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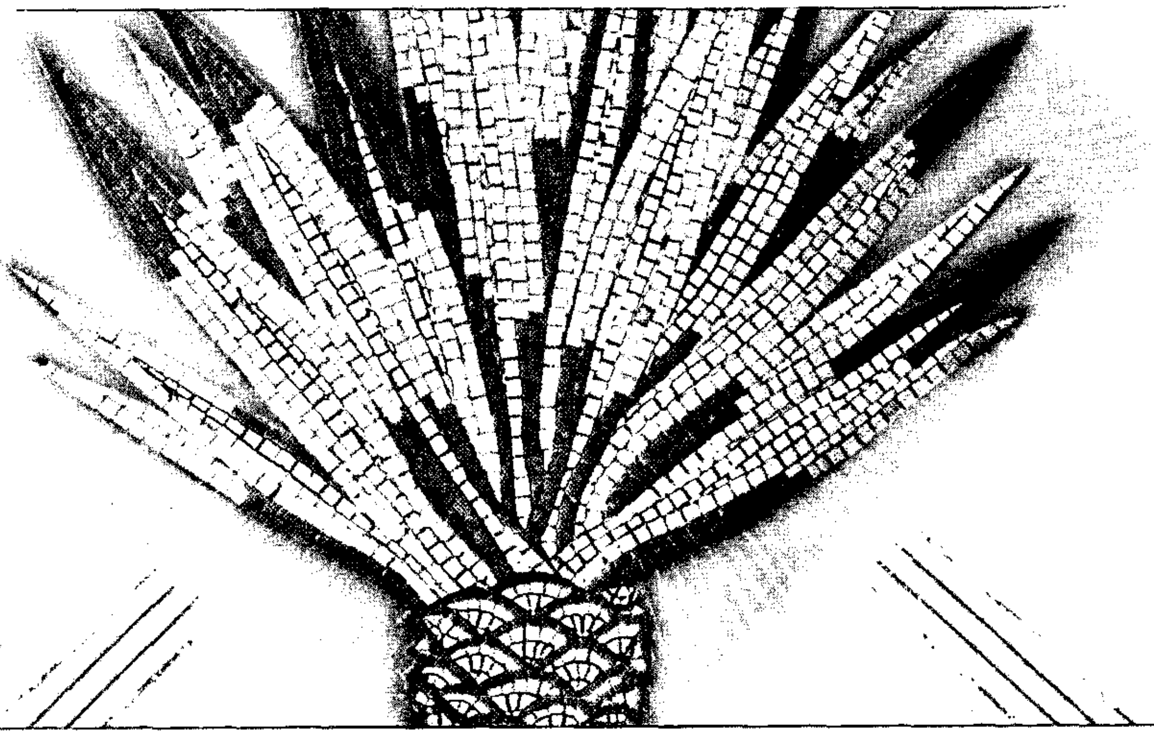
Common Fund for Commodities

Project CFC/FIGHF/07
Kenya–Tanzania, January 1997–December 2005



Product and market development of sisal and henequen

Summary Report

UNIDO

CFC COMMON FUND FOR COMMODITIES

FAO FIAT PANIS

KENYA SISAL BOARD

SISAL

COMMON FUND FOR COMMODITIES

Product and market development of sisal and henequen

Summary Report

Kenya–Tanzania
January 1997–December 2005

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2006

Project Completion Report preparation: National and international experts and consultants involved with the project, with contributions and support from the national teams.
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PRODUCT AND MARKET DEVELOPMENT OF SISAL AND HENEQUEN

SUMMARY REPORT

CONTENTS

Abbreviations

A.	Agave
AD	Air dried
ADMT	Air dried metric tonne
ARI	Agricultural Research Institution
BAP	Benzyl amino purine
BKS	Bleached kraft softwood
CCB	Companhia da Celulosa da Bahia
CEPS	COAID Enhanced Production System for Sisal
CFC	Common Fund for Commodities
COAID	Canada Overseas Agro Industrial Development
CICY	Centro de Investigación Científica de Yucatán
CIF	Cost/Insurance/Freight
DM	Dry matter
FAO	Food and Agriculture Organization
FEX	Fibre extraction
H.	Hybrid
Ha, ha	Hectare
IFAD	International Fund for Agricultural Development
IGGHF	Intergovernmental Group for High Fibre
ILRI	International Livestock Research Institute
KARI	Kenya Agricultural Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
Kg, kg	Kilogram
KLS	Korogwe leaf spot [disease]
KSB	Kenya Sisal Board
kV	Kilovolt
Mara FIP	Mara Region Farmers Initiative Project
MASL	Metres above sea level
mg	milligram
mg/l	milligrams per litre
Ml	Mlola
MT	Metric tonne
MTC	Meristematic tissue culture
NCC	National Coordinating Committee
Nm^3	Normal cubic metre
NTO	National Technical Officer
O&M	Operationa and Maintenance
PCC	Project Coordinating Committee
PEA	Project Executing Agency
SADC	Southern Africa Development Community
SAT	Sisal Association of Tanzania
spp	[Agaves] species
TANESCO	Tanzania Electric Supply Company
TATC	Tanzania Automotive Technology Centre
TOR	Terms of Reference
TSB	Tanzania Sisal Board
TZS	Tanzanian Shilling
UNIDO	United Nations Industrial Development Organization

US$/USD	United States Dollars
WAU	Wageningen University, The Netherlands
2,4-D	2,4-Dichlorophenyl acetic acid

Background

Up to the early 1970's Tanzania and Kenya were the world's leading producers of sisal fibre; Tanzania alone used to produce over 200,000 tons per year. Due to nationalization, changes in technology of bailing hay and straw and the loss of more than 60% of market share to synthetics, the production declined to less than 25,000 tons per year by end of 2002. The project **"Product and market development for sisal and henequen"** was conceived and started its activities in 1997. The project was financed by the Common Fund for Commodities (CFC), the United Nations Industrial Development Organization (UNIDO), the Belgian Government and the International Fund for Agricultural Development (IFAD). It was implemented in Tanzania and Kenya for the benefit of the whole sisal industry worldwide.

The objective of project "Product and market development for sisal and henequen" was to contribute to poverty eradication, economic development and environmental conservation in the region. Sisal and henequen, being drought tolerant, have a great development potential in arid and semi-arid and poor regions in developing countries. The main aim of the project was to promote the development of alternative non-traditional end uses of sisal and pave the way to the access to new markets to supplement the traditional ones. Particular efforts concentrated on the production of fibres to be used in the pulp and paper mills for specialty paper (tea bags, bank notes, filter paper etc). The pulp and paper industry offers a promising alternative to the traditional sisal industry because sisal fibre, if produced at competitive prices, can be successfully considered as an alternative to other fibres normally used to produce paper.

The main project activities focused on the analysis of the available different sisal varieties and on the evaluation of best agricultural practices and on plant multiplication by Meristematic Tissue Culture in order to: improve productivity, reduce costs and therefore produce competitively priced fibre. With the main objective of reducing production costs the project concentrated then on finding appropriate technologies to extract sisal fibres; to do that a hammer mill and a roller crusher were designed and installed at Hale sisal estate in Tanzania. The performance of the developed equipment was evaluated and the two technologies were compared against each other. Different pulping trials were conducted using sisal from the agricultural trials and finally a discrete amount of dry sisal fibre produced in the hammer mill was pulped in an industrial digester. Samples of this fibre and pulp were sent to pulp and paper mills; and a market study was performed to realistically identify the possible market for sisal fibre and pulp. Finally, a feasibility study for a Fibre Extraction Plant was prepared. This demonstration pilot project encouraged the sisal industry in Tanzania and Kenya towards its further development with new perspectives in addition to the traditional long fibre production.

The project also implemented activities oriented towards:

- The utilization of sisal fibre extraction waste for animal food production: Trials with cattle, sheep and goats.
- The utilization of sisal waste for biogas and electricity generation (on going project financed by CFC, UNIDO and the counterpart)
- Recovery of short fibres for pulping, handicrafts and other uses.
- Evaluation of utilization of bole fibre for pulping purposes.

