>
<td>16 - 20</td>
<td>25.4</td>
</tr>
<tr>
<td>Salt (NaCl)</td>
<td>%</td>
<td>33.3</td>
<td>31 - 35</td>
<td>31.3</td>
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<tr>
<td>Iron</td>
<td>%</td>
<td>0.3</td>
<td>0.3</td>
<td>0.9</td>
</tr>
<tr>
<td>Magnesium</td>
<td>%</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Manganese</td>
<td>ppm</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td>Zinc</td>
<td>ppm</td>
<td>750</td>
<td>750</td>
<td>1200</td>
</tr>
<tr>
<td>Copper</td>
<td>ppm</td>
<td>300</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>Iodine</td>
<td>ppm</td>
<td>200</td>
<td>200</td>
<td>N.A.</td>
</tr>
<tr>
<td>Cobalt</td>
<td>ppm</td>
<td>100</td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>ppm</td>
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<td>75</td>
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<tr>
<td>Vitamin A</td>
<td>i.u./g</td>
<td>-</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>i.u./g</td>
<td>-</td>
<td>40</td>
<td>200</td>
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Sources:  1 Performance Report, 1980, Livestock Development Co. Ltd., Guyana
          2 Tropical Products Institute, London, England

resulted in enormous production problems. These included chronic calf diarrhoea, poor conception rates, chronic wasting in a large percentage of the herd and high morbidity and mortality rates.

Currently, the national research programme, in the area of livestock science, has targeted the development of mineral supplements for use in the various ecozones of the country as a priority. This level of consideration has been informed by the need to acquire this important input, on an annual basis, utilizing scarce and often unavailable foreign exchange resources. Even so, it has been recognized that all the required ingredients for a mineral mixture may not necessarily be obtained locally.

The major objective therefore would be in terms of reducing the foreign exchange cost incurred in mineral supplementation.

The experiences of the 1978-1981 period constituted a severe set-back to the fortunes of both cattle enterprises, but moreso the beef unit. At the onset of commercialization, LIDCO envisaged the attainment of a established beef herd of over 5000 head of cattle by 1988, having started with 1891 heads. The dairy unit which commenced operations with 115 heads at the same time was targeted to achieve stabilization at a total herd size of 592 with 200 adult cows. While the latter has managed to achieve the objective (a year ahead of schedule) it is now probable that the beef herd will be stabilized by 1990.

By and large, the technical performances recorded by both units over the years compare quite favourably with other similar operations within other regions of Guyana. In the evolution of its reporting and data gathering systems LIDCO commenced the publication of an Animal Performance Report with effect from 1979. These reports provide data on technical and other aspects of the operating performances of the Company's enterprises. Table 2
provides data on selected technical coefficients achieved at both units over the period 1980-1987.

References


Table 2  Selected technical coefficients for Ebini beef and dairy units, 1980-1987

<table>
<thead>
<tr>
<th></th>
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<td>Beef Unit</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Calving rate %</td>
<td>Beef</td>
<td>42.5</td>
<td>33.2</td>
<td>57.3</td>
<td>54.0</td>
<td>60.9</td>
<td>71.4</td>
<td>50.2</td>
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<td>Beef</td>
<td>24.3</td>
<td>44.2</td>
<td>8.5</td>
<td>7.8</td>
<td>10.4</td>
<td>5.6</td>
<td>8.0</td>
<td>6.5</td>
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<tr>
<td>Adult mortality %</td>
<td>Beef</td>
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<td>18.6</td>
<td>4.4</td>
<td>3.4</td>
<td>2.4</td>
<td>2.0</td>
<td>2.8</td>
<td>2.1</td>
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<tr>
<td>- Cows</td>
<td>Beef</td>
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<td>21.2</td>
<td>8.2</td>
<td>2.4</td>
<td>2.9</td>
<td>2.0</td>
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<tr>
<td>- Heifers</td>
<td>Beef</td>
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<td>18.5</td>
<td>14.1</td>
<td>20.9</td>
<td>11.5</td>
<td>22.9</td>
<td>14.9</td>
<td>17.1</td>
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<td>14.1</td>
<td>20.9</td>
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<td>22.9</td>
<td>14.9</td>
<td>17.1</td>
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<td>98</td>
<td>261</td>
<td>102</td>
<td>387</td>
<td>300</td>
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<tr>
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<td>Dairy</td>
<td>85.2</td>
<td>96.5</td>
<td>95.6</td>
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<td>Dairy</td>
<td>17.9</td>
<td>17.4</td>
<td>33.9</td>
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<td>17.6</td>
<td>13.6</td>
<td>27.1</td>
<td>29.2</td>
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<td>Adult mortality %</td>
<td>Dairy</td>
<td>1.4</td>
<td>15.0</td>
<td>3.9</td>
<td>4.0</td>
<td>3.5</td>
<td>1.5</td>
<td>1.8</td>
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<td>- Cows</td>
<td>Dairy</td>
<td>5.2</td>
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<td>5.9</td>
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<tr>
<td>Ave. daily prod/cow</td>
<td>Dairy</td>
<td>Days 255</td>
<td>280</td>
<td>197</td>
<td>275</td>
<td>252</td>
<td>344</td>
<td>292</td>
<td>298</td>
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Based on geology and land form, four main landscapes have been distinguished in Suriname: Young Coastal Plain, Old Coastal Plain, Zanderij Belt and Residual Hills (see Rellum, 1989). The Zanderij area is level to undulating with sandy and loamy deposits of coarse brown and white sands, subordinate gravels and kaolinitic clays, which rest on a weathered basement. A small part of the White Sands are covered with savannah vegetation of grasses and shrubs, but most of the White Sands and other soils are covered with savannah forest and high forest.

**Pasture development alongside the Suriname river in the Residual Hills area**

At Baboenhol, a place about 80 km south from the coast and alongside the Suriname River, the forest was cleared and citrus, and later pasture, was planted.

The soils alongside the rivers in the Residual Hill area can be considered as river deposits in earlier times and consist of loams and sandy loams. Further from the river are the residual soils from the Residual Hills. The breadth of the strip of these loams and sandy loams alongside the river varies from a few meters to several hundred meters.

The climate in this area is wet tropical with an average annual rain fall of approximately 2200 mm and an average temperatures of 27°C, with average maximum and minimum temperatures of 32 and 22°C respectively. The relative humidity is 70 to 90 per cent. Four seasons can be distinguished: a short dry season in February and March, a long rainy season from April to mid-August, a long dry season from mid-August to the end of November and a short rainy season in December and January. The rainfall in the driest months is seldom below 50 mm.

Citrus and pastures were planted on the loams, sandy loams and residual soils. The grasses planted were mainly *Brachiaria decumbens* and *Brachiaria* sp. (USDA No. 299498). Of the grasses *Digitaria swasilandensis*, Star grass (*Cynodon plectostachyus*) and *Brachiaria humidicola* only *B. humidicola* could maintain itself, whereas Star grass and *Digitaria swasilandensis* lost ground.

Fertilizer is given to most, but not all, of the pasture, depending on the regrowth of the grass. The average fertilizer rate is below 50 kg of NPK (15: 15: 15) per ha per year. Up until now the pastures, especially the Brachiarias, have performed well. Beside fertilizing, maintenance consisted of mowing with a rotary slasher to suppress weed development; this was done on an average about once a year. On some areas after several years the grass growth seemed to slow down, probably due to compaction of the topsoil. Shallow ploughing (< 10 cm) with a disc plough restored the productivity.

The total area of pasture is 800 ha of which 600 ha consist of cultivated grassland and 200 ha natural grassland.

The cattle herd consists of Zebu and grade Zebu. Mating is in two periods of 3 months, so calving also takes place in two seasons. The average time for calving is 8 months.
Table 1 Herd size and performance at the Baboenhol farm, Suriname

<table>
<thead>
<tr>
<th>Year</th>
<th>Herd size</th>
<th>Calving %</th>
<th>Calf mortality (%)</th>
<th>Weaning weight(kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>912</td>
<td>68.5</td>
<td>19.2</td>
<td>174</td>
</tr>
<tr>
<td>1982</td>
<td>1067</td>
<td>62.6</td>
<td>19.1</td>
<td>182</td>
</tr>
<tr>
<td>1983</td>
<td>1045</td>
<td>61.0</td>
<td>19.7</td>
<td>182</td>
</tr>
<tr>
<td>1984</td>
<td>1011</td>
<td>53.5</td>
<td>30.4</td>
<td>176</td>
</tr>
<tr>
<td>1985</td>
<td>950</td>
<td>63.6</td>
<td>16.0</td>
<td>145</td>
</tr>
<tr>
<td>1986</td>
<td>1376</td>
<td>63.2</td>
<td>12.9</td>
<td>143</td>
</tr>
<tr>
<td>1987</td>
<td>1635</td>
<td>54.4</td>
<td>65.0</td>
<td>---</td>
</tr>
</tbody>
</table>

As can be seen in Table 1 the calving rate is moderate and calf mortality high. Up until 1985 little selection took place within the breeding cows on the basis of fertility and calf rearing ability. The average weaning weight decreased after 1984 because of an increased number of animals per ha, though a carrying capacity of 2 animals per ha should not be considered as high. Bulls are sold for slaughter at 400 kg liveweight at which time their age is about 3 years. In general a mineral mix with sodium salt added is given but interruption of this for 2 years did not result in obvious signs of deficiency.

Pasture development on the Zanderij Belt in the Tibiti area

The Tibiti cattle farm is in the Tibiti area on the Zanderij Formation, with an undulating landscape and coarse brown sands and loamy sands. Some small patches of white sands occur where the original vegetation was high forest. Towards the creeks the soil becomes more loamy and here also kaolinitic clays can be found. The ground-water level is at 7 m.

The original high forest occurring in this area was cleared and pine (Pinus caribaea var. Caribea) was planted. Due to the slow growth of the pine, part of the area was made available for pasture in 1981. The main grasses planted on this farm were Brachiaria decumbens, Brachiaria sp. (USDA no. 299498). On limited areas Brachiaria humidicola, Panicum maximum, Andropogon gayanus and Digitaria swasilandensis were planted. Up to now the grasses are: B. decumbens, Brachiaria sp., B. humidicola and A. gayanus have maintained themselves very well, while P. maximum and D. swasilandensis have lost ground.

The climate is similar to the rest of the country with four seasons and where in the dry seasons the rainfall seldom drops below 50 mm in any one month. Because of the excellent drainage of the soils and low ground-water level, grass growth in the dry seasons is low but no permanent damage of the grass has been experienced.

From 1986 spittle bug infestation occurred periodically for short periods on small patches but up to 1988 the grass was able to recover. The infestation was found primarily in the Brachiaria sp. and to a lesser degree in B. decumbens.

Fertilizing is done mainly to favour grass growth over weed growth; 50-100kg NPK (15: 15: 15) per ha per year was applied. Suppression of weed growth is also carried out by mowing
Table 2  Herd size and performance at the Tibiti farm, Suriname

<table>
<thead>
<tr>
<th>Year</th>
<th>Herd size</th>
<th>Calving %</th>
<th>Calf mortality(%)</th>
<th>Weaning weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>100</td>
<td>60.2</td>
<td>7.1</td>
<td>----</td>
</tr>
<tr>
<td>1984</td>
<td>479</td>
<td>62.6</td>
<td>5.3</td>
<td>----</td>
</tr>
<tr>
<td>1985</td>
<td>496</td>
<td>68.8</td>
<td>30.4</td>
<td>160</td>
</tr>
<tr>
<td>1986</td>
<td>594</td>
<td>77.0</td>
<td>15.5</td>
<td>170</td>
</tr>
<tr>
<td>1987</td>
<td>685</td>
<td>1.7</td>
<td>94.0</td>
<td>----</td>
</tr>
</tbody>
</table>

with a rotary slasher. The cattle herd consists of Zebu and grade Zebu and mating and calving take place in two seasons. The average age at weaning is 8 months (Table 2).

Mineral deficiency

Normally the cattle received a mineral mix to which salt was added. The percentage composition of this mineral mix without salt was: 30% Ca; 9% P; 0.8 Mg; 0.1 Fe; 0.01 Co; 0.125 Cu; 0.15 Mn; 0.04 Zn; and 0.007 I. At the beginning of 1985 no mineral mix was available and at the end of that year some calves got diarrhoea that persisted in spite of treatment. Their condition deteriorated and eventually most of them died. Also in older animals a higher frequency of diarrhoea and abortion was experienced. In 1986 the number of animals losing condition increased with symptoms such as loss of appetite, heavy pica, some animals with persistent diarrhoea, increased mortality and decreased calving. In 1987 conditions were especially bad and the mortality was very high (Table 2).

At the beginning of 1988, mineral mix was again available and within 2 months the condition of most of the animals improved dramatically. Chemical analysis of the grass showed a deficiency in Cu and P, and a questionable amount of Zn. The Co content seemed adequate. Iodine could not be analyzed, but in some sheep present at the farm goiter developed, indicating iodine could also be considered as deficient.

Reference

FORAGE PRODUCTION SYSTEMS ON THE ACID INFERTILE SANDY SOILS OF GUYANA

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The forage production potential and possibilities on the acid infertile sandy soils of Guyana are discussed. The major forage species used in pasture production is *B. humidicola*. The major constraints to pasture production are identified as the low nutrient status of the soils, the rainfall distribution and the methods of establishment and propagation. Strategies to alleviate these constraints are the selection of adapted species, mineral and protein-energy supplementation, increased seed production, mechanized transplanting and proper grazing management. Possible integrated crop-livestock systems are suggested.

The acid infertile sandy soils of Guyana belong mainly to the soil orders Ultisols, Entisols and Oxisols. They occur mainly in central Guyana in an area known as the Intermediate Savannahs, and to the south, on the border with Brazil, in an area known as the Rupununi Savannahs (Bullen, 1988). Generally these soils are characterized by inherently poor fertility, low Effective Certain Exchange Capacity (ECEC) and pH and high Al. The physical and chemical properties of these soils have been described in detail by Bullen (1988) and Simpson (1988). The major physical limitation is a serious erosion hazard when the soil is disturbed. The rainfall is bimodal showing greater accumulative patterns from May to August and November to January, with comparatively lower precipitation in the intervening months.

The naturally occurring vegetation consists of a mixture of forest, woody shrubs and grasses. Initial agricultural activity was mainly confined to harvesting operations; firstly of the forest for timber, wood products and fuel. Secondly, the presence of large areas of grassland encouraged the introduction of cattle to utilize these lands; mainly in the Rupununi Savannahs. Very little management was introduced to improve the natural grazing lands. Stocking rates were extremely low (one animal per 12 ha). The animals were rounded-up periodically for extraction for beef. Limited attention was given to the calves at this time. The marketing on the Coast of animals grown in the Rupununi was facilitated by a cattle trail over which the animals were driven to holding areas in the Intermediate Savannahs, from where they were shipped to the Coast. This practice resulted in the animals arriving in poor condition and high mortality rates occurred which prompted the establishment of a research station in the 1940s, not in the Rupununi but at Ebini in the Intermediate Savannahs.

At the research station, the first attempts to introduce improved management were made with the use of improved grasses and the introduction of exotic breeds of cattle. While the research efforts over the years have not always been sustained, valuable experience has also been accumulated in the production
environment and when combined with experiences gained in similar areas of the continent, can inform the development of appropriate forage production systems.

**Forage species used in production**

One of the prerequisites for successful pasture development is the availability of species/cultivars well adapted to the eco-system. Within the Intermediate Savannas the native species, although adapted, were found to be deficient in providing the necessary nutrients for sustained animal production (Holder et al., 1982). To overcome this, a systematic approach to the selection of suitable forages was initiated with the introduction of the Oakes and Schanks (University in Florida) collection in the 1960s. Based on the ratings derived from these, species of the genus *Digitaria* were selected and multiplied for large-scale pasture production (Holder and Latchman, 1971). These species, however, required high inputs of inorganic fertilizers to maintain adequate levels of production. Also, one of the more widely planted species, *Digitaria decumbens* became infected with the pangola stunt virus, resulting in a rapid decline in pasture production (Hunkar et al., 1975). In addition, the economic problems which subsequently occurred limited the use of fertilizers and created the need for new criteria to be used in the selection process of forage species. These criteria dictated that the forage species should be able to sustain adequate levels of production with very few inputs.

In this connection, it became necessary to rapidly identify and introduce forage species resistant to disease, but also which fitted the low input strategy. Initially, *Brachiaria radicans* (Tanner grass) was tried, but this species succumbed to the harsh prevailing conditions of the ecozone. In 1979, *Brachiaria humidicola* (UF 717) emerged empirically as the most suitably adapted forage grass for the ecozone. This species was originally introduced into the Ebini Research Station with the Schank's collection from the University of Florida. It is well adapted to the acid infertile soils and is tolerant of high Al and low soil P (Thomas and Grof, 1986). These authors further pointed out that the plant shows good regrowth after burning and is more flood-tolerant than *B. decumbens*. In Colombia, there was no damage from the spittle bug which affects *Brachiaria* spp. in Brazil. It was also reported to be very acceptable to cattle when kept short and leafy. To date, *B. humidicola* is the major species used for pasture production in these ecozones.

**Constraints to forage production**

**Soils**

The major soil-related constraints are the inherently low nutrient status and poor retention capacity for applied nutrients—a function of the low ECEC. The physical properties are probably more suited to animal production since there is more air and water movement and less risk of compaction and drainage problems during the rainy season than there is with the clay soils on the Coast.

**Rainfall distribution**

In the Intermediate Savannas, the mean annual rainfall is about 2250 mm. The distribution is bimodal showing greater accumulative rainfall patterns from mid-April to mid-August and from mid-November to the end of January (Fig. 1). Consequently, seasonal variation in forage production and quality occur and this is reflected in the changes in animal performance. This pattern is illustrated in Figs. 2 and 3 on continuously grazed *B. humidicola* pastures.

**Establishment methods**

The low availability of pure, viable seed obtained from tropical grasses in the
Fig. 1  Mean monthly rainfall (mm) from 1983 to 1986 at Moblissa
Fig. 2  Pasture dry herbage allowance (kg/animal/day) and silage dry matter allowance (kg/animal/day) at different stocking rates (animals/ha) at Moblissa, Intermediate Savannahs, Guyana

Source: CARDI (1988)
Fig. 3  Forage production at different stocking rates at Moblissa, Intermediate Savannahs, Guyana

(a) Production animal$^{-1}$ for wet season (---) and dry season (-----)
(b) Production ha$^{-1}$ for wet season (---) and dry season (-----)

Source: CARDI (1988)
area dictates that pasture establishment should be by vegetative means. This is obviously a rather labour intensive and costly exercise. In addition the planting rate by this method is slower when compared to direct seeding.

**Strategies to overcome constraints**

**Selection of adopted species**

The first strategy to alleviate the constraints to forage production that are related to soil properties should involve the identification and selection of adaptable forage species. In this regard both grasses and legumes should be evaluated based on the following criteria:

- High dry matter production
- Persistence under grazing
- Ability to compete successfully with weeds
- Ability to associate with desirable species
- Pest and disease resistance
- High animal production potential
- Ease of establishment
- Seed production potential
- Ability to respond to applied nutrients

In Guyana the systematic approach to forage evaluation is continuing, and some species which have shown promise apart from UF 717 are *B. humidicola* (Sheep grass), *A. gayanus* and *B. decumbens*. In addition a volunteer species known as *P. solanum* seems to have great potential for the ecozone. This is based on the potential yields (Table 1) from clipping studies (CARDI, 1983; 1988) and some responses to grazing as shown in Figs. 4 and 5 (Seaton *et al*, 1988).

Based on adaptability, some of the promising legumes are *Centrosema spp*. *Desmodium ovalifolium* and *Stylosanthes* spp. *Calopogium mucronoides* has also proliferated but animal acceptance seems to be very low based on empirical observations.

**Establishment methods**

Concurrent with the evaluation and selection process must be the initiation and development of appropriate seed production capabilities. This is an important prerequisite for the rapid adoption and expansion of the selected species. Also direct seeding for establishment is more compatible with an integrated farming system, involving rotation with annual crops. It is therefore very important that facilities for the cleaning, testing and storage of forage seeds be installed.

In the event, however, that it is difficult to propagate a desirable species by direct seeding, innovations are required to develop mechanical methods of transplanting that give acceptable rates of planting e.g. the type of equipment used in the transplanting of tobacco seedlings should be investigated for the vegetative establishment of pastures. Closer inter- and intra-row spacings are possible and smaller root splits could be utilized. *B. humidicola* should benefit particularly from this because according to Bogdan (1977) the rate of its establishment is faster with smaller root splits.

**Grazing management and utilization**

The objective of grazing management is to utilize a fluctuating supply of herbage effectively and efficiently by regulating the number of grazing animals. Generally the carrying capacity is the optimum stocking rate which can be safely sustained and is related to the forage resources available in the periods of deficit (dry season).

Research at Moblissa, Guyana (CARDI, 1988) indicated that a safe sustainable stocking rate on continuously grazed *B. humidicola*
Fig. 4  Responses to grazing at Moblissa, Guyana: Arcsin transformed percentage of ground covered by grasses before grazing.

Source: Seaton (1989)
Fig. 5 Responses to grazing at Moblissa, Guyana: Square root transformed dry herbage mass (g/m²) before grazing.

Source: Seaton (1989)
Table 1  Dry matter yield (tonnes/ha) of eight grass species at four cutting frequencies

<table>
<thead>
<tr>
<th>Species</th>
<th>Cutting interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 weeks</td>
</tr>
<tr>
<td><em>P. purpureum</em></td>
<td>0.84</td>
</tr>
<tr>
<td><em>B. decumbens</em></td>
<td>1.41</td>
</tr>
<tr>
<td><em>P. maximum</em></td>
<td>1.28</td>
</tr>
<tr>
<td><em>S. sphacelata</em></td>
<td>1.44</td>
</tr>
<tr>
<td><em>B. radicans</em></td>
<td>1.40</td>
</tr>
<tr>
<td><em>D. pentzii</em></td>
<td>1.11</td>
</tr>
<tr>
<td><em>B. humidicola</em></td>
<td>3.21</td>
</tr>
<tr>
<td><em>D. decumbens</em></td>
<td>1.13</td>
</tr>
<tr>
<td>Mean</td>
<td>1.48</td>
</tr>
</tbody>
</table>

S.E. of difference = (a) 0.549; (b) 0.421; (c) 1.191; (d) 1.102

S.E. of difference (a) = Between 2 opposite means
S.E. of difference (b) = Between 2 cutting frequency means
S.E. of difference (c) = Between 2 cutting frequency means for the same species
S.E. of difference (d) = Between 2 different species and different cutting frequency means

Source: CARDI (1983)

Pastures (Fig. 3) was one animal unit per ha without concentrate supplementation. At this stocking rate, grazing heifers gained 0.2 kg per day and milk production averaged 4.5 litre per cow per day (1 animal unit (a.u.) = 400 kg animal).

*B. humidicola* pastures require high grazing pressures if they are to be effectively utilized (Hoyos and Lascano, 1982). Herbage accumulation is very high when the stocking rates and grazing pressures are low. Table 2 shows the high accumulation of dry matter when pastures are leniently grazed. Seaton (1987) reported better animal performance at stocking densities of 4.5 a.u. per ha than at both lower and higher stocking densities. This performance, however, is dependent on an adequate forage allowance. CARDI (1988) reported that animal production can be safely sustained if herbage allowance is not less than 20 kg dry matter per a.u. per day.

If the sustainable stocking rate of 1 a.u. per ha is employed, excess forage would occur in the rainy season. This excess forage can be utilized to increase carrying capacities above 1 a.u. per ha to levels that permit the minimum herbage allowance. Various systems can be employed to accomplish this objective.

- Animals can be imported in the rainy season when forage production is high and exported during the dry season.
Table 2  Biomass dry matter availability (per ha and per animal) before and after grazing for four periods on *B. humidicola* (UF 717) pastures at four stocking rates at Moblissa on the Intermediate Savannahs of Guyana.

<table>
<thead>
<tr>
<th>Rainfall per period (mm)</th>
<th>Stocking rate (animals/ha)</th>
<th>0.9</th>
<th>0.6</th>
<th>0.5</th>
<th>0.4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>301.4</td>
<td>11,365.0</td>
<td>9,578.0</td>
<td>9,156.0</td>
<td>9,092.0</td>
<td>8,313.0</td>
</tr>
<tr>
<td>240.0</td>
<td>11,798.0</td>
<td>11,659.0</td>
<td>9,436.0</td>
<td>9,515.0</td>
<td>9,200.0</td>
</tr>
<tr>
<td>120.7</td>
<td>10,817.0</td>
<td>11,852.0</td>
<td>8,887.0</td>
<td>8,639.0</td>
<td>9,142.0</td>
</tr>
<tr>
<td>594.2</td>
<td>13,580.0</td>
<td>13,573.0</td>
<td>8,167.0</td>
<td>9,562.0</td>
<td>11,609.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rainfall per period (mm)</th>
<th>Stocking rate (animals/ha)</th>
<th>0.9</th>
<th>0.6</th>
<th>0.5</th>
<th>0.4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>301.4</td>
<td>1,268.0</td>
<td>1,064.0</td>
<td>1,526.0</td>
<td>1,515.0</td>
<td>1,663.0</td>
</tr>
<tr>
<td>240.0</td>
<td>1,311.0</td>
<td>1,295.0</td>
<td>1,573.0</td>
<td>1,586.0</td>
<td>1,840.0</td>
</tr>
<tr>
<td>120.7</td>
<td>1,202.0</td>
<td>1,317.0</td>
<td>1,481.0</td>
<td>1,449.0</td>
<td>1,828.0</td>
</tr>
<tr>
<td>594.2</td>
<td>1,509.0</td>
<td>1,508.0</td>
<td>1,361.0</td>
<td>1,594.0</td>
<td>2,322.0</td>
</tr>
</tbody>
</table>
The excess forage can be conserved either as silage, dried grass or deferred grazing for subsequent feeding in the dry season. Conservation of *B. humidicola* by silage or drying has been demonstrated to be technically possible by CARDI (1986). These methods however, have to be evaluated for the cost/benefit ratio in a production system, because of the high cost of the necessary capital equipment and fuel. Deferred grazing is less costly but the technical and economic parameters also need to be estimated.

The latter system infers that some form of rotation is necessary. Strict rotational grazing has limited benefits to improved animal performance (Crowder and Cheda, 1982). It also incurs a high capital investment in fencing. Rotations should therefore be determined on the basis of providing enough herbage to ensure adequate nutrient uptake while leaving enough residual herbage to allow pasture regeneration.

**Supplementation**

(a) Mineral

To sustain animal production on these soils, it is necessary to provide mineral supplements because the soils are extremely deficient in the major essential minerals. At present the practice is to offer a commercially formulated supplement which includes as many as the essential elements as possible. Future work should be directed at measuring which nutrients are built up in the pasture through the excretion of the animals and thus finding what adjustments can be made to the formulation of the mix.

(b) Protein and energy

Protein and energy supplementation is also necessary in order to increase the production of animals with the genetic potential for high production. Supplementation practices will have to be refined as necessary to account for the type and quantities of supplement fed and the grazing system employed to satisfy the nutrient demands of the animals.

**Forage production in integrated systems**

Integrated systems of agricultural production attempt to use various biological units in such a mixture that the units are complementary and the total production from the system is higher than if any one unit were used singly. Benefits to crops derived from grass rotations are: the addition of organic matter; soil erosion control, and the recovery of nutrients from lower down the soil profile to the soil surface. The potential benefits to the pasture derive from the effects of residual fertilizer applied to the crop. Also crops such as peanut (*Arachis hypogaea*) can be fed to animals in the dry season.

Other crops which have potential are cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*) which can produce large quantities of dry matter and energy for dry season feeding.

Other possibilities of integrated systems are grasses and legumes under orchard crops such as *Citrus* spp., coconut (*Cocus nucifera*) and papaya (*Carica papaya*). The major consideration in integrated systems is to ensure that the biological components are compatible.

Animals grazing under orchards must not damage the trees. The type of animal and its use must also be considered. Dairy operations using exotic breeds with low heat stress tolerance may benefit more from the shade under orchards. The type of grasses and legumes selected would also vary because they will be exposed to lower levels of radiation in these systems.

Systems of agriculture for these soils should imitate the natural evolution of species on these soils, which were grasses and trees. The successes of
any system may well depend on the selection of biological units which are compatible with the environment and not antagonistic and destructive.

Conclusions

- Forage production to sustain animal production is possible on these soils. However, continued evaluation to select superior genetic material that improves the quality and nutrient intake of animals is necessary.
- Methods of utilizing surplus forage in the rainy season, to ensure equitable distribution throughout the year, need refining.
- Seed production capability must be increased to meet the demands for rapid pasture expansion.
- Research and production experiences have demonstrated that mineral supplementation is essential for animal production on these soils.
- Crop-livestock systems may offer the best opportunity for maximizing productivity on these soils.

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Seaton, J.M. (1989) Grazing and supplementation studies with growing and lactating dairy cattle at Moblissa Guyana. M. Phil. Thesis The University of the West Indies, St Augustine, Trinidad.


Within the affiliation of CARICOM countries, animal production in the smaller islands is limited by lack of land resources. In such a situation, it is logical to devote the limited areas of available land to the production of high-value crops (vegetables, spices etc.). Steeper, less easily worked land can be used for animal production, but sheep and goats would generally be more profitable than cattle by virtue of their faster rates of reproduction. The large land areas found in the continental countries of Guyana and Belize would then concentrate on row crops and beef production where economies of scale can provide them with a comparative advantage. In this way the CARICOM region as a whole could greatly reduce the importation of basic food items, with consequent benefits for the regional economy.

Such arguments have been advanced many times in recent years. There are, however, technical, economic and political problems in the establishment of such a co-operative scheme. Some of the difficulties involved in animal production in Guyana will be discussed below, and strategies to overcome some of these problems will be suggested. Comments will be restricted to the Intermediate Savannahs in view of their large physical potential for animal production.

Constraints

The combination of highly infertile, acid, sandy soils and a bi-modal rainfall pattern with two sharp, severe dry seasons results in a native vegetation which constitutes a poor diet for the grazing animal. The hardy grasses which inhabit this region (species of Andropogon, Axonopus, Paspalum, Trachypogon etc.) are frequently poor in terms of both yield and digestibility, while acceptability also presents a problem, particularly when the grasses become mature. Native legumes include a range of Desmodium spp (particularly D. adscendens and D. barbatum but these are generally low-growing and make a limited contribution to animal production unless carefully managed. On an ultisol in Belize, considered representative of large areas in Guyana, Suriname and Venezuela, Ahmad (1986) reports animal gains in an 11-month period of 15.7 kg per animal (2 kg per ha) from native pasture. This was increased to 143.1 kg per animal (71 kg per ha) by the annual application of 63 kg per ha of Triple Superphosphate, since this resulted in a ten-fold increase in the growth of native legumes.

The cost and availability of fertilizers for use on pastures represents a constraint to production on these infertile soils, while their sandy nature and low organic matter content (Ahmad, 1989) result in the rapid loss of applied nutrients. The practice of frequent burning to stimulate grass regrowth during the dry season prevents the build-up of organic matter in the soil and this aggravates the fertility problem.

In view of the poor productive potential of native pastures, successful animal production will have to be based on improved species. While there has been a considerable amount of work done on this subject over the years, much of the early experimentation was
based on heavy use of organic fertilizers on demanding grasses such as Pangola \((D. \text{decumbens})\) and this is no longer valid within the present socio-economic context. More recent work, adopting the CIAT philosophy of minimum inputs (e.g., CARDI-IDRC, 1987) has resulted in the identification of promising species, but formal species recommendations have not been widely publicized, nor is there a regular local supply of high quality seed for use in on-farm development programmes. As in many developing countries, the extension services are weak, particularly in the fields of pasture development and animal production.

Added to these problems are others associated with the frontier nature of the region and with the low fertility of the soils. Existing ranches are generally large and capital is limited, so lack of suitable machinery complicates efforts to improve pastures. Access is often difficult by road and always expensive by air. In addition, praedial larceny can restrict the use of outlying areas of isolated properties. The purpose of this seminar is to address this range of problems and to suggest strategies that will assist in the development of an expanded and productive livestock enterprise for the acid, infertile sandy soils. The more political aspects are beyond the scope of a technical seminar and so will not be discussed in detail.

**Level of intensification**

While the nature of dairying, with its regular income from sale of milk, allows and requires a degree of intensification, beef can be produced in systems which range from highly extensive to very intensive. Given the socio-economic conditions which prevail in the Intermediate Savannahs, it is unlikely that beef production will become intensive in the foreseeable future. The following comments will therefore be restricted to relatively low input, extensive grazing systems of animal production.

**Improved pasture species**

The International Tropical Pasture Evaluation Network (RIEPT) of CIAT has been active throughout South and Central America since the beginning of the present decade. Pizarro (1983, 1986, 1988) reports a total of 29 experiments sown in nine countries ranging from Costa Rica and Cuba to Brazil and Paraguay where the soils contained greater than about 70 per cent sand, the reaction was pH 5.2 or below and the P content was generally below 3 ppm (Bray II). While there were local variations, the degree of similarity in the behaviour of a range of pasture species was surprising in view of geographic and climatic differences across the area of study. Amongst the grasses, \(B. \text{decumbens}\) was generally fastest to establish, producing a rapid ground cover and competing well with the existing vegetation. By the second year, however, either \(A. \text{gayanus}\) or \(B. \text{humidicola}\) had become more productive than the \(B. \text{decumbens}\). In recent years, \(B. \text{decumbens}\) has lost favour in large areas of South America as a result of its susceptibility to spittle bug (frog hopper, salivazo). Severe attacks can lead to the destruction of the pasture over wide areas. For some time it was believed that \(B. \text{humidicola}\) was resistant to the pest, since it could support higher populations than \(B. \text{decumbens}\) without suffering apparent damage. It is now known that \(B. \text{humidicola}\) will also succumb when the insect population becomes great enough. Recent emphasis has been placed on \(B. \text{brizantha}\) as a re-placement for both \(B. \text{decumbens}\) and \(B. \text{humidicola}\), since it has a biological mechanism to inhibit the physiological development of the spittle bug, and in this way it prevents potentially dangerous insect population explosions (Lapointe and Ferrufino, 1988). \(A. \text{gayanus}\) shows high tolerance to spittle bug attack, without exhibiting a biological control method. It is also therefore potentially vulnerable. Genuine resistance in grasses, rather than tolerance, is a matter that requires
further research at an international centre.

Amongst the legumes tested in these experiments, there is rather more variation between sites. *Aeschynomene histrix* has often appeared promising in the establishment period, but fails to live up to its early promise. *Desmodium ovalifolium, Pueraria phaseoloides* and *Zornia spp.* are useful in areas where the dry season is short, but they tend to shed their leaves during long periods without rain. *Stylosanthes capitata* is generally considered to be productive only during the wet season. The most consistent legumes appear to be *Stylosanthes guianensis* (when not defoliated by anthracnose) and *Centrosema spp.* (particularly *C. brasiliannum* and *C. macrocarpum*, although *C. acutifolium* merits wider evaluation under these conditions).

Experience at Ebini (CARDI-IDRC, 1987) closely follows results obtained on sandy soils in other countries. It would therefore appear that there are a number of improved grasses and legumes that can be moved with some confidence from the experimental phase into a programme of pasture development. While grasses can be multiplied vegetatively, for all practical purposes, legumes must be established from seed. Since commercial seed sources are poorly developed for the most promising species noted above, steps must be taken to produce seed locally. CARDI is developing a programme along these lines with financial assistance from the European Economic Community but in order to plan successfully, an estimate of the potential seed requirement must be made. It is difficult to make accurate predictions until seed becomes available.

It has been reported that seed of several species, harvested from promising legume introduction plots at Ebini, failed to establish when resown at the same site (J. Smith and P. Osuji; personal communication.). This is clearly a worrying observation since while establishment failures can result from climatic, edaphic or biotic factors, the inherent viability of locally produced seed must be proven beyond doubt before considerable amounts of time and money are spent on the development of a local seed production facility.