The Appraisal Report included the following well-defined and integrated components:

A Development of new sisal varieties and improvement of cultivation practices
B Converting non-used materials in new products
C R&D on sisal processing for pulpable fibre and pilot plant production for market trials
D Market studies and trials

The management and dissemination activities inherent to the project are also well defined in the Appraisal report as follows:

E Project management and mid-term evaluation
F Technology dissemination/investment promotion

The following table summarizes the project development scheme as well as the distribution of tasks and responsibilities among the stakeholders and collaborating institutions.

Project components, sub-components, responsible agencies and specifications for Table for References for Inputs and Cost

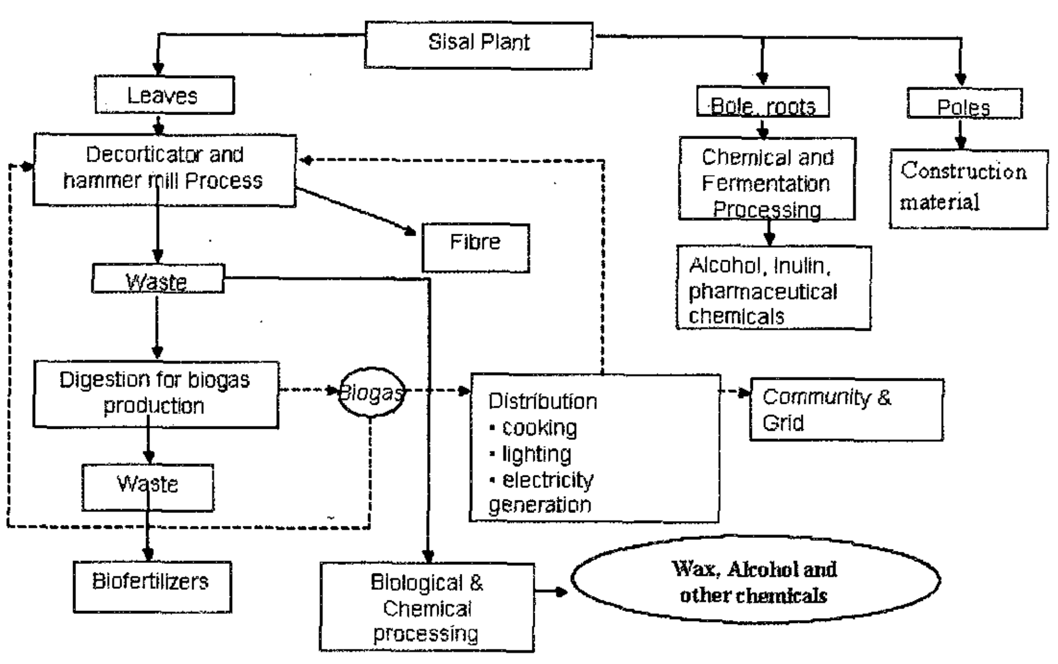
- **Component A** Development of new sisal varieties and improvement of cultivation practices
  - A.1: Review past research and production practices (T-2)
    Kenya (KARI); Tanzania (ARI)
  - A.2: Evaluation of sisal varieties for pulp and fibre (T-3) &
    A.3: Variety trials in estates (T-4, T-4a)
    Kenya (KARI), Tanzania (ARI Mlingano)
  - A.4: Smallholder farming system evaluation (T-5)
    Tanzania (TSA)
  - A.5: Multiplying sisal by Meristematic Tissue Culture(T-6)
    Kenya (KEPHIS), Tanzania (Ari Mlingano)
  - A.6: Mara Region farmers project (IFAD) (T-19)
    Tanzania (TSA)
- **Component B** Converting non-used materials in new products
  - B.1: Improved flume tow recovery (T-7)
    Kenya (KSB), Tanzania (TSA)
  - B.2: Animal feed trials (T-8, T-8a, T-8b)
    Kenya (Kilifi) - Subcontract
  - B.3: Bio-energy from sisal waste (T-9)
    Tanzania (TSA)
- **Component C** R&D on sisal processing for pulpable fibre and pilot plant production for market trials
  - C.1: Sisal fibre production (T-10)
    Tanzania (TSA)
  - C.2: Pulp pilot production (T-11)
    PEA, Tanzania (TSA) – subcontract
- **Component D** Market studies and trials
  - D.1: Market studies and trials (T-12)
    PEA, Tanzania (TSA) - subcontract
- **Component E** Project management and mid-term evaluation
  - E.1: Collaborating institution – Kenya (T-13)
    Kenya (KSB)
  - E.2: Collaborating institution – Tanzania (T-14)
    Tanzania (TSA)
  - E.3: Project execution supervision (T-15)
    PEA, ICB, CFC
  - E.4: Mid-term evaluation (T-17)
    PEA, ICB, CFC, Kenya, Tanzania
- **Component F** Technology dissemination/ investment promotion
  - F.1: Feasibility study – pulp mill (T-16)
    PEA, Tanzania (TSA)
  - F.2: Dissemination Workshop (T-18)
    PEA, Tanzania (TSA)

The presented report briefly summarizes the project achievements, lessons learned, conclusions on project implementation as well as recommendations for further developments. Details about specific sub components are given by the respective addendum for each sub component.

The sisal industry development programme is considered an important example of sustainable agro based industrial development in which the social, economic and environmental aspects are well integrated. The project is also a good example of interagency cooperation.

The results achieved so far encourage the project stakeholders to continue in this direction. There are other parts of the plant to be carefully evaluated and further interventions should be considered. The diagram below presents the approach to be followed for further development of the sisal industry discussed and agreed within UNIDO, CFC, the Tanzanian Sisal Board, the private sector and government authorities.

Sisal Industry Development Diagram



The activities implemented under each of the project subcomponents are oriented towards the improvement of competitiveness and diversification of the sisal industry.

The table below indicates the allocation of financial resources to the implementation of the project components.

Subcomponent	Cost
Subcomponent A1: Review of past research and production practices	62,721
Subcomponent A2: Evaluation of varieties	70,038
Subcomponent A3: Variety trials in estates	372,303
Subcomponent A4: Smallholders farming system evalution	9,510
Subcomponent A5: Multiplying sisal by Meristematic Tissue Culture	617,149
Subcomponent B1: Flume tow recovery	98,187
Subcomponent B2: Animal feed trials	183,136
Subcomponent B3: Bio-energy from sisal waste ***(The cost of preliminary activities performed for this subcomponent were included under subcomponent B1)***	0
Subcomponent C1: Sisal fibre production	421,413
Subcomponent C2: Pulp pilot production	91,309
Subcomponent D1: Market studies and trials	107,468
Subcomponent E1: Collaborating institution – Kenya	206,731
Subcomponent E2: Collaborating institution – Tanzania	309,383
Subcomponent E3: Project execution supervision	539,335
Subcomponent F1: Feasibility study – pulp mill	24,344
Subcomponent F2: Dissemination Workshop	68,094
Total	3,181,121

The actions taken by the project towards the sustainability and competitiveness of the commodity through the integration of the planned activities are summarized component by component in this report and described in detail in the specific sub components reports that offer the total integrated view of the recently concluded project.

Sub-component A.1: Review of past research results and current production practices

Summary

The steady decline experienced in sisal production in recent decades affected both research and development efforts. The need to review the results of past research and production practices was identified during the project design and formulation phase. This was considered necessary in order to avoid the unnecessary repetition of past activities and to learn about current practices. The information collected was used as a starting point for the project research programs designed with the objective of reducing costs and raising productivity.

Two teams of national experts, one in Kenya and one in Tanzania, were selected and contracted by UNIDO in consultation with the respective national counterparts. Each team comprised three national experts: an expert in sisal decortication, a planter and a sisal agronomist. The work carried out by the teams was complemented by the research carried out at the Agricultural Research Institution (ARI), at Mlingano (Tanga, Tanzania.) The National Technical Officer (NTO) in Tanzania contributed to this review providing information on sisal pulping.