**Introduction techniques**

In a review of the role of pastures in the development of acid, infertile soils in Latin America, Spain (1982) considered a range of tillage systems from conventional ploughing and harrowing through minimum tillage of the whole area, tillage only within the planting row, to chemical control and manual tillage only at the planting site. This progression represents reducing costs and erosion hazards, but it also provides a decreasing level of control of the native vegetation. Establishment of all introduced species is favoured by appropriate conventional tillage, but as the degree of land preparation is reduced, so is the number of improved pasture varieties that are able to thrive under the increasing level of competition from the existing sward. In general, pasture varieties have not been fully evaluated under imperfect planting conditions. It is clear, however, that the choice of pasture species to be sown will be influenced by the aggressiveness of the existing vegetation and by the method of land preparation, since a species which is slow to establish will require protection from competition for an extended period.

Planting can be achieved in several ways. It is common in most of tropical South America to broadcast seed onto prepared or burnt land, either by hand or with simple machinery. While this method is relatively cheap in terms of labour and equipment, it requires higher seeding rates, fertilizer efficiency is reduced and weed control can become a major problem. In some areas, seed-gathering ants or adverse climatic factors can drastically reduce establishment. Planting in rows is more expensive, but provides a higher
chance of success, particularly if used in conjunction with the placement of fertilizers below, or alongside of the sown furrow.

Policy issues

Light textured, infertile soils are inherently fragile and are easily destroyed by exploitative agricultural activities. The aim must be to gradually improve soil structure and fertility by practices that allow for a build-up of soil organic matter. In this regard, pastures are of great importance. Even on a cropping farm without animals, leguminous leys need to be encouraged for this purpose. As the region develops, such leys could provide a cash income either in terms of green chop or pasture seed for sale to neighbouring livestock enterprises.

Careful soil husbandry has three policy implications:

- inputs of seed and fertilizers must be available at an economic price, since the native soil fertility is too low to produce acceptable yields of either crops or pastures. This requires political initiative.

- property size must be large enough to allow for ley-farming, even on a predominantly crop farm. Since land is plentiful and population pressure is low in the savannas, it is thought that the smallest properties should be in the range of 50 to 100 ha.

- perennials have a significant role to play in the development of the region. Trees will stabilize the soil and provide shade, fuel, fodder and/or a cash crop.

Agriculturalists must design and demonstrate financially rewarding systems of animal production. If the systems are sufficiently attractive, development of the region for livestock will automatically follow. If not, then political and fiscal incentives may be necessary to ensure the rational utilization of the savannas.

Development strategies

In a situation where capital is limiting, not only must reliable low-cost methods of pasture development be employed, but also the development of an individual property will be gradual, taking place over a period of years. Clearly, the most favoured areas should be developed first. Where there is a greater capacity for nutrient retention (e.g. the Brown rather than the White Sands), pasture establishment could take place in conjunction with a cash-crop in order to take advantage of some of the fertilizer applied to the crop. This technique has been used with success in infertile soils in a number of South American countries. The problem remains, however, of pasture deterioration over time, as a result of falling chemical and physical fertility and redistribution of plant nutrients under the influence of the grazing animal. In the long term, little sustainable development can be achieved unless fertilizers can be made available at economic prices.

In the poorer parts of the region, only by increasing the level of soil organic matter can the moisture and nutrient retention characteristics be improved. In the 1960s in West Australia, a number of unsuccessful attempts were made to establish annual sub-clover (*Trifolium subterraneum*) based pastures on an old beach sand formation at Badgingarra, 320 km north of Perth (Mediterranean climate). Eventually a technique was developed where large-seeded blue lupins (*Lupinus consentinii*) were grown and ploughed in for two consecutive years as a soil improvement mechanism prior to the sowing of the clover. This resulted in
successful pasture establishment. If a similar technique were to be employed in the savannahs, suitable cover crops could include the naturalized species *Calopogonium mucunoides*, or other large-seeded legumes such as Jackbean (*Canavalia ensiformis*) and Velvetbean (*Mucuna pruriens*). This would be an expensive process but there may be no viable alternative.

In infertile soils in the Colombia Llanos, CIAT has, in recent years, developed considerable experience in low density, low cost seedings (Ayarza and Spain, 1988). One technique is to sow strips of improved species into about 20 per cent of a field. The strips are usually prepared and drilled conventionally and fertilizer is placed near to the seed. The area between the strips is not fertilized. The sown species are chosen for their ability to invade the unsown area either by stolons (*Brachiaria* spp.), trailing stems (*Desmodium ovalifolium, Pueraria phaseoloides*) or seed (*Andropogon gayanus, Panicum maximum*). In the first year, they become well established and begin to move out into the surrounding area. At the beginning of the second and subsequent growing seasons, fertilizer is applied only to the area covered by the introduced species. Fertilizer use thus increases with the area of improved pasture. The area is grazed once the initial strips are established, although care must be taken to prevent over-utilization of the introduced pasture. In this way, increased animal production will cover the cost of additional fertilizer.

A variation on this theme, adapted to the use of hand labour, is to spot-spray or manually remove the existing vegetation at a number of sites (500 - 1000 per ha) which are then fertilized and sown with selected species. Again, fertilizer application in the second and subsequent years only takes place on those areas which are invaded by the introduced species. The rate of invasion of the savannah from such extremely low density sowings will depend on the competitiveness of the existing sward, but will be slow, particularly in the early stages. It is, however, an extremely low cost technique which has been successfully used to establish a number of pasture species, particularly associations of *A. gayanus* and *P. phaseoloides* (Spain, 1982). Carefully controlled grazing has been initiated 6-12 months after planting.

In the general development of a property, controlled grazing of already improved areas is of great importance. since in the early stages the animal population is usually in excess of the carrying capacity of the limited areas of introduced pasture. The improved area must then be used strategically. The choice must be made between selecting an appropriate number of highly productive animals (finishing males, lactating cows) to use the area in the longer term, or feeding a larger number of animals for a shorter period during the most critical part of the year. This choice will be determined by the specific requirements of the individual farm, but the fastest returns will be generated by finishing slaughter animals, while the long-term financial stability of the enterprise may well be favoured by feeding lactating cows to increase both weaning weights of the calves and reconception rates of the dams. The importance of the inclusion of legumes is then obvious. Improved grasses may provide sufficient quality to allow livestock to grow and produce for several months of the year, but they can only be considered as a replacement for native pastures. Legumes, with their higher feeding value, can complement the existing pasture. The nitrogen content of the legume will allow the ruminant animal to make better use of relatively indigestible forage. In such a situation the strategic use of legume banks will maximize utilization of the natural pasture, provided that the fodder complex can be protected from fire.

While it is generally accepted that the ideal pasture is a combination of grass(es) with legume(s), the problems of associating the two together are also well known, particularly in infertile tropical soils. Problems of species incompatibility amongst the relatively
few pastures suitable for use in these areas are compounded where there is a large disparity between the palatability of the components of the mixture. In such a situation, grazing management becomes a delicate balancing act that is difficult to achieve on a extensive ranch. Legumes can then be included as separate areas (banks). This loses any advantage that may be gained from the direct transfer of nitrogen from the legume to the grass, but it is offset by increased persistence and ease of management when the two forage groups are physically separated. Some fertility transfer will be assured through the grazing animal, and judicious placement of salt supplements within the grass paddock will assist in the distribution of the dung and urine.

Legume banks can be sown together with a row crop, in order to offset some of the establishment costs. The crop residues can then be grazed together with the legume during the dry season, provided that the crop has been chosen with this in mind. Many food crops produce residues that can be eaten by livestock. The integration of crop and animal production is something that should not be ignored, even on the savannahs.

In a harsh environment such as the savannahs, a major limitation to animal production is high calf mortality, often associated with a combination of poor nutrition and a heavy burden of internal parasites. It is well known that both calf mortality and reconception of dams can be substantially improved by early weaning, deworming and the provision of highly digestible feed to the young animals. Where cows are confined for milking, there exists an opportunity to systematically collect and utilize the dung. If this is applied to a small area, it will rapidly improve the soil fertility to a level where high quality grasses can be grown. The planting of Bermuda (Cynodon spp.) or Digit (Digitaria spp.) grasses for grazing, or dwarf varieties of Elephant grass (Pennisetum purpureum) for cutting would then provide calves with levels of digestible nutrients sufficient to reduce calf mortality and to improve farm profitability.

Constraints such as physical isolation and praedial larceny are problems which have no technical solutions, but rather must be tackled by political initiatives. Nevertheless, if profitable production systems are introduced into the savannahs, people will be encouraged to move into the area to take advantage of the economic opportunities. As the population of the region increases, it will be easier to justify the social expenditure required to solve these problems.

Conclusions

A considerable amount is known about managing low fertility, acid, sandy soils in the tropics. While they constitute an extremely fragile ecosystem which is vulnerable to mismanagement they can, over a period of years, be improved by conservative farming practices, including the use of legume-based pastures or leys which increase soil organic matter and protect it from erosion. Pasture species which are adapted to such conditions have been identified and low-cost introduction methods have been devised. It remains to demonstrate a farming system which incorporates these and other elements into a financially rewarding package which will attract farmers into the savannahs.

References


PRODUCTION OF SHEEP AND GOATS IN GUYANA WITH PARTICULAR REFERENCE TO THE INTERMEDIATE SAVANNAHS *

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The consumption of mutton and lamb in the Caribbean Community (CARICOM) in 1973 was estimated to be 5,400 tonnes, 3,500 of which were imported. Scope for expansion in sheep and goat production within the region is even greater now since there has been no major improvement in production or productivity over the last decade.

In Guyana recently, the decrease in poultry and pig production influenced by the dearth of foreign exchange for imported inputs, and the concomitant increase in beef, mutton and goat meat production highlights the need for concentrated research efforts into the scientific and economic exploitation of ruminant resources. The relatively short generation interval, low capital costs and general consumer acceptability of sheep and goat meats, make the exploitation of these species very attractive. Guyana, because of its physical capacity and geographical proximity to the other markets of CARICOM can be geared to supply a substantial proportion of their requirements for sheep and goat meat, now imported extra-regionally.

Significant physical expansion in animal production on the country's coastal plain is now circumscribed particularly by the demands of the expanding rice industry. The Intermediate Savannah region because of its vastness, proximity to the population centres and ease of accessibility would be a logical area for agriculture generally, and livestock production in particular.

* Not presented at the seminar

Sheep and goat production

The coastal plain

The sheep and goat population in Guyana in 1981 was estimated to be about 188,000 head, approximately 62 per cent being sheep (FAO, 1981). These are maintained primarily in flocks ranging from less than 10 to more than 50 animals in non-commercialized settings, characterized by low level husbandry. Typically, grazing is limited to about 10 hours daily; nightly coralling being the norm for security. 'Pastures' are usually uncultivated lands, playgrounds, roadsides, dams and even canal edges, where the main naturally occurring grasses are: *Axonopus compressus* (Carpet grass); *Cynodon dactylon* (Bahama or Bermuda grass); *Ischaemum timorense* (Lucuntu); *Leerisia hexandra* (Fine grass); *Paspalum repens* (Shrimp grass); *P. virgatum* (Razor grass); other species in the genera *Paspalum*; and *Sporobolus indicus* (Iron grass). Common sedges are *Cyperus articulatus* (Bisi-bisi) and *Rhynchospora corymbosa* (Razor grass). Among the few legumes are *Vigna lasiocarpa* and *V. luteola* (Wild bora).

Only in a few instances is there regular grazing of rice lands after harvest, or land in short or long term fallow following rice cropping. Trespassing in kitchen and flower gardens is prevalent, especially in the suburbs. Supplementary feeding is not common and where practised by more informed farmers, is limited to molasses and rice bran.
Prophylactic programmes are by no means universal, yet apart from moderate to heavy internal parasitism in many flocks and sporadic cases of foot-rot in fewer, there is no generalized health problem. This, it is assumed, is indicative of the animals' hardiness.

Productivity is low. Thus age at first lambing/kidding approaches 2 years. Profligacy is poor since multiple births nationally represent less than 40 per cent of successful pregnancies. Annual lambing/kidding is the norm and juvenile mortality is generally in excess of 25 per cent. Growth rates are poor, a liveweight of 25 kg generally being attained around 2 years after birth.

The largest population of sheep in the country is maintained on the coastal plain. The annual harvest is about 20 percent, which is extremely low. Production is largely in the hands of the private sector, with flock sizes ranging from 10 to 50 animals.

The Intermediate Savannahs

These savannahs are in North-East Guyana, immediately behind the coastal plains and adjoin the upland rain forest regions. Only about 25 per cent of their 2,700 km² is typical savannah; the rest is forested. Less than 10 per cent of the area is cultivated.

Rainfall is about 2,250 mm and 40 to 60 per cent occurs in the long wet season, April to August, and less than 20 per cent in the short wet season, mid-November to mid-February. Mean annual temperature is approximately 20°C with diurnal fluctuations of up to 10°C. Mean relative humidity is 80 per cent but with a substantial diurnal variation. Average daily sunshine is about 5 hours between May and June, and 8 hours between September and October. These low values are created by a pronounced cloud cover. Evaporation and evapo-transpiration are averaged to 140 and 110 mm per month, respectively. Evaporation is highest in the dry months of September and October.

There are four major soil types ranging in texture from coarse white sand (40,500 ha) and pale yellow sand (27,500 ha) through loamy sands (56,000 ha) to the medium textured sandy loams (26,300 ha). The latter three, termed the "Brown Sands," are regarded as agriculturally important. The soils are characterized by high acidity, low base saturation and almost total absence of fertility in the top soil and sub-soil. Organic matter and water holding capacity are low and because of permeability, leaching of applied nutrients is normal.

Vegetation on the "authentic" savannahs consists of *Trachygon plumosus* and *Andropogon* spp. in association with a number of *Panicum* and *Paspalum* spp.

Early attempts to exploit the potential of the Savannahs for livestock production identified several problems. With the establishment of a livestock section in 1941, investigations revolved around the economic rearing of beef cattle. High morbidity and mortality of nondescript but hardy local cattle were found to be associated with the poor quality of indigenous herbage and various mineral deficiencies. About 16.2 ha were required to support one animal. In the 1950s and 1960s the problems were systematically tackled by specialists in range and livestock management and improved grasses, notably *Digitaria decumbens* (Pangola), were introduced along with the use of complete mineral mixes.

There are fewer flocks held by the private sector on the Intermediate Savannahs. The largest flocks are held on the government livestock station, a state corporation and by one large operator.

Pioneering era in sheep and goat production on the Intermediate Savannahs.

In 1972, sheep and goats were introduced to Ebini to intensify exploitation of the Savannahs.
The initial objective was to evaluate these animals on the natural range with minimal ameliorations. Among the factors influencing this approach were:

- the goat's reputation as a hardy animal with propensity to browse, thus making it a 'pioneer grazer'.
- the reputed ability of sheep to select forages
- the relatively high efficiency for roughage digestion by both of these species.

Within 2 years however, this approach was abandoned because of the high morbidity and mortality that the flocks experienced. Mc Phearson (1976) reported adult mortality levels exceeding 25 per cent and a death rate among the juvenile classes of about 45 per cent.

Cumberbatch (1979), found that the 'White flower' weed, *Sipanaea pratensis* (native to the Intermediate Savannahs), was the causative agent of the posterior paralysis syndrome which decimated the flocks between 1977 and 1980. Since poisoning by this weed is potentially a serious limiting factor to the successful rearing of sheep and goats at Ebini, chemical and manual control methods are now routine, pending the elucidation of factors associated with animal consumption of the weed.

Around mid-1975, a system of rotational grazing of planted pastures was introduced. The grasses were *Digitaria pentizii, D. setivalva, D. decumbens and Brachiaria radicans* (Tanner); some of these were grown in association with either of the legumes, *Stylosanthes guyanensis* or *Cajanus cajan*. All animals had free access to a complete mineral mixture\(^1\) while ewes and does were fed a supplement of a commercial dairy ration commencing from about 3 weeks before, to about 4 weeks after parturition. The improved nutritional management enhanced production coefficients. For example, lamb and kid mortality in 1976 was reduced to about 10-15 per cent, and adult mortality to about 8 per cent (Table 1). Fecundity among the ewes and does increased as a greater proportion of breeding females had consecutive parturitions within an 8-9 month period. However, for a number of reasons, these production levels were not consolidated.

### Table 1 Percentage mortality of the sheep and goats population at Ebini.

<table>
<thead>
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<th>1974</th>
<th>1976</th>
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<tbody>
<tr>
<td>Sheep</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ewes</td>
<td>22.7</td>
<td>8.3</td>
</tr>
<tr>
<td>Rams</td>
<td>26.5</td>
<td>8.3</td>
</tr>
<tr>
<td>Juvenile classes</td>
<td>45.1</td>
<td>10.8</td>
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<tr>
<td>Goats</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does</td>
<td>9.9</td>
<td>8.6</td>
</tr>
<tr>
<td>Bucks</td>
<td>58.3</td>
<td>19.2</td>
</tr>
<tr>
<td>Juvenile classes</td>
<td>40.0</td>
<td>15.6</td>
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These coefficients suggest that the miscellany of obstacles to successful small ruminant management in the Savannahs would best be resolved through a properly co-ordinated, multi-disciplinary research approach.

### Intermediate research approach

It is suggested that the sheep and goat unit at Ebini can evolve economic technological strategies relevant to large-scale production, which can then be transferred to the farming community. The initial research

\(^1\) Churn Protective Minerals (analysis in per cent): NaCl, 33.3; Ca, 18.9; P, 8.4; Fe, 0.30; Zn, 0.08; Mn, 0.15; Cu, 0.03; Co, 0.01; I, 0.02; Mo, 0.008.
emphasis will be on nutrition at all stages of the production cycle. A relatively low priority is being given to breeding although the development of strains of meaty sheep and hardy milch-type goats are contemplated (Mc Phearson, 1982).

The optimal use of pastures is *a priori* dictated by the nature of the economics of production. Cognisance must also be taken of the limitations of tropical pastures (when attempting to optimize exploitation with minimal inputs of fertilizer, etc.) in meeting energy and protein requirements of animals during the more critical physiological stages. Theoretically, energy-protein supplementation is desirable at these periods, particularly if the animals are to approach genetic potential. Whether or not this biological ideal is commercially viable should be indicated by an economic study of the various management systems to be developed.

More specifically, the investigations will examine the following:

**Nutrition before and during mating**

Although there has been extensive documentation of the high potential reproductive capability of the Barbados Blackbelly sheep (Mc Phearson 1975; Cumberbatch *et al.*, 1981), there seems to be scant data for controlled experiments aimed at determining the effects of nutrition on the performance of the breeding ewes and does.

While breed differences are inevitable, it is accepted that changes in ewe liveweight immediately before and during the mating period have a pronounced effect on ovulation and conception rate. Thus, for a target mating weight of 51kg, Rattray *et al.* (1980) showed that the expected proportions of multiple ovulations from ewes which gained 6 kg, maintained weight, or lost 6 kg, are 80, 69 and 58 per cent respectively over the period immediately before exposure to the ram.

The Meat and Livestock Commission (1981) suggest that "good quality" pasture at low stocking densities is adequate for mating ewes in fair condition. However, since the programme aims at 8-month lambing/kidding intervals, ewes and does are likely to be bred at times when pasture quality is sub-optimal. Supplementation will therefore be desirable at such times.

The initial work at Ebini will revolve around macro-level experiments to assess the effect of flushing grazing ewes and does using various supplements at different levels over the 3 weeks prior to mating, and the maintenance of these levels during the mating period, on their reproductive performance.

**Nutrition during early and mid-pregnancy**

The management objective during early pregnancy will be to create the environment which theoretically minimizes embryo wastage. Thus, as far as practicable, feeding will be aimed at ensuring that ewes and does maintain body weight during the first month after sire removal, so as to enhance the chances of implantation. The flushing level of feeding will therefore be maintained for 3-4 weeks after the termination of the mating period, except in those instances where specific nutritional investigations are planned.

During the second and third month of pregnancy, the nutrient demand of the conception are not great and a mild degree of undernourishment is tolerated and even advocated in accelerated production systems. High stocking densities on low quality pastures might thus suffice for the majority of ewes/does; only those in continuing poor condition being further supplemented to facilitate optimum placental and uterine wall development.

**Nutrition during late pregnancy**

During the final 8 and 2 weeks of gestation, the foetus attains about 85 and 25 per cent, respectively of its
potential birthweight (Robinson et al., 1977). Ewe nutrition during this period not only influences lamb birth weight, but also has a direct effect on mammary development preparatory to lactation and ewe fitness associated with ease of parturition and condition (Mc Phearson, 1987). The appreciable nutrient requirements of the ewe are, however, seldom met because of the physical limitations associated with the expanding uterus. For multiple bearing ewes particularly, the deficit between actual feed consumption and nutrient requirements may lead to severe under nutrition (Reid and Hinks, 1962), especially when bulky, poorly digested feeds are offered. The sequel to this undernourishment is that the ewe mobilizes her own body tissues, principally fat and protein, to meet the demands of pregnancy. Naturally, the extensive depletion of body reserves can be avoided by the provision of high quality grazing with judicious and prudent feeding concentrate rations of high energy content.

Investigations involving the use of suitable rations envisaged their gradual introduction, from about 100 g per day to no more than 1 kg before parturition.

It is recognized that among the major impediments to efficient feeding and more precise experimentation, is the fact that individual requirements as influenced by stage of pregnancy and foetal numbers cannot be attended to, since management for the immediate future will be on a flock basis. Ewes which conceive late in the breeding season and carrying singles are therefore likely to experience a nutritional advantage over multiple-bearing ewes which conceived earlier.

**Nutrition during lactation**

The nutrient requirements of the ewe are greatest during lactation (Mc Phearson, 1978). Thus, the energy requirement for the twin-suckling ewe has been put at 70 per cent above her requirement during the last fortnight of pregnancy. Forages alone are therefore inadequate for optimum production at this time, and it is recommended that the supplementary feed (about 17 per cent crude protein) should include a protein source of low rumen degradability.

Studies programmed in this area will seek to define the lactation capacity of the available genotypes of various management systems. It is surmised that such data would be pertinent not only to the breed development work proposed, but also for the formulation of neonatal management systems.

**Nutrition in the neo-natal and post-weaning periods**

Research in this area will seek to exploit the high feed conversion and consequent optimum growth rates theoretically possible during this period. The economic rationale of supplementing suckling lambs with cow’s milk rather than optimizing lamb nutrition through the maximizing of ewe lactation by heavy concentrate feeding will be examined. This study will in fact extend the preliminary work initiated during last year which suggests a very limited potential of the available genotypes for accelerated growth prior to weaning (Mc Phearson et al., 1982; Table 2).

As far as practicable, the basic objective of the nutritional programmes planned for the ewe lamb and doe kid, is the attainment of mating weight at about 7 months of age.
Table 2. Mean birth and weaning weights, and weight gains for crossbred Barbados Blackbelly lambs on two management systems

<table>
<thead>
<tr>
<th>Feeding system</th>
<th>Birth weight (kg)</th>
<th>Weaning weight (kg)</th>
<th>Gain from birth to weaning (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control lambs * n=12</td>
<td>1.83 ± 1.158</td>
<td>5.24 ± 1.158</td>
<td>3.41 ± 0.956</td>
</tr>
<tr>
<td>Supplemented lambs ** n=12</td>
<td>2.28 ± 0.57</td>
<td>8.45 ± 0.776</td>
<td>5.63 ± 0.686</td>
</tr>
</tbody>
</table>

* Control lambs — born to ewes having access to *Bracharia humidicola* pasture only. Suckled their dams from birth to weaning at 60 days.

** Supplemented lambs — born to ewes grazing the same pastures but supplemented with a dairy cow ration during the last 3-5 weeks of pregnancy and during lactation. Suckled their dams and supplemented with milk feeds up to 3 weeks, then given creep feed until weaning.

The choice of concentrates

For flushing and early pregnancy, cereal-based and similar supplements are generally used in many commercial operations. In the current year, therefore, the cereals (corn and sorghum) and the legume (pigeon pea) are being cultivated at Ebini specifically for the feed supplementation studies adumbrated herein.

However, during those periods of highest nutrient demand (e.g. late pregnancy and more particularly during lactation) fish meal and soyabean meal are the priority protein supplements. The high cost of these preclude their use presently. Attention will therefore be focused on the (cultivated) grains and more common agricultural by-products such as molasses, rice bran and copra meal. Molasses will be emphasized because of its availability, cost and reported advantageous effect on sheep on low energy rations (Coombe and Tribe, 1963).

It might be appropriate to note here, that in the only local work involving the use of these by-products in controlled supplementary feeding of ruminants, Holder *et al.* (1972) found that a mixture of molasses-urea (3 per cent)/rice bran/copra meal in the ratio 1:1:1, produced superior weight gains in weaner bulls compared to similar animals fed copra meal, or rice bran/copra meal (1:1) mixture, or rice bran and molasses-urea (3 per cent) and grazing *Digitaria decumbens* (Pangola grass) pastures — these supplements being fed in isocaloric rations. In related studies (Holder and Ammeran, 1972), it was found that supplementation with molasses-urea was significantly better than with molasses alone, its restricted feeding was superior to unrestricted supplementation, and that *ad libitum* feeding of molasses unfortified with urea resulted in weight gains inferior to those of animals grazing pasture alone.

The chemical composition of these feeds are given in Table 3.
Table 3  Chemical composition\(^1\) of pastures and feeds used in a trial at Ebini Livestock Station, Guyana

<table>
<thead>
<tr>
<th>Pasture(^2)</th>
<th>Mean</th>
<th>Range</th>
<th>Rice bran</th>
<th>Copra bran</th>
<th>Molasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter (%)</td>
<td>91.34</td>
<td>(90.23 - 91.71)</td>
<td>90.68</td>
<td>92.73</td>
<td>98.11</td>
</tr>
<tr>
<td>Lignin (%)</td>
<td>0.08</td>
<td>(8.01 - 12.37)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>5.35</td>
<td>(4.10 - 6.30)</td>
<td>13.34</td>
<td>24.95</td>
<td>2.66</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>6.78</td>
<td>(5.48 - 8.53)</td>
<td>11.06</td>
<td>6.22</td>
<td>14.92</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>---</td>
<td>---</td>
<td>22.16</td>
<td>11.18</td>
<td>---</td>
</tr>
<tr>
<td>Ca (%)</td>
<td>0.263</td>
<td>(0.218 - 0.310)</td>
<td>1.361</td>
<td>0.138</td>
<td>0.840</td>
</tr>
<tr>
<td>P (%)</td>
<td>0.152</td>
<td>(0.126 - 0.182)</td>
<td>1.327</td>
<td>0.536</td>
<td>0.100</td>
</tr>
<tr>
<td>Na (%)</td>
<td>0.162</td>
<td>(0.111 - 0.210)</td>
<td>0.016</td>
<td>0.0116</td>
<td>0.287</td>
</tr>
<tr>
<td>K (%)</td>
<td>1.37</td>
<td>(0.86 - 1.97)</td>
<td>0.564</td>
<td>1.878</td>
<td>4.724</td>
</tr>
<tr>
<td>Mg (%)</td>
<td>0.088</td>
<td>(0.074 - 0.106)</td>
<td>0.779</td>
<td>0.259</td>
<td>0.729</td>
</tr>
<tr>
<td>Fe (ppm)</td>
<td>781</td>
<td>(515 - 1506)</td>
<td>401</td>
<td>787</td>
<td>400</td>
</tr>
<tr>
<td>Zn (ppm)</td>
<td>107</td>
<td>(96 - 124)</td>
<td>440</td>
<td>483</td>
<td>154</td>
</tr>
<tr>
<td>Mn (ppm)</td>
<td>3.32</td>
<td>(2.20 - 4.74)</td>
<td>440</td>
<td>26</td>
<td>13</td>
</tr>
<tr>
<td>Al (ppm)</td>
<td>545</td>
<td>(477 - 608)</td>
<td>184</td>
<td>85</td>
<td>128</td>
</tr>
</tbody>
</table>

Source: Holder \textit{et al} (1972)

1. All values except dry matter expressed on a moisture-free basis.
2. Average value with range for nine samples

\textbf{In perspective}

The work proposed herein represents the first phase of a long-term research project. The ultimate objective is an integration of large-scale sheep and goat rearing as part of a wider management system involving the production of grain, orchard and other tree crops, and even a beef cattle operation.

It is accepted that in the quest to satisfy the substantial regional need for animal protein, production from the sheep and goat is unlikely to displace the importance of cattle, poultry and pigs. Nonetheless, it is suggested that regional governments should allocate more funds for the development of sheep and goat production systems, since potentially the returns on investment can be very high and fairly quick.

It is believed that for an outlay of about G $ 1 Million, the technical course for commercial exploitation of sheep and goats on the Intermediate Savannahs of Guyana can be charted in less than 5 years.

The time is opportune for a small ruminants project to be conceptualized along the lines of the Moblissa-based CARDI/IDRC Milk Production Systems Project or the Government of Guyana / USAID project of 1969 to 1972.

\textbf{Acknowledgement}

The author wishes to record thanks to Dr M. A. Granger for useful discussions.
References


TECHNICAL SESSION III

DISCUSSION

Rapporteur: R. N. Cumberbatch

G. Muller (CARDI, Trinidad and Tobago):
What percentage of the area at the LIDCO operation at Ebini is under *B. humidicola* and is there an alternative forage species available?

C. Bullen (LIDCO, Guyana):
In the beef operation the only forage is *B. humidicola*, and about 90 per cent of the dairy forage is *B. humidicola*. Because we are a commercial operation it is difficult to have an alternative forage species, but we are supportive of the work of NARI and CARDI under the Livestock Research Programme where other forages are being looked at.

C. Alvares (University of Suriname):
It is important to have other grasses as a stand-by in the event of problems with the planted species.

R. Fletcher (CARDI, Montserrat):
Is there any advantage to using micronutrient fertilizer on pastures to reduce mineral supplement dependence?

C. Alvares:
It is cheaper to give the mineral directly to the animal.

N. Holder (LIDCO, Guyana):
I support Dr Alvares' statement and would add that mineral nutrition is rather complex. Efforts were made to introduce minerals in the soil and test the subsequent uptake. It was found that when there was a decrease in available forage there was an increase in mineral consumption. Iron was one of the more limiting elements.

P. Osuji (CARDI, Trinidad and Tobago):
Why were the calcium levels so high in the overseed presented? Is there a reason for these high levels?

C. Alvares:
We are utilizing a standard mix which gives good results.

P. Osuji:
Could Mr Holder comment on the ratios in the Ebini mineral mix?

N. Holder:
At Ebini, we are using a mix specially formulated for the Intermediate Savannahs.

H. Adams (CARDI, Guyana):
Why is there a failure of grass-legume associations? Maybe we are not coping properly with nature. There are naturally occurring mixes — are we looking at the wrong legumes?

C. Alvares:
Legumes are used to supply N. Native legumes are low in N and there is little nodulation. N supplies from these legumes are also low.

C. Bullen:
In grass-legume associations one species can be grazed to the exclusion of the other. Our experience at Mobilissa is that spontaneous associations have survived. However it is difficult to maintain compatibility when they are grazed.
L. Smith (Ministry of Agriculture, Barbados):
Was any financial evaluation done based on breed performance? How will rearing animals on pasture at Ebini affect their performance on the coast?

C. Bullen:
We did not do any evaluations but from empirical observations and looking at separate groups, the Zebu and Santa Gertrudis seem to perform better than the other animals.

N. Holder:
It was found that when animals were weaned on the range they did not catch up to those weaned off improved pastures even though they had superior daily weight gains. Also there was a lower calving rate on the range.

C. Douglas (CARDI, Antigua):
Are there any benefits to be derived from orchard crops and livestock? Was an evaluation done?

J. Seaton (CARDI, Guyana):
No evaluation was done.

J. Cropper (Consultant, Guyana):
Is there any integration of the crop-livestock system, even on an experimental scale?

J. Seaton:
Attempts were made using *B. humidicola* and corn.

N. Holder:
Integration is a research problem that must be addressed by the research organizations.

L. Simpson (NARI, Guyana):
The difficult part is how to fit the integration of crop and livestock systems into the production system. The equipment is not available and assessment is difficult.

J. Piggot (GUYSUCO, Guyana):
Grass must be considered as a crop.

M. Holder (Ministry of Agriculture, Belize):
What role would *B. humidicola* play in developing the White Sands for pasture?

J. Seaton:
*B. humidicola* can play an important role, but there should be no urgency in attempting to develop the white sand areas.
TECHNICAL SESSION IV

Chairman:  J. Ruinard, University of Suriname
The Moblissa area

Moblissa is in the Intermediate Savannahs region of Guyana, an area of about 2,700 km². The Intermediate Savannahs lie at an altitude of 24-27 m above sea level and are situated between the low lying coastal belt (elevation 3 m below sea level to 5 m above sea level) and the mountainous region of Guyana with elevations above 700 m.

Moblissa’s climate is characterized by an average annual rainfall of 1,750 to 2,000 mm and a mean temperature of 27°C. The area’s rainfall pattern is similar to that of the coastland of Guyana with two wet seasons from mid-November to mid-January and from mid-April to mid-August.

In general, the vegetation of the Moblissa area consists of highland forests and marsh and swamp vegetation in an approximate ratio of 1:8.

The soils of the Intermediate Savannahs have generally described by Downer (1972). They range in texture from white sands and pale yellow sands through loamy sands to sandy loams. The ‘Brown Sands’ of the Intermediate Savannahs are of the Oxisol and Ultisol soil groupings and the Moblissa 'Brown Sands' display similar chemical and physical properties to the soils of the Intermediate Savannahs including the Ebini sandy loam soils. These soils are inherently low in plant nutrients and possess the property of phosphate fixation. They are also highly permeable and leaching of applied nutrients is to be expected.

The Moblissa Dairy Ranch

The Moblissa Dairy Ranch is situated approximately 90 km from Georgetown and 15 km off the Soesdyke/Linden Highway. The Ranch consists of approximately 486 ha of brown sand soil lying between the Moblissa and Bamia rivers.

It was acquired by the Livestock Development Company Limited (LIDCO), from the Ministry of Agriculture of the Guyana Government in September 1976. Initial operations at Moblissa began in 1973 under the management of the Ministry of Agriculture but up to 1976 land clearing and pasture establishment were the main activities. The broad objective of the Moblissa Dairy Unit is the production of milk from forages – grasses, legumes.
The Moblissa Dairy Settlement Scheme

The Moblissa Dairy Settlement Scheme was established 1976 around the Moblissa State Ranch operated by LIDCO and was intended to be the first of 11 satellite co-operative farms which were to be set up around public sector dairy farms as part of the National Dairy Development Programme. The scheme aimed at resettling coastal dairy farmers "in an environment conducive to the development and expansion of the dairy industry". It was intended that farmers participating in the scheme would benefit from the Moblissa State Ranch through the use of some of its infrastructural works, from technical services made available by the Ranch and from the demonstration effect of improved practices on the State Ranch.

The total area of the scheme was 728 ha of brown sandy soil. Thirty-five farmers were to be accommodated, each being allocated 20.8 ha. Based on a carrying capacity of one animal unit to approximately 0.4 ha, each farmer would have been able to maintain 50 animal units on 20 ha and utilize the remaining 0.8 ha for a house lot with a vegetable garden.

Farmers were to be organized into a co-operative society which was to have responsibility for housing, machinery, refuse disposal, milk marketing, transportation, the management of a collective herd, farm supplies and a consumer shop. The society was to be administered by the Ministry of Cooperatives who were to appoint a resident manager responsible for the day to day operations of the society. Each farmer was to maintain his own herd. A collective herd was to be established to cater for the following:

- surplus heifers produced by settlers at Moblissa
- young surplus steers which could be fattened for sale.

Participants were to have access to long-term and short-term credit through a credit agreement between the Guyana Government and the International Development Association (IDA). Provision was also to be made for farmers to be trained in aspects of sociology to assist them in adjusting to the Moblissa environment and arrangements were to be made for technical training in the fields of dairy management, pasture management and co-operative management. The farmers were also to have access to an Extension Officer who was to be based at Moblissa.

The Moblissa Settlement Scheme did not develop as planned. The scheme began during the last quarter of 1976 with 13 farmers, a manager was appointed shortly after in the same year. Within a year of the society's operation, wrangling among the members and the dissatisfaction of some farmers with the manager culminated in the manager's resignation. Thereafter members managed their individual herds with varying degrees of success. By the end of 1981 only five farmers out of the original membership of 13, still occupied plots at Moblissa. Economic changes have lead to renewed interest in dairying and the number of settlers has now risen to 15. However the activity spread at Moblissa has included milk production, beans, peanuts, tobacco, small ruminants, beef and pigs.

One of these small farms is described and its system analyzed for this presentation.