An international consultant reviewed the different reports prepared and summaries of them were discussed during a review workshop held in Tanga on 22 - 24 April 1998. At the workshop a number of recommendations were prepared and activities to be undertaken by the project were identified. The Project Coordinating Committee (PCC) later recommended that a report summarizing the available information and proceedings should be prepared in the form of a Technical Paper. Following the outline prepared by the international consultant, a consultant from Kenya was contracted to compile the various reports and proceedings and the resulting document was published as CFC-UNIDO Technical Paper No.8. "*Sisal. Past Research Results and Present Production Practices in East Africa. Present Status, Problems, Opportunities and Future Prospects*". The Technical Paper was distributed to sisal producers, including smallholders in Kenya and Tanzania, and to the participants in a Dissemination Workshop held in Tanga in February 2003.

The objective of the subcomponent was fully achieved despite some delays, and the outputs were produced as originally envisaged in the appraisal report. Even though the publication of the Technical Paper was not originally planned, it turned out to be an important tool for the dissemination of the sub-component results to sisal growers and stakeholders, as well as for providing a useful source of information for planning future research and development at the scientific, technological and industrial levels.

Lessons learned

The design of the sub-component as reflected in the activities included in the Appraisal Report did not foresee the publication of the results of the study undertaken by the national teams of experts. Nevertheless, the publication turned out to be very important to orient the activities and the programs to be included as part of the other project subcomponents as well as to disseminate information to sisal stakeholders from an early stage of the project.

The fact, however, that the publication was not explicitly included in the Appraisal Report contributed to the delay in publication as a proposal had to be submitted and approved by the PCC. The design and formulation of future projects should always include funds to consolidate the review of literature and current practices in one document. This will facilitate the decision-making and the implementation process.

Conclusions and recommendations

The objective of sub-component A.1 was fully achieved, despite some delays in its implementation. The sub component outputs were produced as originally envisaged in the Appraisal Report.

Besides the planned outputs, an additional output was also produced, the Technical Paper, which is an important means of disseminating project results and a good source of information for future research and development activities at the scientific, technological and industrial levels.

The funds allocated to A.1 in the Appraisal Report were appropriate for implementation of the original activities and covered also the production and dissemination of the Technical Paper. The design and formulation of future projects in which literature and current practice reviews are included, should allocate funds to publish the results of the reviews.

Sub-component A.3: Variety trials in estates

This project sub component developed its activities in Kenya and in Tanzania under the specific characteristics of the sisal plantations in both countries

Part One: Kenya

Summary

Organized sisal research in Kenya was interrupted in 1972 before concluding the research work on hybrids including H 1155, 1269, 1300, 1475, 1660, 6064, 7131 and 11648, selected from a series of crosses made at the Agricultural Research Institute (ARI) at Mlingano. The above led to a loss of most of the crosses obtained in Kenya, but farmers involved in field trials, kept and multiplied a few promising clones including hybrids 11648 and 1300 which they later grew commercially in their estates. Most of the research information and data collected previously was also left unattended and with the final closure of the High Level Sisal Research Station at Thika almost all the information was lost. In spite of this unfortunate loss however, it was found that bits and pieces of research information, maintained in various libraries and data banks including KARI, Ministry of Agriculture, Kenya Sisal Board, and sisal estates, formed a valuable foundation from which existing knowledge about sisal could be re-built and extended.

The need to build on existing knowledge, to select varieties for pulp, and to expand varieties available for traditional uses was identified as one of the major strategies to generate improved sisal production in the short run.

Consequently, a sisal variety trial was conducted in three agro-ecological zones where sisal is commercially grown in Kenya, representing high, mid and low altitude areas, to evaluate the performance of the existing Sisal varieties and clones. The trials were conducted in Nakuru (1,200 – 1,500 Metres above sea level - MASL), Kibwezi (900 MASL) and Malindi (0 - 20 MASL). The trials were designed in a completely randomized block design with four replicates and *Agave Sisalana*, *Agave Hildana*, H. 11648, and H. 1300 as treatments. Data on growth, fibre yield and pulping was continuously taken and analyzed.

Results show that Kibwezi (Mid altitude zone) recorded the best performance for all varieties, followed by Nakuru and lastly Malindi.

Hybrid 11648 was the highest producer of fibre yield in all sites followed by hybrid 1300, *Hildana* and the *Agave Sisalana*.

Rainfall was the most critical climatic factor affecting leaf production and consequently fibre yield.

Leaf width and leaf productivity per unit of time were found to be the most critical plant characteristics influencing fibre productivity. The wider the leaf, the higher the fibre yield while the higher the number of leaves produced per plant per month, the higher the fibre productivity.

Malindi recorded the highest disease and pest problems, followed by Kibwezi and lastly Nakuru.

Sisal weevil was the most troublesome pest, while soft and dry bole rot were the most severe disease problems.

Hybrids 11648, 1300, Mlola 487, ML1 and *Agave Sisalana* were most susceptible to weevil and diseases.

Agave Sisalana and *Agave Hildana* simultaneously produced poles from suckers at the time of flowering in all sites, confirming the possibility of the existence of variability in suckers.

Pulping and pulping tests carried out on all the varieties, showed that, Hildana and *Agave Sisalana* recorded higher pulp yield and strength in Nakuru in the first to fourth harvests. *Agave Sisalana* also performed better at Kibwezi in the first to fourth harvests. At Nakuru, *Agave Sisalana* recorded higher breaking length and burst strength in the later stages.

Generally *Agave Sisalana* and *Agave Hildana* appeared to perform better in terms of combined pulp yield and strength throughout the experiment compared to H. 11648 and H1300.

For pulping purposes, the current results indicate that *Agave Sisalana* and Hildana could be considered better varieties when grown at Nakuru while *Agave Sisalana* is the best at Kibwezi. However, the tests did not give a consistent trend most probably due to different conditions of the first and second tests. It is recommended to conduct confirmatory pulping and pulping tests in uniform conditions and procedures.

Lessons learned

The objective of sub-component A.3 was fully achieved, despite some delays in implementation, and the outputs were produced as originally envisaged in the Appraisal Report.

Conclusions and recommendations

The trials were conducted at similar conditions to those at which farmers in respective areas grow commercial sisal. The only major variation was the spacing, spatial arrangements and that the trials were kept completely weed free by hand weeding throughout the trial duration. The trials were planted using single row method with spacing of 2.5 meters between rows and 1.25 meters between plants. This gave a plant density of 3,200 plants per hectare compared to 3,333 plants/hectare done by farmers in double rows. Disease and pest control was done following the conventional recommendations but the routine was strictly followed.

With the exception of Malindi trials, the costs of the variety trials (USD/ha) were lower than the estates costs, if fencing, enumerator and caretaker are not considered.

The average fibre productivity per hectare in the estates currently lies between 0.5 – 1.5 MT/Ha where the latter is realized in the best-managed estates. The experiments demonstrated that with application of better agronomic practices, it is possible to increase production per hectare considerably. At Kibwezi, all the varieties recorded more than 2.5 MT/Ha, while Hybrid 11648 recorded an average of 5.32 MT/Ha.

With no fertilizers applied, this production confirmed that a high level of management, application and maintenance of sound agronomic practices could considerably enhance sisal production. The main variation from the normal farmers' practice was that the plants were planted in single rows with more space between plants, the trials were kept completely weed free, old and drying leaves were removed routinely. These practices reduced the competition for nutrients and moisture as much as possible. During harvesting a certain optimum number of leaves (not over cut) was left on the plant to ensure adequate photosynthetic surface, and enough leaf surface area for trapping and collection of moisture from even the slightest shower.

It was noticed in all sites that *Agave Sisalana* which has a sparse leaf formation suffered more from moisture stress and made the situation worse by drooping leaves backwards and hence directing any trapped moisture further away from the plant base. Hybrids 11648 and 1300, which have a dense leaf formation, trapped moisture and directed it to the base of the plant.

It is suspected that the lower yields at Nakuru and Malindi are strictly related to soil fertility status. For example at Malindi where yields were poorest, the soils were very low in Nitrogen, Potassium, organic Carbon, Magnesium and Zinc.