Characterization of a Farm

Farm family

The farm household consists of the farmer, his wife and a few young children. The farmer comes from a
very long tradition of cattle rearing on the coast and has good primary education.

The farm

The farm, like most of the satellite farms at Moblissa is 20.8 ha. Most of this land is fenced and planted to pasture consisting of predominantly *B. humidicola*, *B. decumbens* and a variety of legumes. Among the legumes *Desmodium adscendens* a native of Moblissa, is widespread and makes a significant contribution to the pastures.

Other feeds available to the farm include wheat middlings, rice bran, copra meal and broiler starter. The costs of these ingredients are summarized in Table 1.

Table 1 Cost of feed ingredients used at Moblissa farm.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>G$ per 45kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat middlings/</td>
<td>50.00</td>
</tr>
<tr>
<td>rice bran</td>
<td></td>
</tr>
<tr>
<td>Broiler starter</td>
<td>200.00</td>
</tr>
<tr>
<td>Copra meal</td>
<td>65.00</td>
</tr>
</tbody>
</table>

The animal inventory on the farm at the time of this study is summarized in Table 2 which shows clearly that while cattle (dairy) is the main focus of this farm, small ruminants and, until recently, pigs play a significant role.

Other farm assets

The farm assets of this farm have been quantified in Table 3. Other livestock are valued at $68,000. However, and perhaps successfully, the farmer insisted that these did not contribute to farm income since he used the meat for his family or gave it free to his friends.

Table 2 Animal inventory on a Moblissa farm at November, 1988

<table>
<thead>
<tr>
<th>Dairy cattle</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Breeding bulls</td>
<td>2</td>
</tr>
<tr>
<td>Young bulls</td>
<td>4</td>
</tr>
<tr>
<td>Breeding cows</td>
<td>15</td>
</tr>
<tr>
<td>Calves: Male</td>
<td>1</td>
</tr>
<tr>
<td>Female</td>
<td>12</td>
</tr>
<tr>
<td>Heifers: 1-2 years</td>
<td>4</td>
</tr>
<tr>
<td>2-3 years</td>
<td>5</td>
</tr>
<tr>
<td>Total herd</td>
<td>43</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sheep</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ewes</td>
<td>11</td>
</tr>
<tr>
<td>Breeding rams</td>
<td>1</td>
</tr>
<tr>
<td>Young rams</td>
<td>7</td>
</tr>
<tr>
<td>Lambs</td>
<td>5</td>
</tr>
<tr>
<td>Total flock</td>
<td>24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Goats</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucks</td>
<td>3</td>
</tr>
<tr>
<td>Ewes</td>
<td>24</td>
</tr>
<tr>
<td>Kids</td>
<td>18</td>
</tr>
<tr>
<td>Total flock</td>
<td>45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Poultry</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Creole laying hens</td>
<td>50</td>
</tr>
<tr>
<td>Turkeys</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ducks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hens</td>
<td>13</td>
</tr>
<tr>
<td>Young hens</td>
<td>5</td>
</tr>
<tr>
<td>Ducklings</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
</tr>
</tbody>
</table>
Table 3 Assets of a farm at Moblissa in 1988

<table>
<thead>
<tr>
<th>Asset Type</th>
<th>G$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash</td>
<td>1,500</td>
</tr>
<tr>
<td>Market cattle</td>
<td>16,000</td>
</tr>
<tr>
<td>Breeding cattle</td>
<td>155,000</td>
</tr>
<tr>
<td>Cattle other than breeding</td>
<td>69,000</td>
</tr>
<tr>
<td>Other livestock (sheep, goats, poultry)</td>
<td>68,000</td>
</tr>
<tr>
<td>Machinery and equipment</td>
<td>22,000</td>
</tr>
<tr>
<td>Buildings and improvements</td>
<td>169,000</td>
</tr>
<tr>
<td>Non-farm assets (personal, household, vehicles, etc.)</td>
<td>25,000</td>
</tr>
</tbody>
</table>

**Marketing**

Milk marketing was the major marketing activity of the farm. With the farmers' vehicle in disrepair the marketing of milk was restricted to farm gate sales or sales at Linden through other farmers who had transport. In either case the unsatisfied demand for milk ensured good prices even at the farm gate.

**Farmers constraints**

The analysis of the farm diagnostic data suggested that the farmer had the following problems:

- Milk marketing
- Lack of extension services
- Lack of drugs and mineral supplements
- Disorganized and unreliable feed supply
- Lack of adequate pastures and equipment for pasture development
- Inadequate water and electricity supply

**Economic analysis of the small dairy**

**Objectives:**

- To characterize the farm in terms of inputs and outputs.
- To estimate farm costs and returns over a 4-year period at constant prices.
- To assess the ability of the farm to meet debt and other commitments.
- To assess the profitability of such small farm systems.

**Methodology:**

A farm business and financial analysis package was used to assess the economic performance of the small dairy farm.

The model analyzed only the costs and returns associated with the dairy operations.

Inputs into the model were provided by the farmer and included:

- Number of units produced.
- Number of units sold.
- Death loss.
- Replacement animals kept.
- Average weight per unit sold.
- Average net price received per unit sold.
- Quantities and prices of feeds needed.
- Direct variable costs.
- Direct labour requirements, etc.
- Other farm costs.
- Assets and liabilities, etc.

Net farm income was used as a measure of profitability.
**Results**

Some selected outputs of the analysis are summarized in Table 4. Data are shown for both the base year, 1989, and for the 4th year, 1992. Information relating to loans and debt service obligations are also included in Table 5.

The profitability of the farm is clearly indicated by a net farm income of $184,000 (1989) and $420,060 (1992). The corresponding incomes after debt service were $111,200 for 1989 and $281,260 for 1992 (Table 4).

**Conclusions**

A number of conclusions can be drawn from the analysis of this satellite farm at Moblissa:

- Small scale dairying at Moblissa is profitable.
- Profitability is due to good prices for milk — price changes have not been taken into account.
- Profitability has led to the farmer desiring expansion therefore he needs:
  - more land
  - more credit
  - more inputs
- Profitability has been achieved on dairy operations alone. Subsidiary enterprises e.g. small ruminants have not been included.

**Table 4** Selected outputs of the economic analysis of a small dairy farm at Moblissa

<table>
<thead>
<tr>
<th></th>
<th>1989 (G$)</th>
<th>1992 (G$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash income</td>
<td>218,600</td>
<td>455,400</td>
</tr>
<tr>
<td>Cash expenses (Total)</td>
<td>96,860</td>
<td>160,200</td>
</tr>
<tr>
<td>Net farm income before tax</td>
<td>121,240</td>
<td>327,960</td>
</tr>
<tr>
<td>Plus capital sales</td>
<td>62,760</td>
<td>62,760</td>
</tr>
<tr>
<td>Net farm income</td>
<td>184,600</td>
<td>420,060</td>
</tr>
<tr>
<td>Net income after tax</td>
<td>156,200</td>
<td>326,260</td>
</tr>
<tr>
<td>Debt service obligations</td>
<td>65,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Income after debt service</td>
<td>111,200</td>
<td>281,260</td>
</tr>
</tbody>
</table>

**Table 5** Information on bank loans in connection with a small dairy operation at Moblissa

<table>
<thead>
<tr>
<th></th>
<th>(G$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal</td>
<td>65,000</td>
</tr>
<tr>
<td>Source</td>
<td>Gaibank</td>
</tr>
<tr>
<td>Interest rate</td>
<td>12 per cent per year</td>
</tr>
<tr>
<td>Debt service (principal &amp; interest)</td>
<td>1936 per mth (1989)</td>
</tr>
<tr>
<td>Additional loan needed: to purchase generator (1990) and four cows (1990 and 1992)</td>
<td>90,000</td>
</tr>
</tbody>
</table>
In one judgement based on the 7 years this farm has been monitored, the success of the farmer owes much to:

• Dedication
• Know-how
• Management
• Planning

• Extension support
• Favourable markets

The question that needs an answer is whether additional infrastructure support would enhance farm profitability.

Reference

COMMERCIAL AND MANAGEMENT CONSIDERATIONS FOR RESEARCH IN SOYABEANS IN THE INTERMEDIATE SAVANNAHS OF GUYANA

L. Chin
National Edible Oil Company Ltd.,
P.O. Box 10729
Georgetown, Guyana

The achievement of sustained production of soyabees in the Intermediate Savannahs must involve a strategy for survival during the infant development stages and one to ensure commercial viability in subsequent years.

The strategy for survival entails the procurement of appropriate financing during the early potential cash deficit years. Such financing should ideally be of a development grant nature or secondly loans with a moratorium on repayment to take the project over the cash-short early years.

Cash flow elements

Net Cash Flow for a specified period = cash inflow - cash outflow, which should be > 0.

Let us examine the two main components of this equation and relate them to the elements in the Profit and Loss Statement for a 400 ha unit of operation (Table 1)

Table 1 Cash inflow and outflow related to profit and loss for a 400 ha unit of operation

<table>
<thead>
<tr>
<th>Cash inflow</th>
<th>(G$)</th>
<th>Profit &amp; Loss</th>
<th>(G$)</th>
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</thead>
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<tr>
<td>Cash sales</td>
<td>2,430,000</td>
<td>Sales</td>
<td>2,700,000</td>
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<td>Payment debtors</td>
<td>270,000</td>
<td>Other income</td>
<td>10,000</td>
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<tr>
<td>Other income</td>
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<tr>
<td>Loans (short-term)</td>
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<tr>
<td>Loans (long-term)</td>
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<tr>
<td>Grants</td>
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<tr>
<td>Equity</td>
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<tr>
<td>Total Inflow</td>
<td>2,710,000</td>
<td>Total Income</td>
<td>2,710,000</td>
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<table>
<thead>
<tr>
<th>Cash outflow</th>
<th></th>
<th>Costs</th>
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<tr>
<td>Direct labour wages</td>
<td>161,000</td>
<td>Direct cost</td>
<td>1,530,000</td>
</tr>
<tr>
<td>Direct machine cost</td>
<td>255,000</td>
<td>Contribution</td>
<td>1,180,000</td>
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<tr>
<td>Direct material cost</td>
<td>816,000</td>
<td>Overheads</td>
<td>1,265,000</td>
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<td>Overheads</td>
<td>1,265,000</td>
<td>Depreciation</td>
<td>431,000</td>
</tr>
<tr>
<td>Payment Creditors</td>
<td>0</td>
<td>Profit/(Loss)</td>
<td>-516,000</td>
</tr>
<tr>
<td>Total Outflow</td>
<td>2,497,000</td>
<td></td>
<td></td>
</tr>
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</table>

Net Cash Flow | 213,000 |  |
Profit and Loss account

It can be seen from Table 1 that the elements of the profit and loss statement make up the major parts of the cash flow statement. To the extent that there is a loss that may result in a negative cash flow for example during the development stages and at the beginning of the learning curve, it would be necessary to actively pursue:

- the initiation or increase of inflows such as loans, equity contributions or grants
- the reduction of variable expense elements such as material cost, fuel cost and labour cost
- the reduction of overhead costs.

Cost sensitivity

Let us examine in Table 2 the areas which can impact on the net cash flow pointing out the potential impact of agriculture research, but focusing only on those areas where the potential impact, negative or positive, is more than $250 per ha individually.

(i) The potential yield under practical conditions for the soyabean variety Jupiter R is estimated to be 2500 kg per ha. Varieties yielding 3000-4000 kg per ha are possible and screening must be continued with such targets in mind.

(ii) Poor seed quality, especially reduced viability resulting from inadequate storage conditions, can increase seed usage by the order of 100 per cent.

(iii) The analysis in Table 2 is based on recovery of the costs of land reclamation over 10 years, the costs of the low-grade Rock Phosphate input, and of depreciation of fixed assets by one crop only per year — the major crop as planted in May/June. The yields to ensure recovery of variable costs are 1040 kg per ha for the May/June crop and 790 kg per ha for the November crop for the standard conditions of price of output and of costs of inputs.

(iv) To the extent that another crop of soyabean or other crop can be produced in the short rainy season with planting in November and that yields are above that required to recover variable costs, then to that extent the project viability would be increased. With a projected standard yield of 1200 kg per ha for the short rainy season, and a calculated yield to recover variable costs of 790 kg per ha, the evaluated risks are a complete loss once every 3 years or a yield of 600 kg per ha every 2 out of 3 years.

(v) The cost of low grade Rock Phosphate is significant — G$1020 per ha. A 50 per cent saving would be achieved if the period of application can be extended from 3 to 6 years. Research should be undertaken to evaluate the factors influencing the prolonged effectiveness of a single application.

(vi) The level of Muriate of Potash in the current technology package is considered to be too high by some scientists. A reduction to 50 per cent has been recommended. This requires some simple trials to evaluate maximum economic yields.

(vii) The cost of insecticide is G$397 per ha for three applications. Early detection of insect attack can reduce this cost by spraying the limited acreage initially affected. There is the risk that the current recommended insecticide, monocrotophos, may be ineffective due to build up of resistance with a potential of total crop loss valued at G$5949 per ha. The value of stocking, for such emergencies, alternative insecticides with significantly different mechanisms of action must be worth considering.
Table 2  Elements in Profit & Loss Statement and Sensitivity for soyabeen production on the Intermediate Savannahs of Guyana

<table>
<thead>
<tr>
<th></th>
<th>Practical range</th>
<th>Potential impact yield (GS)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>3.96 - 5.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,360 - 2,800</td>
</tr>
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<td></td>
<td></td>
<td>5,386 - 14,476</td>
</tr>
</tbody>
</table>

|                  |                 | 200 - 1,000                |
|                  |                 | 570 - 1,020                |
|                  |                 | 680 - 905                  |
|                  |                 | 200                      |
|                  |                 | 505                      |
|                  |                 | 782.5                     |
|                  |                 | 715                      |
|                  |                 | 705                      |
|                  |                 | 905                      |
|                  |                 | 1,370                     |
|                  |                 | 725                      |
|                  |                 | 417.5                     |
|                  |                 | 782.5                     |
|                  |                 | 200                      |
|                  |                 | 75 - 225                  |
|                  |                 | 540 - 1,370               |
|                  |                 | 3960                     |
|                  |                 | 570                      |
|                  |                 | 270                      |
|                  |                 | 397.5                     |
|                  |                 | 1,370                     |
|                  |                 | 1080                     |
|                  |                 | 468.3                     |
|                  |                 | 3.96 - 5.17               |
|                  |                 | 1,360 - 2,800              |
|                  |                 | 5,386 - 14,476             |

C. CONTRIBUTION (S3 - V) per ha

<table>
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<tr>
<th></th>
<th>20 67</th>
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<td></td>
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<tr>
<td></td>
<td>Overheads</td>
</tr>
<tr>
<td></td>
<td>400 ha</td>
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<tr>
<td></td>
<td>1,265,000</td>
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<tr>
<td></td>
<td>3,163</td>
</tr>
<tr>
<td></td>
<td>1200 ha</td>
</tr>
<tr>
<td></td>
<td>1,799,000</td>
</tr>
<tr>
<td></td>
<td>1,499</td>
</tr>
<tr>
<td></td>
<td>4200 ha</td>
</tr>
<tr>
<td></td>
<td>4,270,000</td>
</tr>
<tr>
<td></td>
<td>1,017</td>
</tr>
<tr>
<td>Depreciation</td>
<td></td>
</tr>
<tr>
<td>400 ha</td>
<td>431,000</td>
</tr>
<tr>
<td>1200 ha</td>
<td>873,000</td>
</tr>
<tr>
<td>4200 ha</td>
<td>2,715,000</td>
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<tr>
<td></td>
<td>1,078</td>
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<tr>
<td>PROFIT/ (LOSS)</td>
<td></td>
</tr>
<tr>
<td>400 ha</td>
<td></td>
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<tr>
<td>1200 ha</td>
<td></td>
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<tr>
<td>4200 ha</td>
<td></td>
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<td></td>
<td>-2,175</td>
</tr>
<tr>
<td></td>
<td>-160</td>
</tr>
<tr>
<td></td>
<td>402</td>
</tr>
</tbody>
</table>

Research considerations:

\( ^a \) Seed quality; new varieties.
\( ^b \) Depth of incorporation.; frequency of application.
\( ^c \) Quantity for maximum economic yields.
\( ^d \) Minimum tillage, use of pasture grass Brachiaria humidicola.
\( ^e \) Bulk transport
(viii) Ineffective inoculum could lead to significant loss in yield. Current problems of poor nodulation must be solved in order to improve economic viability.

(ix) Poor land preparation due to inadequate machinery and inexperienced machine operators can lead to inadequate depth of root penetration, reduced tolerance to moisture stress and to problems in harvesting.

Marketing considerations

In identifying the strategy to be adopted to maximize returns, the following are to be recognized, analysed and the market niches exploited:

- Soyabean utilized directly as human food can attract a price that is 200 to 400 per cent higher than that obtained when made available for processing into oil and oil meals. From the national point of view, this is a more economic use of a resource, since the conversion of feed animal protein is only about 33 per cent efficient.

- Soyabean can be processed into sprouts, tofu, tempeh, soy sauce and a large range of products which creates value added in the economy.

- In the Guyana context, the opportunity profits arising out of the downstream conversion of soyabean meal into poultry meat and eggs is identified for exploitation since the enterprise would be in control of the supply of the input that currently limits production.

Cost element of production

A pictorial presentation of the cost elements of production of soyabean is shown in Fig. 1.

On the basis of the 80:20 rule or Pareto Principle, we should spend 80 per cent of our management time on the 20 per cent most important cost areas i.e. materials cost, overheads and depreciation.

Overheads and depreciation per ha can be reduced by increased hectareage and putting in a second crop during the short rainy season.

Short-term strategy for long-term profitability

Yield of beans is a crucial element in the profitability equation. Long-term profitability will be influenced by the relationship of yield to the cumulative hectareage planted by the project. Yield per acre is expected to increase directly with the logarithm of the cumulative hectareage planted. This is the well known "Experience Curve" effect that has been used as a fundamental basis of Japanese strategy to reduce costs and gain a market share in many of the industries of which they are now leaders.

It must be part of the strategy of the project to achieve rapidly a high level of cumulative hectareage, making each hectare a different experience if possible. There must be constant and systematic approaches to yield improvements and cost reduction.

The predicted trend in yield improvements is shown in Fig. 2.