All varieties performed best at Kibwezi followed by Nakuru and lastly Malindi.

Hybrid 11648 performed best of all the varieties in all the sites followed by Hybrid 1300, *Agave Hildana* and then *Agave Sisalana.*

Hybrids 11648 and 1300 were more susceptible to diseases and pests particularly bole rots and weevil damage. Malindi was the worst site in this respect followed by Kibwezi. Nakuru recorded negligible disease and pest problems apart from sun scotch in the early stages of growth.

The main determinants of fibre yield were the number of leaves harvested per harvest, leaf fibre content, leaf width. Leaf length had the least effect. This indicates that for selection of high performing clones the parameters to look for include mainly the number of leaves produced per unit of time, leaf width, and the average leaf fibre content.

Rainfall was the most critical factor affecting leaf production particularly distribution.

It was observed that during poling, *Agave Sisalana* and *Agave Hildana* simultaneously produced poles from suckers. This phenomenon was also observed in other Agave species in the field. It was also observed that in old hybrid 11648 fields plants with variegated suckers were common, while some large plants were still growing long after the field was cut out. In an abandoned *Agave Hildana* field, vigorous plants were found still growing in thick bush growing up to three meters high. Observations were also made of *Agave Angustifolia* and Hybrid 11648 plants producing both albino and normal bulbils from the same pole. Since suckers and bulbils are vegetatively produced these observations indicate that there is variability in the bulbils and suckers produced by Agave plants, which could explain the farmers' fears that the sisal plantations have changed over time.

This phenomenon requires further study to ensure that any superior Agave varieties developed are maintained for longer periods

Sub-component A.3: Variety trials in estates

Part Two: Tanzania

Summary

The project benefiting from a number of recommendations resulting from the complete review of the literature on sisal in East Africa, and the April 1998 workshop, designed the COAID Enhanced Production System for Sisal (CEPS) for producing sisal in an integrated approach with pulp mill operation. This CEPS production system became the central issue for A.3 in Tanzania and was developed at Katani Hale Estate. CEPS trials aimed at confirming and demonstrating the new sisal agriculture production system. The validity of the information would naturally be more reliable if it could be confirmed through a scientifically designed and managed trial considering the most important factors: planting density, variety, and date of total defoliation. As such, a 3-factor variety trial was designed for implementation at the Agricultural Research Institute (ARI) at Mlingano. The results achieved in this trial would help explain the observations obtained in the CEPS trials. Unfortunately the results obtained in the 3-factor variety trials did not meet the expectations, as for management reasons it was difficult to utilize the results provided in a constructive way and to compare them with the CEPS results.

Apart from improving yield and quality through improved nursery and cultivation practices, the sub-component research activities also included soil fertility management trials (implemented at Gomba Estate by ARI, Mlingano), enhanced nursery trials, ultra high density trials and selective leaf defoliation trials (these were developed at Hale Estate). The results obtained, in particular, from the CEPS trials are very encouraging.

Besides the agricultural results obtained as such, an important contribution to the project was the definition of production costs; these were used as an input in the feasibility analysis for a fibre extraction (FEX) plant (sub-component C.1).

Samples of the trials (both CEPS and 3-factor) were pulped and the pulp was tested. The results from these tests are included in the report for sub-component C.2.

Lessons learned

As for other sub-components, changes and adjustments were necessary during implementation in order to meet the main objective of improving planting material to produce sisal fibre at competitive prices for both the traditional and the pulp and paper market. In particular it was set as target for CEPS trials the production of sisal pulping fibre at about US$ 100 per MT. The CEPS trials were made large enough to simulate commercial scale application and therefore the related costs.

Because of many factors related to unavailability of resources or of timely funding, some interventions were either inadequately conducted or not done on time. This is clearly reflected in the performance of the trials as well as in the efficiency in the use of the funds. Nevertheless it was possible to estimate the costs involved in the different phases (nursery – field) to demonstrate the adequacy of the CEPS program to be used in the feasibility analysis for a Fibre Extraction Plant.

With respect to the fertilizer trials at Gomba, it should be noted that the bulk nature of lime and sisal waste causes higher transport costs, which is a major limitation for their application in sisal fields. Mining activities (removing of sisal waste from the collecting pit) of sisal waste and its application also is a major problem for its application. The industry should therefore look for alternative equipment for application of sisal waste. The system used at Rea Vipingo in Kenya, where excavators and muck spreaders are used in mining and spreading of the waste in the sisal field, needs to be further evaluated.

The advantages of sisal waste application include its high content of nitrogen, improvement of soil structure and water holding capacity. Similarly planting of cover crops between the broad lanes should be encouraged to improve soil fertility (soil nitrogen and organic matter improvement.)

Application of cover crops in sisal plantations has not been adopted. Research for other cover crops, beside tropical kudzu, which can be consumed as food, are likely to be adopted particularly by smallholder sisal growers to improve soil nitrogen and organic matter. Gomba sisal estate has started using Dolichos lablab (Fiwi), which is consumed or sold for making biscuits. Such cover crops can significantly reduce the production costs and improve the soil fertility status for sisal production.

The deficiencies in managerial approach towards the project objectives and activities at the ARI Mlingano institution affected the performance of the 3-factor trials, the data collection and data exchange with the national and international agronomists. The fertilizer trials also experienced, to a certain extent, the same problem.

Consequently, an integrated and comprehensive review of the results achieved in the CEPS trials, 3-factor trials and fertilizer trials was not possible. In terms of cost reduction, the information utilized to perform the feasibility analysis was obtained from the CEPS trials only.

The implementation arrangements with Katani Ltd. for the CEPS trails proved to be satisfactory, despite the fact that because of delays in reporting that caused unavailability of resources or of timely funding, some interventions were either inadequately conducted or not done on time.

Conclusions and recommendations

At higher plant densities, due to competition for available space and nutrients, plants tend to produce fewer leaves than at lower densities. Similarly at higher densities plants tend to be shorter due to competition for moisture and nutrients.

In this study the third harvesting period (48 months after planting) produced more total biomass than the first and second harvesting time (42 months after planting). This implies that the longer the plants stay in the field the more they tend to increase both in size and weight.

Hybrid 11648 is susceptible to bole rot, zebra disease and KLS disease while *Agave. Sisalana* and *Agave Hildana* are resistant to the above diseases. These observations have been experienced as reported in previous studies. However all varieties were equally affected by sisal weevil particularly during the first two years which called for integrated sisal weevil control at immature stage.

Since pulping tests have indicated lower costs in terms of chemicals when using fibre from the leaves, it is important that farmers concentrate on selective leaf harvesting as opposed to whole plant harvesting as earlier envisaged. However pulping studies to optimize pulp yield from the boles should be undertaken to increase total utilization of the sisal plant.

Sub-component A.4: Evaluation of Smallholder Farming System

Summary

The smallholder/outgrower scheme has recorded good progress with nine estates showing interest and seven having planted a total of 1,811 hectares by December 2004. In this scheme 2,485 families have 21,070 hectares allocated. The scheme created potential employment opportunities for more than 7,000 people. Smallholders were able to grow sisal and food crops on the same land using the same labour. The smallholder scheme in estates has similarities with the Mexican and Chinese smallholder schemes. In the Mara Region 48 hectares were planted involving 76 farmers. This created more than 500 employment opportunities. This has similarities with the smallholder scheme in Brazil. The project monitored the Mara Region Farmers Initiative Project (Mara FIP) financed by the International Fund for Agricultural Development (IFAD).

The adoption of the scheme has reduced production costs since land preparation costs and field maintenance costs are much lower. The scheme has created commercial farmers out of peasant farmers and spread the benefits to many more people than before. Appropriate technologies for fibre extraction were developed for Mara Region and proved quite suitable. Four mobile decorticators made locally were delivered to Mara Region and there is demand for more. This has increased efficiency. In organizing the production process farmers were trained on sisal husbandry, encouraged to form groups/primary cooperative societies, savings and credit societies. The response was good but continued evaluation was necessary.