The Project must also find mechanisms for financing any cash deficits in the early development years. This will be taken care of by the Stockfeeds Levy Fund which was conceptualized since 1980 and established in 1984. The Fund is used to finance the development of inputs for stockfeeds.
| % total variable costs | Depreciation | G$ per ha.  
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>23</td>
<td>1077.5</td>
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<table>
<thead>
<tr>
<th>Overheads</th>
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<table>
<thead>
<tr>
<th>Labour</th>
<th>335</th>
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</table>

<table>
<thead>
<tr>
<th>Machine</th>
<th>520</th>
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<tr>
<th>Materials</th>
<th>3825</th>
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</table>

Figure 1. Cost elements of production of soyabeans
Organizational relationships

It is an empirical observation arising out of the Caribbean Technology Policy Studies organized jointly by the University of the West Indies and the University of Guyana that most of the research findings of research institutes in the Caribbean do not reach the productive sector. This finding is similar to what obtains in other developing countries. In nearly all cases where the research findings reach the productive sector, there is a close and direct collaboration of the productive agency and the research institute.

It is in recognition of this observation that CARDI and the Soyabean Company are collaborating directly at the operational level. This should set the stage for the successful development of soyabean production.

Figure 2. Yield of soyabean vs. cumulative area (ha) planted.
TECHNICAL SESSION IV

DISCUSSION

Rapporteur: G. Muller

R. Fletcher (CARD, Montserrat):
At present, CARDI is funding the R/D effort. In the future, would NEOCOL be willing to fund this effort?

L. Chin (NEOCOL, Guyana):
There is a close relationship between CARDI and the Soyabean Co. and there is no real separation between experimental and production expenditure. The company is willing to finance the operations in the absence of CARDI.

J. Cropper (Consultant, Guyana):
Have devaluation and the availability of foreign exchange for high levels of inputs been taken into consideration?

L. Chin:
All of the Company's analyses assume devaluation. However, it is risky because it attempts to predict a rate of exchange for the US dollar. We have assumed $30. We assumed, also, that output prices will rise in sympathy with devaluation and that local input prices will not rise as quickly.

CIDA is expected to donate CAN$30M of fertilizer over 3 years — provided there is an agreement with the IMF.

Our equilibrium position assumes that foreign exchange will be available if the project is shown to be available.

H. Adams (CARDI, Guyana):
Dr. Osuji, were there any problems in developing small dairy farms?

Would the Soyabean Co. support the development of infrastructure in the Intermediate Savannahs? If not, who would be responsible?

P. Osuji (CARDI, Trinidad and Tobago):
I had indicated a few problems including marketing, extension services and infrastructural support.

L. Chin:
Kimbia has about $30M of infrastructure in place, but it is not fully utilized. The Company would contribute to improvement of the infrastructure.

P. Rellum (University of Suriname):
Are you using varieties other than Jupiter? Will soyabean be grown in rotation with other crops?

L. Chin:
We are using Jupiter R and Pelican, but NARI/CARDI are evaluating other varieties.

My objective is to get two crops per year every year to replace US$2M of imported soyabean. The researchers need to provide me with the answers so that I can get the required volume of soyabean.
H. Adams:
We need to develop rotations of soyabean with other crops - cotton, cowpea, peanut, sorghum and others.

Yields will increase when infrastructure is in place.

L. Smith
(Ministry of Agriculture, Barbados): The system should be geared for two crops to spread capital costs and utilize the basic infrastructure. Can you get two crops a year with that cropping system?

J. Ruinard (University of Suriname):
The infrastructure for soya can also be used for other crops.

F. Mc Donald (CARDI - Dominica):
An analysis of the two previous failures of soyabean production would be instructive.

L. Chin:
Agronomically, it is possible to produce a reasonable crop. The failures were due to:

(a) logistical problems
(b) inadequate/untimely financing.

Soyabean can contribute to the Soyabean Company's future cash flow, to the needs of the community and to foreign exchange savings. Management, in its widest sense, is crucial.

The onus for success of the enterprise rests with the Board and Chief Executive who should enjoy the rewards for success — or sanctions for failures.

C. Douglas (CARDI, Antigua):
Was variability in yield considered in a sensitivity analysis.

L. Chin:
At 1500 kg per ha, we would make a loss, but the potential yield is 3000 kg per ha. We have used 2500 kg per ha in our calculations, but the research component should increase yield from 2500 kg per ha to 4000 kg per ha. At 3000 kg per ha, soyabean is competitive for export, say to Trinidad & Tobago.

P. Osuji:
At what yield is soyabean profitable?

L. Chin:
Looking at yields only, 3200 kg per ha is a break-even figure for export.

If the Company is given the freedom to exploit the market it can sell soyabean at about S7.70 per kg.
TECHNICAL SESSION V

Chairman: W. Treitz, CTA
MANAGEMENT OF ACID SANDY SOILS - THE IBSRAM APPROACH

Otto Spaargaren
IBSRAM
P.O. Box 0-109
Bangkhen, Bankok 10900, Thailand

Population pressure in several tropical regions is forcing farmers onto marginal lands with acid sandy soils. Appropriate soil management technologies are required to cultivate these soils profitably. These technologies include management of organic matter to improve the nutrient-holding capacity and the soil moisture characteristics, the use of adapted crop varieties, and agroforestry techniques. Livestock development can be taken into account to provide organic fertilizers.

IBSRAM'S network approach for soil management research, as developed in Asia and Africa, could be applied to develop the proper technologies. This research strategy aims at validating and adapting newly developed techniques in farming system practices. The core experiments of the network projects usually have four cropping experiments based on the traditional or current farmers' systems at various levels of input, while satellite experiments are conducted to refine single components of the system. The multidisciplinary research includes soil scientists, agronomists, agro-economists and sociologists.

If this type of research is to be applied to acid sandy soils, it has to be conducted carefully, and the results obtained should be soundly validated, in order to avoid the risk of desertification of these fragile soils.

The successful use of acid sandy soils in the tropical regions is one of the last frontiers soil management research has to tackle. Comprehensive research in the past few decades has concentrated on the development of low- and high-input technologies that allow cultivation on a sustainable basis of the highly weathered and leached soils dominating the tropics. Seldom has this kind of research been extended to sandy soils. The reasons are obvious. Their very low agricultural potential never allowed large populations in these areas, and therefore the demand for appropriate management technologies was virtually non-existent. The increasing pressure on the land has made people move into these marginal areas, and they require techniques to enable them to cultivate their new lands.

In order to develop technologies to cultivate specific soils one has to look at a number of variables. First there is the socio-economic aspect. What are the current practices being used? What kind of crops are grown? Do farmers market their produce or is it only for home consumption? Then there is the environmental aspect. What does the environment (soils, climate) allow the people to do? And, if new techniques are used, what impact does it have on the environment? Thirdly there is a crop factor. How can crops already being cultivated be adapted to new techniques? How will new crops perform and be accepted by the people growing them? All these factors have to be taken into account and put together, if one wants to cultivate new lands successfully.

IBSRAM (International Board for Soil Research and Management) is an international agency dedicated to assisting and speeding applications of soil science in the interest of increasing sustainable food production in developing countries. In its approach, as will be outlined later, it takes all
these factors into account, with emphasis on the soil.

**Occurrence and properties of acid sandy soils.**

Acid sandy soils are found throughout the tropics, sometimes as patches, sometimes over large areas. In South America they occur in the coastal zones of Guyana, Suriname, French Guyana and Brazil; in Colombia and Venezuela in the Rio Negro and Orinoco regions; and in the Amazon basin in Brazil, Colombia, Peru and Bolivia. In Africa they are patchy along the coast in the west, but a very large area of acid sandy soils occurs in eastern Angola and western Zambia, with outliers in the south of Zaire. They are also frequently found on the Central African plateau along streams and shallow sub-surface waterways. In Asia, acid sandy soils occur in Malaysia, Thailand and Sri-Lanka, both along the coast and in inland positions.

Sandy soils have a low macro- and micronutrient supply, a low nutrient-retention capacity, a low water-holding capacity, and when exposed are liable to wind erosion due to the lack of aggregation of the soil material. Soil temperature in the surface layer is often high in areas with high solar radiation. They may or may not have a high organic matter content. This depends on the amount of biomass produced and the rate of turnover of organic matter in the soil. In addition acid sandy soils may have a high Al saturation, although in absolute terms the Al content is not high.

A prominent feature in the strongly leached sandy soils is that under natural conditions vegetation relies on its own produce, and all roots are concentrated in the surface layer. Leaching in these soils has reached the stage that the sub-surface part virtually consists of silica and titanium oxides, with no nutrients left. These soils can easily turn into deserts, if no care is taken to preserve the humus-rich surface layer during the land clearing and post-clearing management practices.

**Management options for acid sandy soils.**

Soil management aims at alleviating constraints so as to arrive at the most profitable balance between inputs and outputs. If sandy soils are to be cultivated successfully, several options are available. Management can aim at increasing the amount of available nutrients and moisture, prevent leaching so as not to lose valuable nutrients and not to create a potential source for groundwater pollution, and to diminish the risk of wind erosion. The answer to this approach lies in organic matter.

Many centuries ago, farmers in western Europe were already using the beneficial effects of organic matter, when they were forced on the acid Spodosols of northern Germany, the Netherlands and Belgium. They collected "plaggen" (topsoil cuttings), and mixed it with farmyard manure which was then applied to the soil. Over centuries soils were built up in this way which are now among the most productive soils in western Europe.

We may not have the time or the materials available to use this technique in the tropics. However, it is possible to apply soil management techniques that will increase the amount of organic matter: the return of crop residues, the introduction of (preferably leguminous) fallow into the rotation, and mulching will in the long run increase the amount of organic matter. The beneficial effects will be that the nutrient-retention capacity will be increased, the surface layer can store more moisture, an aggregation of soil particles will take place, and important nutrients like P and S will be more readily available (Greenland and Dart, 1972).

Another approach is to accept the soil's limitations and to use cultivars that are adapted to poor soil conditions. This may be called the crop option. Cassava
is an example of a crop that can stand the low nutrient content of sandy soils. This option is used in many parts of Africa and Asia, both at subsistence level and on a commercial basis. In some cases cassava cultivation combined with proper soil management techniques has proved very successful. In northern Thailand, for instance, the area used for cassava has increased from 200,000 ha in 1969-71 to about 1.5 million ha in 1985 (Ahn, 1988). And this development has taken place on acid sandy soils.

Another crop option is paddy rice. From the point of view of the soil, however, sandy soils can only be used if there is an impermeable layer to prevent water from leaving the system. Submergence has the advantage that the soil pH will be raised and nutrients like P will become more readily available. Because of the low supply of nutrients from sandy soils this option should include fertilization.

Other crops that have performed well on acid sandy soils are pearl millet, groundnut (if liming is carried out), cashew nut, and pineapple.

Agroforestry techniques provide yet another option. The difficulty with agroforestry will be the establishment of the trees. The seedlings have to be nursed carefully to supply them with adequate nutrients and water. Once established, the trees can cycle the nutrients. However, this technique will not contribute much to the improvement of the water-holding capacity, and is therefore only partly an answer to the management of acid sandy soils.

The network most closely related to the topic of this meeting is the sub-network on the Management of Acid Soils in Sub-saharan Africa. The main objective of this network is to validate and to adapt soil management techniques in order to arrive at farming systems that yield sustainable food production on the acid of soils of Africa, thus reducing the need for shifting cultivation. The acid soils studied in this network are defined as soils having a pH (H₂O) of less than 5.5 and are more or less limited to Ultisols and Oxisols. The main problems with these soils concern the toxic levels of Al, often a low effective cation exchange capacity, severe imbalances in nutrients like Ca, Mg, K, P, S, Zn, B and Mo, as well as all kinds of fixation problems, adverse surface soil properties (notably liability to sealing, crusting and compaction), sometimes low soil moisture retention due to micro-aggregation, and delicate organic matter dynamics. The research
projects of the network are designed to alleviate these constraints. They are carried out by national agricultural research systems, and are co-ordinated by IBSRAM.

The projects are designed with core experiments and satellite experiments. In the sub-network mentioned above the core experiment comprises the traditional or current farming system, derived low-input farming systems, and high-input system(s). Generally two derived low-input farming systems are studied, one based on minimum application of fertilizers plus the use of acid-tolerant varieties, and one with leguminous crops and soil covers, which consequently aims essentially at organic matter management. The high-input experiment is based on optimal liming and fertilizer application based on frequent soil analyses. All core experiments use maize as the common crop to facilitate comparison between the projects.

In the satellite experiments trials are conducted to refine soil management practices. They deal mainly with tests on optimal fertilizer application, on screening promising varieties, on the interaction between treatments, and on monitoring soil changes. Once management practices analyzed in the satellite experiments are well understood and found to be applicable to the farming systems tested, they are incorporated in the core experiment. The satellite experiments are carried out on similar soil to the one used for the core experiment.

Because the research is soil-based, close monitoring of the soil is an essential part of the research. It starts off with a detailed soil characterization of the site of the experiments. This is supplemented by a socio-economic survey to analyze the farmer's practices and to define the current farming system. During the project, frequent testing of important soil parameters take place to monitor the effects of the various treatments on the soil. In the end the aim is to determine the sustainability of the farming systems tested in terms of soil and crop performance, acceptability by farmers, and economic returns. Therefore the team of researchers comprises soil scientists, agronomists, agro-economists, and sociologists, supported by various units like laboratories for soil and plant analyses and data-processing units.

To arrive at common methodologies and research practices, training of the project's field staff is an important component of the IBSRAM approach. IBSRAM has organized specialized training courses focusing on soil and site characterization, soil management options, experimental design and data processing, for various co-operators of the networks as well as for researchers from other countries, as preparatory part of the projects.

**Conclusion**

The network approach adopted by IBSRAM may well work in the adaptive research on farming systems for low fertility acid sandy soils in the Caribbean. CARDI already provides a perfect framework for setting up and administering such a network. IBSRAM'S experience and the knowhow of international agricultural research centres can be used to formulate the research programmes and outline the possible options for such a network. These options should include organic matter management, adapted crop varieties, agroforestry and livestock but above all the research should be carried out very carefully, and the resulting management options should be very sound in order to avoid complete destruction of the fragile acid sandy soils, which can easily be turned into completely unproductive deserts. IBSRAM is willing and ready to assist.
References


PRESENTATIONS OF THE WORKSHOP DISCUSSION GROUPS

Terms of Reference for Workshop Groups

Objective:

To identify components of the farm systems and strategies for the Savannahs given the constraints and opportunities identified during the Technical Sessions and using the individual and collective experiences of the members.

More specifically:

- Identify and outline the soil, agronomic, research, development, communication training and other needs of such systems.
- Pinpoint technologies that are considered ready for use; those that need adaptation and validation; and areas needing sustained research efforts.
- Consider and recommend strategies for crop-based or animal-based farming systems that are sustainable, environmentally sound and economically attractive.

GROUP 1 REPORT

Chairman: L. Simpson
Rapporteur: C. Bullen
Presenter: C. Bullen

The group in considering the task at hand, took note of:

- the fragility of the eco-system,
- the harsh nature of the environment and
- the need for consideration to be given to the involvement of people in the development of the region.

To this end a number of attractive models of farming systems were identified and described. Attention was also given to the research and development programmes, the training, requirements and issues relating to communication, pertinent to these systems.

Models

1. _Arable crop/pasture rotation systems and variations_

   Characteristics

   - land clearing should involve minimal soil disturbance
   - conventional tillage to incorporate limestone
   - cultivation of row crops with reduced tillage for 2 - 3 years
   - introduction of suitable forage species
   - Period of utilization for livestock production
   - return to commencement of cycle
Areas for research

- Methods and rates of limestone application.
- Length of the cycle.

Alternatively, this system may start with establishment of pastures to be followed by arable cropping.

2. Cultivation of perennials

Here a number of variations were thought to be viable both for small-and large-scale agriculture.

- mono-cultures of chosen perennials e.g. oil palm, mango, citrus.

- perennials in association with forages which may be used in either grazing systems for small ruminants or "cut and carry" systems for livestock in smaller scale farming.

- perennials in association with row crops which may be grown during the establishment of the perennial and later to be followed either with a cover crop of legume or grass, or some other system of utilization for livestock production.

3. Agro-forestry systems

The components of this system include:-

- initial conventional tillage to incorporate limestone
- cultivation of Leucaena or Glyricidia in rows
- cultivation of arable crops under reduced tillage in association with the above
- mulching of the row crops with prunings of the woody leguminous species.

This system is labour intensive and may only be available for the less mechanized, smaller-scale farming systems.

4. Reduced tillage/live mulch system

The components of this model include:-

- initial conventional tillage for limestone incorporation
- establishment of a suitable legume-mulch
- cultivation of row crops under reduced tillage with the mulch which should be chemically controlled.

In this model, there will be need to determine the length of the cycle i.e. the frequency of the limestone application.

5. Utilization of abandoned lands

Here it was recognized that a considerable acreage in the Savannahs had been utilized for arable cropping in areas such as Eberaabo, Kibiliri and Kimbia. It was noted that these lands had benefitted from enhanced soil fertility and this was reflected in the increased biomass. It was suggested that these lands can be utilized for purposes such as pastures, perennials or arable crops. Utilization should involve:-

- continuous clearing through brush cutting
- slow degradation of the biomass to allow for organic matter enhancement
- soil testing to determine the chemical status

Research and development programmes

Consistent with the development of the above-mentioned models, it was
suggested that the following research and development programmes should be on-going:

- Soil fertility research to determine optimum levels of soil nutrients required for crop production.

- Pest and disease management to adequately assess the levels of tolerance or economic threshold levels of pests and diseases as well as to recommend suitable control measures. Particular reference was made to the need for characterization of weeds and weed successions within the various models and methods of effecting control.

- Identification and selection of adaptable varieties/cultivars of crops and forages to be grown in the ecozone. It was recognized that this work is on-going and that it should be intensified.

- Agrometeorological data collection and analysis should be greatly enhanced using the modern technologies which are now available. This service should permit a predictive capability in terms of weather and should also provide information on inter-relationships between weather pattern and soil-moisture relations and the incidence of pests and diseases.

- Baseline information on the erosivity of rainfall and the erodibility of soils is also seen as a priority.

- The need was expressed for the putting in place, in the savannahs, a seed production capability for the various crops of interest.

- The group noted and emphasized that the economic feasibility of the various models required research.

- The research and development programme by reason of its broad-based nature required a multi-disciplinary approach.

- Research should be integrated with development.

Communications

The group felt that in this area there was need for:

- The establishment of a research network to facilitate the exchange of ideas, information and data regarding similar eco-systems.

- Such a network would also facilitate the exchange of germplasm and other relevant material.

- The creation of an inventory or data bank on research pertinent to low fertility acid sandy soils. It was suggested that this task may be undertaken by CARDI/CTA. It was also felt that greater use should be made of research information available through CTA.

Training

While noting the general need for a greater number of trained scientists to research the problems of low feasibility acid sandy soils, the group pointed to specific needs in terms of:

- Exchange visits by researchers to facilitate the exchange of ideas and information.

- Enhancing the skills of researchers in agrometeorology.

- Social aspects of community development.

Consensus was also reached that this workshop should be viewed as the first of a series dealing with the problems of low fertility acid sandy soils.
GROUP II REPORT

Chairmen: P. Osuji and V. McPhearson
Rapporteur: C. Wickham
Presenter: P. Osuji

In making recommendations, it was assumed that:-

- In the short- to medium-term there would be no foreign exchange to allocate to the Intermediate Savannahs.
- Fertilizer allocations for the Savannahs are likely to go to the grain legume/cereal crops.
- The pasture/crop rotations envisaged, will allow the pasture to benefit from the grain legume/cereal production, and the crops to benefit from the animal production.
- Mineral supplementation for animals will however remain as a demand on foreign exchange because of:
  • the need to import certain components, even for the locally produced mixtures
  • the continued importation of complete mineral mixes
- There will be a continuing need for foreign exchange allocation for the purchase of machinery and agro-chemicals.
- Appropriate policy instruments will be in place to support the research and production thrusts in the Savannahs, for example social infrastructure.

Current technological options

The following technological options were considered by the group to be ready for use:

- Pasture-based beef and dairy production systems.
- Grain legumes.
- Cover crops (leguminous fallows)
- Small ruminant systems
- Orchard/tree crops
- Cotton

Opportunities for integrated production systems

The group examined the animal and crop production systems, and the urgent need for integrating them. The opportunities identified include:

- Beef production at relatively low input levels could earn income which may be used to purchase capital inputs needed to support the crop operations, thus fostering strong crop/livestock linkages. This crop/livestock linkage will create the right conditions for a multiplier effect within the systems and the economy. Examples of these multiplier effects would be:-
  a) employment generation
  b) infrastructural development
  c) biogas technology development
d) soil fertility enhancement

e) agro-forestry systems

- It is expected that the by-products of orchards and annual crops will augment the feed inputs in the animal systems.

**Constraints and research opportunities**

The constraints identified informed the research opportunities. The key constraints identified as:

- Over-dependence on a single grass species, *B. humidicola*.
- Low nutritive value of the forage species.
- Pests and diseases and a high incidence of weed infestation.
- The unpredictability of the rainfall.
- Poor selection, handling, management and maintenance of equipment.

The group agreed that the research should be user-oriented and should be long-term and sustained.

Research opportunities were identified in the following areas:

- Pasture-grain legume (soyabean, cowpea, peanut) systems.
- Tree crops - small ruminant systems.
- Tree crops - leguminous cover crops - small ruminants.
- Natural range animal systems.
- Seed production for crop and animal production.
- Poultry production systems, for example utilizing resources produced in the Savannahs.

- Economics of the various production systems.
- Mineral supplementation.

Research strategies required would include:

**Soil management**

- institution of contour cultivations, strip cropping and crop rotations.
- determination of the appropriateness of tillage implements and depth of cultivation.
- serious consideration of conservation tillage techniques in relation to soil fertility enhancement, weed control, soil moisture conservation and erosion control.

**Soil chemistry**

- further study of the exchangeable bases (K, Ca, Mg) and their interactions on the exchange complex. Correlation with yield and productivity.
- monitoring of P fixation, release and accumulation.
- more detailed studies on trace element fertilization.
- studies on the efficiency of various fertilizer sources of plant nutrients e.g. limestone, K, P, Mg, N, trace elements.

**Agronomy**

- effect of crop rotations on soil fertility - involving both crop and animal systems.
- rooting depth of crops and soil moisture availability as it relates to depth of placement of fertilizers and depth of tillage.
- use of foliar fertilizers.
weeds and their relation to fertility status.

Management and agro-economic considerations

- cost effectiveness of various technological innovations.
- a more comprehensive integration of soil fertility management techniques into the overall production system.
- streamlining management of field operations to permit proper and timely application of technology.
- proper record keeping.

Policy issues

A number of policy issues were identified including:

- need for a holistic development plan for the Savannahs rather than a piecemeal approach.
- need for third country tariffs to protect regional animal production from extra-regional production.
- need for attractive remuneration packages for research and production workers in the Savannahs to ensure long-term research and production efforts.

Technology transfer

The technology transfer activities will include on-farm demonstrations, pilot plant activities, field days, seminars and conferences.
Technical Session V

Rapporteur: D. Walmsley

Management acid sandy soils: the IBSRAM approach

J. Ruinard (University of Suriname):
Forestry has been tried successfully on the acid sandy soils in Suriname. *Pinus caribaea* was planted in the 1960s. Also there has been some agro-forestry.

L. Daisley (Ministry of Agriculture, St. Vincent):
Why do you discourage shifting cultivation practices? This has proven to be the only form of sustainable agriculture in the world. Also it does not require massive inputs and leakage of foreign exchange.

O. Spaargaren (IBSRAM, Thailand):
The situation in South America is different from that in Africa and Asia where population increases have been enormous. As a result, in shifting cultivation, the time allowed for regeneration between cropping periods has been severely curtailed — 3-4 years compared to 20 years in the traditional system. This has often led to degradation of the soils. In these circumstances the farmer needs to be provided with alternative, low input, techniques.

L. Daisley:
Pressure on the land is not necessarily due to population pressure. There are other agencies which force farmers into marginal land. We should bear in mind the distinction between 'production systems' and 'farming systems'.

O. Spaargaren:
It is often observed in Africa that when the infrastructure is improved, people move. For example people came to live alongside the new roads and started cultivating for a distance up to 3 - 4 km from them. There is no population pressure to do this.

P. French (Demerara Tobacco Co., Guyana):
Can you tell us something about the methods used to increase the waet holding capacity of sandy soils in the Sahara and Israel — not only organic matter but other materials?

O. Spaargaren:
Tests are being made on the Nile delta region of Egypt in the use of silica gel to increase CEC. Some promising results have been obtained.

J. Seaton (CARDI, Guyana):
What methodology is used to set up agro-forestry systems?

O. Spaargaren:
Experience in Africa has shown that systems such as alley cropping (with tree crops) take a long time to establish and it is difficult to convince farmers of the benefits which may not come until 5 years ahead.

Both IBSRAM and ICRAF (International Council for Research in Agro-forestry) have established demonstration sites to show the beneficial effects.
Group Discussions

S. Parasram (CARDI, Headquarters): What can be done about establishing a community within the Savannahs to provide a labour force for the R & D operations?

H. Adams (CARDI, Guyana): A 'lure' would be needed. This could be the provision of good living conditions. If "factories" for food processing were set up in the area, people would be attracted.

W. Treitz (CTA, The Netherlands): The recommendations given have been directed by the economic and physical conditions existing in Guyana and Suriname. To what extent are they relevant to other Caribbean countries?

L. Simpson (NARI, Guyana): The group recommendations have come from a wide cross-section of participants — including people from the Caribbean islands who have taken account of the situation there. The flexibility of the proposed models will allow for their adoption in other countries than Guyana.

L. Smith (Ministry of Agriculture, Barbados): The systems described would not be appropriate for the majority of the West Indian islands.

P. Osuji (CARDI, Trinidad and Tobago): An increase in production activities in Guyana would benefit the Caribbean. Also there are acid soils in Trinidad to which the technology generated in Guyana could be transferred.

L. Daisley: There is a need for low input systems to conserve foreign exchange.

C. Alvares (University of Suriname): The main question is: Do we want to carry out investigations just to satisfy our curiosity? If this is so, at what cost and what is gained? The possibilities should be worked out based on previous experience, and the research programme should take into account the costs involved.

W. Treitz: Research can be very expensive but, as the Hon. Minister pointed out, can also be profitable. Planning of research is fundamental if there is to be a favourable cost benefit.

S. Surajbally (Natural Dairy Development Programme, Guyana): Investment in the Savannahs would include manpower, materials and money. Optimal utilization of foreign exchange is an important option. With regard to the beef/dairy aspects, infrastructure should come first.

P. Osuji: The group did not recommend that infrastructure come after the policy instruments had been put in place but rather that infrastructure would be included from the beginning.
CLOSING SESSION

Chairman: H. Saul, CARDI
CONCLUSIONS AND RECOMMENDATIONS

J. Smith
CARDI, Guyana

Low fertility acid sandy soils represent a significant proportion of the agricultural land resource of the Caribbean Community (CARICOM) region. The workshop reaffirmed the potential contribution of these soils towards efforts aimed at attaining regional food self-sufficiency and food security.

While possibilities for large expansion of agricultural output remain there are significant constraints which must be addressed before these soils can be brought into economically viable production. Among the constraints identified for the development of these areas in Guyana and Suriname are:

- low inherent chemical fertility, high erodibility and compaction of the soils,
- lack of suitable policy instruments
- inadequate infrastructure

The seminar put forward the following conclusions and recommendations

1. That a systems approach to agricultural research and production was crucial for successful management and exploitation of the soils in question.

2. That continuous monocropping of open row crops was highly unlikely to be sustainable and should not be recommended.

3. That an approach whereby multidisciplinary teams of research scientist working to develop production systems in close alliance with commercial producers, would seem most likely to deal effectively with the attending complex technical and managerial factors and, therefore, hold the best chances for success.

Four principal production models were suggested.

Model I. Rotations of short-term row crops with pasture systems

This model is based on the fact that these fragile soils need frequent breaks from annual crops in order to promote improved soil structure, re-introduce organic matter and control weeds. Essential features are:

- the production cycle can commence using either open-row crops or pastures
- the crops will be rotated at a predetermined optimum frequency
- output from the system can be a variety of crop products (soyabean, peanut, cowpea, etc) or animal products (beef, milk, mutton, etc.)
Model II.  *Perennial crops systems*

A number of perennials (oil palm, mango, citrus) could be grown under a monocultural system or may be grown in association with pastures or in conjunction with open-row crops. The open-row crop option may be possible during early establishment only. There is also the possibility of growing timber trees such as *Pinus caribaea*.

The output from this system could be a number of products for perennial crops and/or animal products or, in early establishment, products from row crops.

Model III.  *Agroforestry system*

The cultivation of arable crops in conjunction with such species as *Leucaena* or *Glyricidia* in alley cropping patterns could provide for organic matter build up as well as provide an additional source of forage for use, particularly during the dry periods of the year.

Component research

The proposed models could be refined over time through research into their respective components:

- determination of fertilizer and liming regimes required for production of various crops.
- tillage methods and systems, including mulching, minimum tillage and strip cropping, and their affects on crop performance and soil erosion.
- pest and disease management to adequately assess the levels of tolerance and economic thresholds as well as the determination of suitable controls.
- identification and selection of adaptable varieties/cultivars of crops (including forages).
- argometeorological data collection, analysis and interpretation for the enhancement of predictive capability in terms of plant/soil moisture relationships, incidence of pests and disease, delineation of cropping seasons and the relationship between intensity of rainfall and erodibility of soils.

4. That there was need to develop a formal and informal network of researchers working on low fertility acid soils. Such a network will, among other things, continue the exchange of information and ideas as well as the exchange of germplasm and other relevant material.

5. That an effort (supported by perhaps CTA and CARDI) should be mounted to assemble, review and publish relevant research information on the management of the soils in question currently existing in various research centres.

Such a review should be aimed at supporting the development of the models specified above and would be an invaluable resource for future research and development efforts concerned with expanding agricultural production on low fertility acid sandy soils.
CLOSING ADDRESS

Mr Louis Wiltshire

Deputy Secretary General of the Caricom Secretariat

Thank you Mr Chairman.

When the Secretary General telephoned me last week to enquire whether I would be available and willing to deliver this closing address, I said "well yes I would be here and I would be willing".

I am not a technically qualified person in the field of agriculture, but agriculture is one of the major sectors with which CARICOM deals. We put in place therefore a system of preparation in which I was able to call upon the advice of Dr Frank Gumbs, who has recently joined us from the University of the West Indies, and subsequently I asked others of our staff, who have been following the meetings of the Ministers of Agriculture and the evolution of policy over the last few years, to give me some additional ideas.

I took into account that this is a technical meeting of scientists, administrators and practitioners, focused on a highly specific and technical subject and that CARICOM is not a technical agency but a Secretariat for the Community as a whole. The Secretariat's primary importance lies in the fact that it is a principal channel of contact to the political directorate — about whom we have heard so much in the last several days — and which is responsible for guiding our paths in the countries of the Community in the very difficult times through which we are passing.

I suffer from a disability as I do not present scripted addresses, so that there is the need in the style of preparation and presentation through which I go to identify a theme which would be a unifying force to hold together and make meaningful, to the extent possible, whatever I might be able to say, drawing on the general material, the knowledge, the concerns, which are addressed at the CARICOM level and attempting to relate it to the practical and the technical, which is the special focus of this Seminar.

I do think that it is interesting that one of my last public functions as the 5 years of my term as Deputy Secretary-General draw to a close, is an agricultural event because I remember distinctly that in April of 1984, when I was just a few months into my term, my first external public commitment was in agriculture, at the Meeting in Saint Lucia of the Standing Committee of Ministers Responsible for Agriculture. Then, too, as a novice both on the regional scene and certainly in the area of agriculture, I wondered what I should say. Some of you may be aware that prior to coming to CARICOM, most of my career took place overseas, much of it in the United Nations system, in New York and Paris, as a career diplomat from the Trinidad and Tobago Government's Foreign Service, who had by accident spent some 12 years or so on secondment to the United Nations and UNESCO. So when I came back into the region and then was asked by the Government to come to CARICOM, it was an interesting challenge.

Now, one cannot be in the region without becoming immediately aware of the importance of agriculture. It was important in 1984. Then, the Ministers were grappling with the fall-out from decisions by the Heads of Government in July 1983 which had taken the agricultural arrangements in place in the Community, as it were by the scruff of its neck, shaken it up, and launched it on an unknown path into the future — a path which has resulted in what is now known as the New Marketing Arrangements for Agricultural Products — but a path which had the Minsters in some
confusion; which put the Secretariat into turmoil and tested its resources of personnel, of know-how, of skill and dedication, to the utmost.

At that Meeting, in the Cariblue Hotel in the north of Saint Lucia in 1984, Ministers grappled with a variety of tasks and concerns. It was quite clear that agriculture was not performing those tasks; was not making the contribution to the regional economy and to regional development which it could and which it should. They dealt with agriculture in the broader sense ... I remember discussions on the fisheries sector which, by and large, is under-exploited in the region. And of course the Ministers had to grapple with the problem of trade in agricultural products as well as trade in semi-processed agricultural products; with the agro-industry complex; with the many barriers of transport, of funding and organization; of the application of R & D know-how to the actual processes on the farm, or in the agro-industrial enterprise.

Over the years which have ensued since then, we have come up with firm arrangements for marketing, and they are beginning to work. But every meeting, not merely of the Ministers of Agriculture, but of the Council — the Common Market Council — sees intense discussions about the problems of oil and fats, of the market for arrowroot diminishing constantly; of the intrusion of external supplies, whether it is soyabeans in place of coconut oil or whatever, supplanting gradually, but apparently relentlessly, local production.

In the area of the use of something like coconut oil, we came across problems highlighted by the Ministers representing countries which were put in the dock for not taking up their full quantities of coconut oil. One Minister dramatically produced a bottle of virtually frozen coconut oil. He said that when the consumers in his country went into the supermarkets with the temperatures which normally prevailed there and saw products looking like this (that is, frozen) they had no inclination to buy it. One heard as well of problems — practical problems — like the splattering of coconut oil when you use it to cook. One heard of the health hazards from cholesterol which had become of such considerable concern in recent years as we grapple, in another sector, with the diseases of life-style.

And then one became aware that there were institutions in the region which were capable of tackling and resolving technically those problems. The Secretariat approached CARIRI and learnt that there were no insuperable technical problems to resolving any of those difficulties. But we learnt also that no one in the coconut industry had approached CARIRI previously for the technical analysis and, hopefully, resolution of those problems.

And that highlights the problem which to some extent is being tackled at this Meeting today; the nexus between agriculture — agricultural production — and more particularly the people who deal with it practically on the one hand and the research establishment on the other. The extent to which those people who have benefitted from the educational processes and who have come back to work in the region are actually applying themselves to problems of concrete concern to the Community as opposed to things which are academically interesting and which might look well in publications in North America or Europe.

What is exciting to me about this meeting is that it does bring together the researchers and the practitioners. It also represents practical and on-going collaboration between functioning institutions at regional level such as CARDI and UWI, which provided a team of speakers at the Opening Ceremony and participation subsequently, and international agencies like CTA. I was fortunate to participate in the first of this series of seminars in Trinidad and Tobago, also funded by CTA, when we focused, at least at the Opening Ceremony, on this very problem of the connection between research and development and the practical problems of getting agriculture moving.
Now, as a layman, I am acutely conscious that in very few countries of the world is agriculture a successful sector. One hears of stories in the Soviet Union and other developed countries — Britain, France for example — where agriculture is and continues to be a problem. One hears of solutions brought about more by the throwing of aimless sums of money at the problem than by any rational arrangements — solutions clearly beyond our means, because we do not have endless sums of money to throw at anything.

In this context, agriculture of course has to fit into the general world in which we live — a world which, to an audience in Guyana, I do not need to say is becoming increasingly difficult. In the Caribbean Community, we had an exercise which culminated earlier this year in the presentation to our Heads of Government of a report called "Caribbean Development to the Year 2000: Challenges, Prospects and Policies". I had the benefit of sitting in on one or two of their sessions as they worked and early this morning I was reviewing some the sections on agriculture, on trade, on production, and as I looked at what it had to say on the different sectors, it was clear that none of it would surprise you.