Lessons learned

Development lessons

The original project design was modified to include sub-component A.6, Mara Region activities, which were not foreseen in the Appraisal Report. The sub-component proved very effective in contributing to alleviate poverty within the farmers' community.

Operational lessons

From the experience gained and from the arguments presented during the project final dissemination workshop in November 2004, it is evident that the smallholder and outgrower farmers in the Estates and in Mara Region need title to the land where they are growing sisal. This will widen ownership and contribute to poverty eradication in the rural areas where all the sisal estates are located.

The scheme is already contributing to increased employment opportunities in the rural areas and thus reducing migration to urban centres. The scheme has contributed to food production and increased farmers' incomes and reduced sisal and food production costs. As the income of the farmers increases, the central and local government levies will also increase, thus enabling them to provide services to the economic infrastructure in a more efficient manner.

In organizing the farmers, cooperative groups have been formed to enhance the cooperative spirit and mobilize savings for investment and economic development. Plans are underway to make farmers shareholders in the processing units thus widening ownership further and ensuring that farmers get all the benefits arising from technological improvements and increased demand. Katani Limited has handed over all mature sisal areas to smallholders. Tanzania Sisal Board will henceforth hold the master lease for estate land excluding built up and factory areas, and each smallholder will hold a sub-lease for the land allocated to him/her. Increased production and lower costs of production will make the sisal industry more vibrant and more competitive in the market place.

The scheme has significantly reduced fire outbreaks affecting all estates in the sisal industry, for example in 1999 Katani Ltd. lost 1,000 hectares valued at TZS 450,000,000 (US$ 600,000) through fires.

Projected earnings to smallholders in Katani Limited from 2005 to 2015 are US$ 31 million. By the end of December 2004 smallholder farmers had invested the equivalent of US$ 637,294 in planting and maintaining the 1811 hectares allocated to them.

The following are the key lessons learnt during the implementation process:

1. Capacity building through participatory approaches and training are necessary for success.
2. There exists a great potential in self-help development, which could bring faster development and cost effectiveness.
3. A multidisciplinary approach is necessary for successful development of new ideas.
4. The commitment and full cooperation of political leaders is necessary for smooth implementation.
5. Development financial institutions are crucial but are lacking in Tanzania and need to be established urgently. Agricultural loans at affordable interest rates are required for the revival of the sisal industry. Commercial financial institutions in Tanzania are cautious in financing agriculture due to its dependence on rains. Sisal can survive with little rain but very few people know this.
6. Ownership must be clearly spelt out from the beginning and beneficiaries should contribute in the form of labour, materials and cash for project sustainability.
7. Successful implementation takes time and promoters need patience and close follow up.
8. Sisal has proved it is indeed an insurance crop as when weather conditions were adverse, farmers survived on the proceeds from sisal.
9. Wood fuel is still by far the largest source of energy in the rural areas and the development of small biogas plants will contribute significantly to improving women's access to labour-saving technologies, health and the environment. Less than 10% of the Tanzanian population is connected to electricity and alternative sources of energy using agricultural waste are in great demand.

10. Subsidies and incentives in the form of reduced taxes, exchange rates, costs of diesel, power and employment are required in promoting new ideas.

Conclusions and recommendations

Most crops in Tanzania have received soft loans and grants from the Government and donors amounting to billions for their revival and increased production. Such assistance has been extended to coffee, tea, cotton, cashew nuts and other crops. Sisal is the only crop where Tanzania has excelled internationally and despite its decline, the country can re-attain its position much more quickly if the Government increased moral and financial support to smallholder sisal farmers. The Government has declared its intention to support the industry. In April 2004, the Regional Commissioner met with sisal stakeholders in Tanga Region. Resulting from this meeting a Task Force was set up to chart out the quick revival of the industry and identify problems requiring Government intervention. The first report has been submitted.

Financial assistance is required as a package covering the following areas:

1. Soft loans to sisal smallholder and outgrower farmers as well as large-scale farmers in land preparation, procurement of seeds, maintenance of sisal fields, procurement of farm tractors and tools/equipment for cultivation and transport.
2. Affordable loans for processing factories so as to increase their demand for fibre and increase the utilization of the sisal plant to add value to sisal.
3. Financial assistance for training and for research on and development of new products.
4. Assistance for promotion and expansion of markets for sisal products in the local markets, East African Community markets, SADC, Middle East and Far East markets.
5. Put in place policies, which attract investments in sisal growing and processing.
6. Establish savings and credit societies leading to establishment of a Sisal Bank.

It is further recommended that efforts be continued in fostering self-driven initiatives among farmers by strengthening the cooperative groups, providing legal status, providing education to the groups on participatory planning, monitoring, evaluation and organization.

Sub-component A.5: Multiplying Sisal by Meristematic Tissue Culture

This project sub component developed its activities both in Tanzania and Kenya adjusted to the specific characteristics of the sisal industry in both countries

Part one: – Kenya

Summary

Sisal breeding research in East Africa was initiated in 1931. The aim was to develop high yielding, good fibre quality that was hardy and also easy and cheap to grow. From the efforts of selection and crossbreeding, several varieties were commercialized including *Agave Sisalana, 1300*, hybrid 11648, *Agave Hildana* etc. As a result of the discontinuation of research in Kenya in 1972, with the closure of the Kenya high-level sisal research station Thika, and lack of funding for sisal research in the Mlingano research station based in the Tanga province in Tanzania, the sisal crop has witnessed a deterioration of existing varieties due to segregation and other factors. Fortunately within the estates where farmers have been maintaining the varieties they have observed some plants that are vigorous and out-yield the others. Bulking such plants using the conventional systems of planting sucker and bulbils has not been very successful due to mix-up of low- and high-yielding bulbils/suckers in an uncontrolled manner. In addition it has not been possible to follow up the outstanding accessions.

The tissue culture multiplication component of the Project "Product and Market Development of Sisal and Henequen Products" aimed at identifying such plants and at multiplying them rapidly, in order to increase the production of sisal in East Africa and, at the same time, develop efficient *in vitro* multiplication techniques for sisal.

The project also aimed at building the capacity of local personnel in the field of sisal biotechnology as well as at improving laboratory facilities and furbishing them properly (equipment, chemicals, consumables).

Refinement of the media and *in vitro* growth conditions for Agave species (spp) was undertaken. Results from field transferred tissue culture collected at Teita Estates, Mwatate in the Coastal province revealed that tissue culture derived plants were superior to plants raised from bulbils in respect to: leaf unraffling, increase of plant height, diameter of leaf growth and in total biomass production. Results of the initial trials have interested commercial growers of sisal to try tissue culture raised plants and compare them with those from traditional propagules including bulbils, suckers and rhizomes.

The performance of the laboratory was considered satisfactory, even though at the end of the project KEPHIS was still not in the position to deliver MTC (meristematic tissue culture) plants at industrial scale. Nevertheless, the staff were trained and showed the commitment and the capacities required to meet this goal in the near future, with the economic support of the Kenyan Government, through the Kenya Sisal Board (KSB). More training in scientific and technical report writing would

have been beneficial, as the quality of the reports does not adequately reflect the work done.

Lessons learned

The KEPHIS laboratory in Kenya performed very well, despite the numerous drawbacks (like the loss of large quantities of green material during the renovation works) and the limited financial resources available..

Nevertheless during project implementation the laboratory could not prove to be able to delivery MTC plants in quantities sufficient to meet the demand of the sisal estates in Kenya. It is foreseen that this will be possible in the future, if the Government will keep supporting the laboratory through the KSB and the estates establish partnership agreements with KEPHIS.

The international expert provided guidance to the technicians and to the laboratory manager through formal and hands-on training that proved to be effective. More coordination with and/or the selection of a better contractor would have avoided the contamination occurred during the renovation works.

Conclusions and Recommendations

The sisal tissue culture as an effective, efficient means of checking the production of leaf yields of all sisal genotypes has been demonstrated by the preliminary trials. However it is necessary that the tissue culture plants be followed up throughout the productive life span of the crop. This will help answer questions like whether the performance can be sustained, how the tissue culture plants perform under pest pressure in the field, and how much suckers from tissue culture plants from pre-nurseries and multiplication fields can contribute to build-up of biomass in order to reduce production costs.