I heard, for example, Dr Smith saying something of balance of payments and there is a sentence in that report which says "balance of payments effects on the agriculture and food sectors are pervasive". I think people in Guyana would regard that as an understatement. That section of the report started with an attempt to define the relationship of agriculture to the economy and it says "the agricultural sector has significance in the process of economic growth and development deriving from its direct contribution to employment and incomes, it's role as a foreign exchange earner and in import substitution in food and raw materials, its demand for the output of the manufacturing sector and other sectors, and its contribution to aggregate savings and capital formation".

I am not sure that that would be regarded as complete, but it goes some distance. But then the Report goes on to quote another Caribbean Community Study which indicated that in most of the CARICOM economies both agriculture and food production, on a per capita basis, have either decreased below levels achieved in 1961 or have stagnated — with the only exceptions, generally speaking, being legumes and poultry production, which experienced positive growth between 1980 and 1984. It cites, furthermore, the fact (which I think even to laymen has been apparent over the last couple of decades) than, in most countries, the area in agriculture has declined especially as housing and industrial development encroached. I remember being puzzled in Barbados in the early 1960s as more and more agricultural land was taken out for housing, in a country with an absolute limit on its land space, where people still believed in the absolute indispensability of individual houses as opposed to the North American model of high-rise apartments — and the consequences are becoming apparent. Guyana is, of course, along with Belize, one of the few countries where this severe limit on land space, on space available for agriculture, is not a significant constraint.

But even in Guyana the newspapers tell us that we have reached a stage in recent months where, for the first time, the principal sugar exporting countries of the Caribbean have begun to import sugar. And we know, over the past few years, of the decline in rice production. Apart from that, of course we are aware of the significant decline in income from the export of sugar, of bananas, and of all the other traditional crops as well as the extreme difficulty which the region has experienced with its efforts to diversify and to find non-traditional exports to fill the gap in the performance of the traditional export crops.

And now at the end of the 1980s we have learnt — from the experience of Trinidad and Tobago, which previously seemed to be such a shining exception, in the golden years in the 1970s — that there are no easy solutions and that, in any case, there are no
solutions which can be relied upon to the complete exclusion of agriculture. In the last couple of years, Trinidad and Tobago has seen an absolute profusion of agricultural production, with a tremendous decrease in prices of watermelon on the streets and so on. As one drives from the airport to Port-of-Spain, one sees, once again, the fact that when "push comes to shove", as we say in Trinidad and Tobago, you have to get back to the land.

But, if the experience over the last couple of decades is reliable, if we have, as countries, such incredible difficulty in increasing agricultural production, if when foreign exchange constraints become dominant and even our regular production declines because our traditional reliance on imported inputs is no longer available to us, then what is left? And clearly what is left is the intensive application of our know-how, our brain power, to the solution — to the creation of new solutions.

So, it was with some considerable interest that on Monday I listened to the speeches on the potential of the Intermediate Savannahs and then I took the opportunity on Wednesday to join a field trip and, for the first time in over 20 years, went to Ebini to see what was happening. I saw young people on top of their subject, who knew exactly what was happening, who were in charge. But I also heard at the same time the hesitation in responding to more extensive questioning: how will these Intermediate Savannahs be brought into full and productive employment? When that question was asked, we were told that it would be dealt with later, but later never came.

We heard how an experimental cultivation of 300 acres of soyabeans, cut back to 150, was going to jump marvellously to 1,000 acres. But detailed probing as to the technical underpinning for a successful leap at that kind brought the explanation that that was a political directive. The query as to whether it would not be more prudent to go to 500 first, was met with the acknowledgement "Yes it might be", but with an absence of flexibility actually to do that.

And I wonder if that did not highlight something of importance for us in a gathering such as this. I think that while our political directorates are inevitably focused on the short-term — on the solutions which will magically remove the difficulties which face us on a day-to-day basis — since it's hard to find the foreign exchange to provide feed for animals, feed for chickens (and which of us likes eggs which do not have the traditional yellow colour?) for a variety of inputs which are required in agriculture, nevertheless the people who have to do it and who know the reality, are not always clear that it is possible for them to say frankly to the political directorate: "it is not safe; it is not prudent; it is not wise". We do not need to risk another showpiece failure which will setback enthusiasms and provide a disincentive to those people whom we have to induce to go into production, into farming in the Intermediate Savannahs, with all the difficulties which are involved in living away from the metropolis.

Is it not the role of the skilled technicians, the researchers, the administrators who are on the ground, who know what has to be done, who are working conscientiously at the forefront of available knowledge in the region — is it not their duty to formulate practical proposals as the basis for political directives when political directives come, in the absence of that, to say frankly, and to the extent that this is required, courageously, "we should not do this"? We know that not everybody likes the bearer of bad news. But is that a responsibility which we can escape? I personally think not. (But sometimes people say that I am too outspoken, that I do not know how to speak to politicians. I think there is only one way to speak to politicians and that is to say exactly how you see things; because over time they begin to trust that when they hear something from you, whether or not they like it, that is likely to be the case. So, they might as well hear it earlier, rather than later as an the explanation for failure).

Now, I regret that I did not hear this morning (I thought in fact it was part of the Closing Ceremony) the full conclusions of this meeting but I looked through the
Agenda, the detailed Agenda: the economics of small farm systems which Dr Smith was due to talk about a few days ago; the beef cattle industry; the issue of crops to be produced. When I tied that in with the discussion, which one heard, as to whether soyabeans was the right crop or whether it should be peanuts; whether cowpeas was really going to catch on and whether it was an economic crop; whether oil palms or coconut or cashewnuts — which of these should be concentrated upon; when I thought back to the kinds of questions Professor Ahmad raised in his formidable opening presentation on the real fragility of the ecosystems with which one has to deal in those Intermediate Savannahs, and the probability that throwing too many inputs, such as heavy machinery, could just be destructive, I was very curious to discover what where in fact the detailed conclusions, what is the programme of action which has emerged by consensus from these discussions.

I am a firm believer in the critical importance of the kinds of interactions which take place when people get together in this kind of meeting. As someone who is normally condemned to attend meeting after meeting, I know that, despite the ease with which people can dismiss more meetings, in fact meetings are crucial paths on the way to development, to the exchange of information and to the emergence of a clear cut, well-founded consensus of what needs to be done, how we need to move forward to make the contributions which this sector has to make if we are to break out of the constraints and straight jacket of those economic disabilities which preoccupy us today.

Mr Chairman, you promised the meeting a short session. I will therefore not go on much further, except to say that we in CARICOM will be looking forward with close interest to the results of this meeting. We wish to encourage the external donors like CTA to continue their very important contribution of support to the work which has gone on and which can continue to go on in the region; to the cross-fertilization which, without that financial support, would not take place quite so easily. I know that they must be examining whether, after the completion of a series of such seminars, it is not important to move on to something else. I am acutely conscious that in the Caribbean we do in fact have significant resources of skilled personnel. What we need from our outside friends, more than anything else, is the financial support to enable those people to function and to come together.

How would the people in Guyana, facing their foreign exchange constraints, ever have arranged for as many specialists as were able this week to participate in this discussion, how would they otherwise have arranged for the to participate in this kind of exchange, which, I am sure, even without having participated in it in detail, has clearly been useful in a way that would not otherwise have been possible if this had taken place entirely within the national context, within the context of the financial constraints which are dominant and inescapable?

So I say, therefore, to the external donors whom we have come to rely upon to such an extent and who, when they forge the kind of permanent and ongoing arrangements which CTA has forged with CARDI and with other institutions of agriculture in the region, can be relied upon — because in this as in other areas, predictability and sustainability are important so that they can plan in a systematic fashion rather than scrambling. So we are extremely grateful to the CTA as one of the instruments of cooperation between Europe and the Caribbean, as one of the ACP regions, for the kind of solid support which they have provided here and in the past couple of years in this process which culminated here today.

I would like to say, in conclusion, that in CARICOM as this moves up with its results to the Ministers, as we examine its relationship to the more general sector programme determinations (which were made by the Ministers recently, on the basis of wide-ranging examination and enquiry at the regional level) that we look forward to being able to see in the next couple of years the real benefits: in production which does not have a destructive set of consequences of side-effects — production that could make a
difference, both to the imports, to the employment and to the improvement, both in the nutritional status and the quality of life, of the people of Guyana and the region.
VOTE OF THANKS

Dr Michael Granger

Director, NARI

Cde Chairman and Deputy Executive Director of CARDI; Cde Louis Wiltshire. Deputy Secretary General of the CARICOM Secretariat; Cde Minister of Agriculture, Dr P.L. Mc Kenzie; Vibert Parvatan, Cde Minister in the Ministry of Agriculture; The Honourable Minister of Agriculture from Antigua, Mr Hilroy Humphreys; Your Excellencies; Members of the Diplomatic Corps; Dr Werner Treitz, Deputy Director, CTA; Guests; Colleagues:

The realization of the critical status of our regional food supply and security has dawned. It was indeed a long time in coming but now during the decade of the 80s it has come with a vengeance. Not that we all were not conscious of it, but we viewed it primarily from an individual country basis hoping that each of us could satisfy our own national needs in free trade on an open international market. Of course we were all too naive in our perceptions of the international marketplace. But the effects of the oil crisis two decades later now ensures that no Third World cartel will be permitted to exist; the high cost of foreign exchange — particularly to those countries whose tastes are alien to the regional production capability; and the growing protectionism in some developed countries helped to precipitate in the collective regional consciousness, the tenuous and precarious status of our food supply.

We have now come to the end of a rather highly successful workshop on Farming Systems for Low Fertility Acid Sandy Soils. Cde Chairman, as exciting as the workshop has been I still have one nagging fear. A fear that emanates from my past experiences that, after such mentally stimulating discussions one will eventually see a beautifully prepared Proceedings and then seven years later we will meet again to discuss exhaustively the same subject with an new set of faces. The thought of this frightens me. I wish to propose that based on the recommendations an activity time frame be developed, funding for implementation be identified, and let us meet again annually discuss the results of the progress made so that there would be some continuity.

The Regional Food and Nutrition Plan, also underwent a protracted period of gestation. It has now been accepted and approved for implementation by our respective Heads of Government and puts in vivid perspective what we have been doing; what we were permitting to happen to us, and what we must do if the regional ship of our food supply is to be righted.

We now recognize, at the highest levels, that regional food supply and balanced nutrition can be more rapidly achieved through a co-operative effort and so there is now leadership by example for us to emulate. The realization that we are all in the same ship with 13 captains not effectively communicating can only be catastrophic, so the team effort has emerged as the only viable solution bearing in mind that cartels are no longer in vogue. But Cde. Chairman, communication or the lack of effective communication, is the one most debilitating retardant to both the national and regional efforts at reducing the embarrassingly high food import bill.

Our regional institution, CARDI, was established to address regional agricultural research and development needs and to also strengthen the national capabilities. I am the first to admit that it did undergo a somewhat extended period of growing pains but I am now proud to say that CARDI is maturing rapidly and is indeed our Regional Research and Development arm.
The Caribbean, as a whole, has never really been short of technical competence but we have nevertheless lost a lot of our experienced skills. The papers presented at this workshop were indeed of a very high standard and attest to the quality of skills now available. Our major problems were with our inability to optimize the use-efficiency of these skills. CARDI is one mechanism through which the individual and collective expertise within the region could be focused on both regional and country-specific problems.

The concept of togetherness, of oneness, is only now becoming dominant in our agricultural development. The need to share ideas and experiences; problems, solutions, successes and failures is great. The need for professionals to be brought together frequently at such fora as this workshop, is overwhelming and an absolute necessity if regional food supply is to be assured. Financing for such meetings is always limiting.

It is therefore withing this context, Cde Chairman, that I wish to extend our heartfelt appreciation:

- To our regional organization, CARDI, for taking the initiative in this respect in bringing so many experienced scientists together to participate

- To Dr Werner Treitz, the Deputy Director of CTA — and on whom we will now have to confer honorary regional citizenship for his interest in our regional agricultural development and for convincing his colleagues at CTA that the investment in the region is indeed critical.

- To Professor Amad for focusing so intently on the delicate nature of the environment we examined.

- To CTA for providing the necessary financial resources.

- To those agencies that have expressed their togetherness with CARDI - Guyana, in making this workshop the success it has been - NARI, LIDCO, NEOCOL, GNS, etc. and specifically I must single such individuals as Nigel Cumberbatch, Courtney Bullen and their teams for readily accepting the national responsibility.

- To Mr Louis Wiltshire for giving so precise an interpretation of the political, environmental and sociological problems of agricultural development the region.

- Above all Cde Chairman, I must, on behalf of the organizers, say thanks to all participants, those who took time to prepare and present papers and those who have participated in one way or another in the discussions and workshop per se.

- To Dr P. L. Mc Kenzie, our Minister of Agriculture, for taking time off to be with us to set the tone and to declare the workshop open.

- Finally Cde Chairman, a special thank-you must be extended to the Honourable Minister of Agriculture, Mr Hilroy Humphreys from Antigua, whose interest as manifested by his active participation throughout the workshop was indeed a morale catalyst that allowed us to feel that indeed we are making a contribution and that someone is prepared to be advised. I do hope this ice-breaking phenomenon is contagious.

Thank you all.
# ANNEX 1

## LIST OF PARTICIPANTS

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<td>Lionel H. Smith</td>
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<td>James Smith</td>
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<td>John Smith</td>
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<td>Otto Spaargaren</td>
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<td>Jillian Spencer</td>
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<td>Steve Surujbally</td>
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<td>Werner Treitz</td>
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<td>Hugh W. Wilson</td>
<td>Ministry of Food Production</td>
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<td>Rosemary Yansen</td>
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## ANNEX II

### ACRONYMS and ABBREVIATIONS

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<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACIAR</td>
<td>Australian Centre for International Agricultural Research</td>
</tr>
<tr>
<td>ACP</td>
<td>African-Caribbean-Pacific</td>
</tr>
<tr>
<td>BD</td>
<td>Bulk density</td>
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<tr>
<td>CARDI</td>
<td>Caribbean Agricultural Research and Development Institute</td>
</tr>
<tr>
<td>CARDATS</td>
<td>Caribbean Agricultural and Rural Development Advisory and Training Service</td>
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<tr>
<td>CARICOM</td>
<td>Caribbean Community</td>
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<tr>
<td>CIAT</td>
<td>International Centre for Tropical Agriculture</td>
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<tr>
<td>CTA</td>
<td>Technical Centre for Agricultural and Rural Co-operation</td>
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<tr>
<td>CIIMMYT</td>
<td>International Maize and Wheat Improvement Centre</td>
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<tr>
<td>DEMTOCO</td>
<td>Demerara Tobacco Company (Guyana)</td>
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<tr>
<td>EEC</td>
<td>European Economic Community</td>
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<tr>
<td>EMBRAPA</td>
<td>Empresa Brasileira de Pesquisa Agropecuaria</td>
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<tr>
<td>FAO</td>
<td>Food and Agricultural Organization of the United Nations</td>
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<tr>
<td>GDF</td>
<td>Guyana Defense Force</td>
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<tr>
<td>GOG-MOA</td>
<td>Government of Guyana - Ministry of Agriculture</td>
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<tr>
<td>GNS</td>
<td>Guyana National Service</td>
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<tr>
<td>GNTC</td>
<td>Guyana National Trading Corporation</td>
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<tr>
<td>GUYSUCO</td>
<td>Guyana Sugar Corporation</td>
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<tr>
<td>IAST</td>
<td>Institute of Applied Sciences and Technology (Guyana)</td>
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<tr>
<td>IBSRAM</td>
<td>International Board for Soil Research and Management</td>
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<tr>
<td>ICRISAT</td>
<td>International Crops Research Institute for the Semi-Arid Tropics</td>
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<tr>
<td>IDRC</td>
<td>International Development Research Centre</td>
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<tr>
<td>IICA</td>
<td>Inter-American Institute for Co-operation on Agriculture</td>
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<tr>
<td>IIITA</td>
<td>International Institute of Tropical Agricultural</td>
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<tr>
<td>INTSOY</td>
<td>International Soyabean Programme</td>
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<td>ITCZ</td>
<td>Inter-Tropical Convergence Zone</td>
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<tr>
<td>LDC</td>
<td>Less Developed Country</td>
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<td>LIDCO</td>
<td>Livestock Development Company Limited (Guyana)</td>
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<tr>
<td>MDC</td>
<td>More Developed Country</td>
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<td>NARI</td>
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<td>NEOCOL</td>
<td>National Edible Oil Company Limited (Guyana)</td>
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<tr>
<td>OAS</td>
<td>Organization of American States</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>OECS</td>
<td>Organization of Eastern Caribbean States</td>
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<td>RIEPT</td>
<td>International Regional Trial Network</td>
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<td>SOYCO</td>
<td>Soyabean Company (Guyana)</td>
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<td>USAID</td>
<td>United States Agency for International Development</td>
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<tr>
<td>UWI</td>
<td>The University of the West Indies</td>
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</table>
The Technical Centre for Agricultural and Rural Co-operation (CTA) was established in 1983 at Ede/Wageningen. It operates under the Lomé Convention between Member States of the European Community and the ACP States. CTA is at the disposal of the ACP States to provide them with better access to information, research, training and innovations in the fields of agricultural and rural development and extension.

THE ACP STATES
Angola
Antigua and Barbuda
Bahamas
Barbados
Belize
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Cape Verde
Central African Republic
Chad
Comoros
Congo
Côte d'Ivoire
Djibouti
Dominica
Dominican Republic
Equatorial Guinea
Ethiopia
Fiji
Gabon

Gambia
Ghana
Grenada
Guinea
Guinea Bissau
Guyana
Haiti
Jamaica
Kenya
Kiribati
Lesotho
Liberia
Madagascar
Mali
Mauritania
Mauritius
Mozambique
Namibia
Niger
Nigeria
Papua New Guinea
Rwanda

St. Christopher and Nevis
St. Lucia
St. Vincent and the Grenadines
Sao Tome and Principe
Senegal
Seychelles
Sierra Leone
Solomon Islands
Somalia
Sudan
Suriname
Swaziland
Tanzania
Togo
Tonga
Trinidad and Tobago
Tuvalu
Uganda
Vanuatu
Western Samoa
Zaire
Zambia
Zimbabwe

THE EUROPEAN COMMUNITY
Belgium
Denmark
France
Germany (Fed. Rep.)

Greece
Ireland
Italy
Luxembourg

Netherlands
Portugal
Spain
United Kingdom

CTA
Technical Centre for Agricultural and Rural Co-operation
(ACP-EEC Lomé Convention)

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