1. The follow-up of field trials and collection of other plants from the fields was slowed down by transportation constraints; timely supervision of operations should be allowed.

2. The financial support of the Kenyan Government, through the KSB is vital to allow the laboratory's delivery of MTC plants to the industry; KSB role is crucial to maintain close cooperation with the estates.

Subcomponent A.5: Multiplying sisal by Meristematic Tissue Culture

Part Two: Tanzania

Summary

Many cultivated agaves are sterile clones, sometimes polyploidy that rarely produce viable seeds. Sisal (*Agave Sisalana*) is a perennial monocarpic plant that flowers once and then the plant dies. The plant is mainly propagated vegetatively through bulbils, suckers and rhizomes. Rhizomes are difficult to trace underground and they are labour demanding. Suckers are produced throughout the plant's life span but the best ones are those produced during the first two to three years. Suckers need grading before they are transplanted, and if this is not done properly, the plants lack growth uniformity which leads to difficult field operations like leaf cutting and early poling which translates to low yields and poor productivity of the industry as a whole. Bulbils provide the highest quality planting material but these are produced only once when the plant flowers at 8-10 years. Bulbils require to be raised in a nursery for about 18 months before they are transplanted to the field. Establishment of a bulbil nursery is one of the most costly undertakings in sisal cultivation for both the estate growers and the smallholders.

Lack of good planting material at a reasonable price in the sisal industry is associated with the long life cycle of the sisal crop to produce bulbils and with costly nursery management. It is in this context that the need for multiplying sisal by meristematic tissue culture (MTC) became a vital project activity. Micropropagation techniques have the advantage of quickly multiplying large numbers of uniform clonal plantlets, with high survival rates, growth vigour and genetically pure progenies. Micropropagation of sisal commercial cultivars is anticipated to play a vital role in providing good quality planting material, which can restore the production of the sisal industry in Tanzania. Another reason to apply modern biotechnologies to sisal in the framework of this project was the fact that the original project idea was to harvest the pre-flowering whole plant for the extraction of pulpable fibre eliminating with that the possibilities of having bulbils and consequently reducing the amount of potential plant material for plantation expansion.

After extensive refurbishment works of the laboratory and of the green house (1998-1999), the MTC laboratory facility was established at Mlingano in August 2000 with the objective of multiplying promising sisal cultivars by MTC in order to promote the production of standard planting material and shorten the time needed by breeders to produce new varieties for commercial production.

The project outputs were set to provide a definition of a MTC protocol for the commercial cultivars, to produce a technical manual for the wide application of the protocol and to produce and supply new planting materials throughout the sisal industry. The sisal industry, through the Tanzania Sisal Board (TSB) provided counterpart funding.

Commercial cultivars that were used in the tissue culture laboratory were: *Agave Sisalana* L, *Agave Hildana*, ML 487 and Hybrid 11648, and the non-commercial *Agave Amaniensis*. According to the laboratory staff, for the period 2000 - 2004 a total of 21,000 explants have been put in induction utilizing the same procedure developed and applied at the "Centro de Investigación Científica de Yucatán (CICY)" for henequen.

The five varieties responded differently *in vitro*, with *Agave Amaniensis* outperforming the others in terms of time taken for induction and number of shoots produced per explant. The hybrid Mlola (ML) 487 had to be abandoned because of the poor response in induction. By September 2004 about 12,940 shoots had been produced, out of which 7,180 were in open nurseries at Mlingano and Kisangata estate; in the green house there were 4,435 shoots and 1,326 were *in vitro*.

Major set backs were the following: insufficient staff training and experience, fungal and bacterial contamination, phenolic oxidation, vitrification, low shooting in initiation and frequent power cuts. The problem of fungal and bacterial contamination was seriously tackled and at the end it was reduced to 5% thanks to the improvement of surface sterilization and to the utilization of antibiotics. Selecting young and healthy mother plants reduced phenolic oxidation. Shoot vitrification was low in the three commercial cultivars of Hybrid 11648, *Agave Sisalana* and *Hildana* while at the beginning it was rather high in *Agave Amaniensis*. As a solution the hormone benzyl amino purine (BAP) was applied to *Agave Sisalana* first at 12.5 mg/l and then at 10 mg/l. By using the later concentration, shoot vitrification was contained.

Cutting experiments to culture from axillary buds produced more shoots than culturing from meristem tip. Experiments into the effect of hormones and nitrogen balance were carried out but preliminary results achieved so far have not indicated the effective concentration to utilize. However, in order to monitor the trend, more time is needed to repeat the experiments before conclusions can be drawn.

Adequate equipment and chemicals for the laboratory were procured by the project and counterpart contribution was provided by TSB. Capacity building of laboratory staff was done through short courses, exchange visits and during the visits of the international expert. However, more training activities should be undertaken.

The performance of the laboratory was evaluated as limited. Little commitment was shown by the management and by the staff of ARI Mlingano, despite the many efforts undertaken by project stakeholders to improve the laboratory performance. The reports prepared were very poor and the reliability of the data and information provided is questionable. Many contradictions and inconsistencies have been found in the reports prepared by the laboratory staff and in general terms, the explanations provided did not satisfy the expectations of the project. The information included in this final report has been put together in the best possible way, but the scientific value of the provided data is questionable and should be verified. Despite the commitment of the Government to take actions, the management of the laboratory remained unchanged during the project implementation period. It is hoped that, in the future, improvements will be possible as the fully equipped MTC laboratory is available and the improved performance of trained staff would certainly allow for delivery of tangible results in sisal MTC in Tanzania.

Lessons learned

The performance of the ARI Mlingano laboratory was evaluated as limited. Little commitment was shown by the management and by the staff of ARI Mlingano, despite the many efforts undertaken by the project stakeholders to improve the laboratory staff performance.

During project implementation different actions were taken to resolve the issue, without any success especially because the promised change in the laboratory management never materialized. Lastly an exceptional National Coordinating Committee (NCC) Meeting was held on 15 July 2004 and it was decided to take away from ARI Mlingano the management of the MTC Laboratory. The responsibility of the laboratory was given to the Tanzania Sisal Board (TSB). It was also suggested to relocate the laboratory to a different institution, but the alternative was not feasible in the time scale given. The Director General of TSB was asked to set up a management structure that would turn round the laboratory in the shortest time possible.

The laboratory is fully equipped and staff is trained, so under an improved management it is foreseen that good results would be achieved for the benefit of the sisal industry.

According to the laboratory the following problems were encountered:

Training

The training program was insufficient taking into consideration that Mlingano staff had no practical experience at all in tissue culture or any biotechnological activity. The training could have been supplemented by more exchange visits to Kenya but these were also given very low priority. Short-term training in biotechnology laboratories would have also assisted Mlingano staff to solve the operational problems encountered during the project period.

Technical consultancy

The consultation period, especially for local consultancy, was insufficient. It is found that local consultancy was stopped, following the advice of the international consultant, a bit too early. Local consultancy was necessary to complement the efforts of the international consultant from CICY.

Low shoot initiation from induction and multiplication

Low shoot initiation has been a persistent set back at Mlingano laboratory. However, the experience gained with the cutting experiment proved that that A. Sisalana, A. Hildana and H. 11648 initiate better from axillary buds than from meristem tips. Also it has been learnt that plant tissues away from the meristem tip have higher concentration of microbial contaminants than the meristem tip. Partly, this is due to a long time stay in the soil, so this has posed a great challenge on the success of the shoot production using axillary buds.

Contamination

The problem of fungal contamination has been a great issue, especially at the outset of the project. However it was greatly reduced after utilization of different sterilization techniques, experience in seasonal collection of mother plants and identification of areas with low concentration of innoculums of fungal diseases.

Power

For the whole project time Mlingano has experienced irregular power supply due to rationing and faulty power line. The stand-by generator could not be run continuously due to limited supply of fuel. The problem of electricity supply to the institute has greatly affected supply of light in the growth rooms and frustrated efforts to culture more, hence the total output of the laboratory at Mlingano.

Quality of material produced

There has not been enough time to assess the quality of the material produced, as the plants are still at nursery stage. However, initial measurements of growth parameters, such as plant height, leaf number, and leaf length for the hybrid at Mlingano indicate the tissue cultured plants are growing better than the normal bulbils.

Conclusions and recommendations

According to the experience gained in 4 years of operations, the best mother plants are from fields less than three years old or one year old nursery plants. Suckers from old fields mostly get phenolic oxidation. Observations indicate that the concentration of BAP are effective at rates between 10 -15 mg/l. The levels of 2,4-D used are 0.025mg/l for all stages except rooting, where 11mg/l IBA was used. Growth was better in media without hormones. The optimal initiating condition for the explants was a light/darkness regime of 16/8-hour.

In terms of variations of each species or variety it can be concluded that the three agaves Hybrid 11648, *Agave Sisalana* and *Agave Hildana* behave differently in induction under the same conditions of light, temperature and humidity. Cubes were taken from the upper part only (meristem tip). *Agave Sisalana* outperformed the other two in the early trials but later on, after gaining experience in extracting the meristematic parts, H.11648 performed better than A. Sisalana and A. Hildana, with more than 50% initiated shoots. A. Hildana has been the poorest performer, but successful cubes produce 6-8 shoots per cube. In the three varieties shooting was between 4-12 weeks, while A. Amaniensis was the best with two parts shooting within eight weeks.

The project output included the definition of a meristematic tissue culture technique for sisal and production of a technical manual for its application and production of new plants through the new system. More time is required to carry out experiments to analyze the efficiency of the process, as the available information is not enough to come out with a technical manual/protocol for mass production of sisal varieties plants through tissue culture by Mlingano staff. The ongoing experiments need to be finalized and the results should be included in the manual/protocol (that should have been prepared by ARI Mlingano as one of the sub-component outputs).

The project published the Technical Paper No. 38 *"MANUAL FOR THE IN VITRO CULTURE OF AGAVES"* to disseminate the acquired experiences in this field.

More time is required to repeat the experiments so as to check the reproducibility of results that will lead to a reliable and well-defined tissue culture protocol. More financial support is needed to complete the process of defining the protocol, staff capability building, writing the technical manual and the technology transfer process.

Large-scale production is proposed to be an output of a technology transfer process after the procedure of micro propagating the local commercial cultivars is defined. The laboratory will be expected to produce enough biomass for establishing nurseries in estates depending on availability of funds from the industry and/or government

A draft business plan for sisal research in Tanzania, including the MTC laboratory activities has been prepared and distributed to relevant stakeholders for comments. When finalized and approved, the plan is expected to contribute to create the basis for massive MTC of agaves in Tanzania.

It is the opinion of the PEA that radical changes at the management level are required in order for the MTC laboratory at ARI, Mlingano, to deliver the same results as in Kenya by KEPHIS and subsequently to provide MTC plants to meet industry demand.

Sub-component B.1: Improved Flume Tow Recovery System

This project sub component developed its activities both in Tanzania and Kenya adjusted to the specific characteristics of the sisal industry in both countries

Summary

The waste produced in sisal line fibre extraction includes short fibres known as "flume tow"; small quantities of the flume tow are recovered manually, while most of it is dumped in the land together with the other components of the decorticator waste.

One of the issues included in the line of action to achieve the goal for market expansion is the valorization of wastes to increase the value-added of sisal plant and reduce pollution. The development of an efficient system for the recovery of the flume tow was considered necessary and the sub-component B.1 was conceived to address this issue. Two operational flume tow recovery plants were constructed and installed, one in Kenya (at Rea-Vipingo plantation) and one in Tanzania (at Kwaraguru estate).

A flume tow recovery plant includes the following basic equipment: conveyors (or elevator) to lift the waste, a squeezer to remove water, and a rotary screen (or cage) to separate the flume tow from the parenchyma. Different trials were performed with the two plants, in Kenya the production of flume tow ranged from 28 Kg/hour to 47 Kg/hour while in Tanzania it was, on average, 45.44 Kg/hour. The lower yields of flume tow obtained at Rea-Vipingo indicate better mechanical conditions of the decorticator compared to the ones of the decorticator at Kwaraguru.

A preliminary economic study performed with the two plants indicates that even though the flume tow recovery system is mechanically successful and produces the expected output, it is not, however, viable economically as it is now. The low selling price of the flume tow does not represent any sustainable improvement to the profitability of the sisal fibre extraction.

Lessons learned

Recovering flume tow: an economic evaluation

Kenya

According to the economic evaluation that was done in Kenya, drying and handling labour costs and electricity costs represent approximately 80% of the costs of production. Three different approaches were considered while trying to reduce costs. The lowest production cost (cost to run the recovery plant, dry the flume tow and prepare it for sale) achieved was KES 12.85 per kilogram. This was not acceptable as the market price at the time of the project (2001) was about US$ 200 per tonne, or approximately KES 14 per kilogram.
The manufacturing and assembling costs, including taxes and labour, totaled US$ 25,978.

Tanzania

The flume tow recovery plant was test run and all the components constituting the plant were closely inspected for performance. Designed speeds were met. Test data were collected on flume tow recovery. An average of 45.44kg per hour of sun dried flume tow could be recovered giving about 454 kg per shift. This cost about TZS 37,527 per tonne, collected and ready to sell (no carding was performed at Kwàraguru).

A current market price of about TZS 50,000 per tonne gives a margin of profit of TZS 12,473 per tonne.

The manufacturing and assembling costs, including taxes and labour, totaled US$ 23,020.

Flume tow production costs in Kenya and in Tanzania

	KWARAGURU 2004		REA VIPINGO 2001	
	TZS/kg	**US$/ tonne**	**US$/ tonne**	**KES /kg**
Drying and handling labour	11.86	11.29	67.33	5.05
Recovery plant labour	12.56	11.96	13.33	1.00
Carding machine labour	none	none	13.33	1.00
Baling press labour	3.56	3.39	3.33	0.25
Electricity costs	5.16	4.91	68.00	5.10
Baling materials cost	4.40	4.19	6.00	0.45
TOTAL COST	**35.42**	**35.74**	**171.32**	**12.85**
Price US$/tonne ex-factory		**47.62**	**200**	
Net profit US$/tonne ex-factory		**11.88**	**28.68**	

Note: All dollar conversions used are as at the end of 2004:
1 USD = 1050 TZS = 75 KES

Development lessons

The required system as per specifications was designed, fabricated, installed, and tested at the two estates in Kenya and in Tanzania. The implementation of sub-component B.1 activities followed the Appraisal Report, with the exception that the flume tow was not evaluated for pulping. The dirty brown colour of the flume tow and the parenchyma content makes the fibre not suitable for pulping, especially in Tanzania where carding was not done and the hammer mill proved to deliver much better fibre more efficiently.

The plant seems to remove enough suspended solids to make the effluent suitable for feeding the biogas plant, even though a screw separator is foreseen before the biogas plant inlet tank.

Operational lessons

The implementation arrangements proved to be satisfactory. The implementation in Tanzania experienced many delays, partially due to the contractor internal organization and partially to the changes in project location.

Since the location of the biogas plant will be changed, the flume tow recovery plant will have to be moved from Kwaraguru to a new estate.

Conclusions and recommendations

Kenya

The length of the leaf that is related with the age of the plant influences the percentage of flume tow recovered from the small drum: the shorter younger leaf produces higher losses in the decorticator, hence more flume tow.

The average production capacity of the flume tow recovery plant is 39.51 ± 4.73 kg/hour.

It is important to thin out (for ventilation) the output from the rotary screen before sun drying and to turn it from time to time during drying to avoid fermentation and development of a dirty brown color.

Carding losses are about 5% of the dried flume tow recovered. This operation improves the texture, appearance and color, hence the grade of the product. Sisal growers are encouraged to improve upon the quality of their flume tow to reach one of the higher grades and command better prices.

Drying and handling labor and electricity costs account for approximately 80% of the production costs associated with labor for the various operations, electricity and baling materials only. The lowest cost achieved is KES 12.85/kg of baled flume tow. This cost is very high and does not allow for production, as the market price for this product is approximately US$ 200/tonne or KES 14/kg.

Even though the flume tow recovery system is mechanically successful and produces the expected output, it is not, however, viable economically in its current format.

The recovery of the flume tow perhaps could be more viable economically and environmentally friendly if instead of just collecting the flume tow it could be combined with the utilization of the green matter or flesh in the waste for production of other by-products such as hecogenin, inulin, biogas/electricity, sodium pectate, waxes, etc.

Tanzania

For the duration of the tests, the flume tow recovery plant has demonstrated that it is capable of being used in the recovery of clean flume tow.

Due to low efficiency of the decorticator and inadequate water supply to the decorticator, the waste discharged to the flume tow recovery plant was above expected quantities and was not uniform.

The flume tow recovery system has also demonstrated that it can be used as a primary stage in the separation of mucilage and green flesh, from the rest of the biomass, in quantities, which can be used in the biogas plant. However, because the mucilage still contains, some short fibre, means should be incorporated in the biogas plant to recover traces of short fibre still remaining in the mucilage. Energy from biogas production can be used to generate heat and electricity in order to power the decorticator and flume tow recovery plant

Based on the trials, it is noted that the use of a flume tow recovery system for short fibre extraction is feasible and more efficient than manual extraction and that it gives cleaner flume tow. This clean flume tow may find different uses including that of pulping. However, the parenchyma level depends on the decorticator efficiency. Under low decorticator efficiency some parenchyma still adheres to the flume tow and cannot be separated in the flume tow shaker screen, making it unsuitable for pulp production.

The flume tow recovery plant operates at little profit, and because of the low selling price of the flume tow, is not viable economically as it is now.

Sub-component B.2: Animal Feed Trials

Summary

At the time of project formulation, limited exploration of using boles and decorticated wastes as animal feeds had been undertaken in Kenya and Tanzania, but the results had been encouraging. Therefore, during the design and formulation phases of the project, needs were identified to further refine the bogas (green material in the waste) and to test the effectiveness of feeding fresh and ensiled bogas to dairy and beef cattle, sheep and goats. Sub-component B.2 was conceived to address these needs.

Sub-component B.2 objectives are to develop viable animal feed using boles and bogas and to test their effectiveness through animal feed trials. The expected outputs originally foreseen are as follows: (1) Technical manual on compounding feed rations using sisal waste as main constituent; feed trial results for cattle (beef and dairy), sheep and goats; a technical design of feed machine and equipment; and (2) Feasibility study for animal feed production unit based in sisal waste products.

The target beneficiaries are the animal growers, particularly sisal small holders in drought-prone areas in Africa and other regions.

The activities were sub-contracted to a Kenyan company: Kilifi Plantations Ltd. that was selected through a competitive bidding process. During implementation, the protocol of experiments, prepared following the Appraisal Report, was changed following the recommendations of the International Livestock Research Institute (ILRI) expert.

Despite the consultations conducted before and during the implementation of the trials, the protocol of the experiments was often criticized and the reliability of the results achieved raised many reservations. In particular the negative results obtained with goats were discussed; the diets for goats and sheep need to be revised and a period for acclimatization to adapt to the new diet and to confinement conditions should be allowed.

Fresh and ensiled bogas are suitable for feeding beef steers. The mean values of growth rate were statistically similar for the three diets. Growth rate was 1kg daily, which was expected from the diet offered.

The mean daily dry matter (DM) intake for cows fed bogas was significantly ($P<0.01$) lower than the cows fed control diet and the cows fed bogas were generally weak. This behavior may have been associated with low DM intakes but no conclusion could be substantiated by the data collected. It is recommended that in future studies measurements of live weights and body conditions be included in order to confirm whether DM intakes have an influence on the cows' health and milk production. Further studies are recommended to establish the effect of bogas on rumen fermentation and nutrient metabolism.

The sheep fed the three diets lost weight during the four initial months and started to recover it only after the fifth month. The growth performance of goats on all three diets was also very poor. This observation indicates that sheep and goats are

susceptible to diet changes and confinement. It is recommended that the duration of similar future experiments be extended and the diet revised, as all three diets tested were not optimized and need to be modified and better balanced.

The technical manual on compounding rations using sisal waste was not produced and the financial appraisal needs revision based on the results of new trials, particularly for goats and sheep.

Lessons learned

Results achieved

All experimental animals consumed all the concentrate, which was offered in a separate trough. Left over forage was difficult to quantify due to spillage from the troughs and tramping. It was therefore difficult to determine DM intake. An attempt was made to determine intake for the cows, which had minimal spillage. Live weight data is reported for sheep, goats and steers while DM intake and milk yield is reported for the cows.

Beef steers

The experiments were conducted for 36 weeks (29 September 1999 to 30 June 2000), but results were reported for only 24 weeks. The animals were in good health and none died throughout the experiment. Growth rates were calculated for each animal by linear progression of body weight on week of measurement. The average growth rate was statistically similar between the three groups (7.2 ± 0.2 kg/week) and equivalent to one kilogram daily.

Dairy cows

The experiments were carried out over 33 weeks and during one lactation period only, because the contractor was not able to inseminate the cows as planned.

The mean daily DM intake for cows fed bogas was significantly lower ($P<0.01$) than that of cows fed the control diet. The effect of the diet on live weight and body conditions was not quantified but cows fed bogas were generally weak and this may have been associated to low DM intake. Eight animals suffered from ailments such as abscesses, hind limb and food rot. Of these, six were fed fresh and two ensiled bogas.

The average milk production from cows fed fresh bogas tended to be lower than the production of those on the other two treatments. The 0.5 kg difference in milk production however was not statistically significant ($P>0.05$). The decline in milk yield for each cow was calculated by linear progression of milk yield on week of experiment. Effects of other factors like lactation number, stage of lactation and genotype were also examined but none were found to be significant. Four cows (one from the group fed on ensiled bogas and three from the Control group) did not acclimatize to the experiment and were removed from the trial. This is why the initial daily milk yield per treatment was not similar.

The decline in milk yield per week for the cows fed bogas also tended to be lower than that of cows fed the control diet (0.072 vs. 0.11 kg/day). Over the 33-week experimental period, the cows fed fresh bogas produced less total milk than cows on each of the other diets.

The constraints associated with the use of sisal waste as feed for ruminants relate partly to the organic acids (mainly lactic and oxalic; Preston and Leng, 1987). Naseveen and Harrison, (1981) found that cattle fed sisal waste developed acidosis and barely maintained body weight. Bogas used in the current studies had high lactic and oxalic acids (1 and 5.2% in DM respectively).

Goats

Feed trials were conducted for six months (from 29 September 1999 to 31 March 2000), but results were reported for five months only.

No analysis of variance was conducted because of the high mortality and lack of acclimatization to the experimental conditions. The means were calculated only for initial body weight, final body weight and weight change during the experiment together with their standard errors.

Deaths due to lactic acidosis were caused by the fact that the goats preferred to eat the concentrate first leaving the forage part of the diet. A mixed diet (also for sheep) might have been a better option to avoid this problem. The other major cause of death was starvation and some of the animals that survived refused to eat and hence the losses in live weight. Goats fed on fresh or ensiled bogas lost between 15 and 10% of their initial weight compared to 0.6% weight loss for the control animals.

Sheep

As for the goats feed trials were conducted for six months (from 11 December 1999 to 30 June 2000), but results were reported for five months only.

No analysis of variance was conducted and the means were calculated only for initial body weight, final body weight and weight change during the experiment together with their standard errors. Sheep were not weighed in March 2000. The sheep gained some weight during the last two months and this may be a result of the sheep acclimatizing to the experiments. The control trial presented higher mortality than the other two diets and the number of sheep that died by acidosis was the same in the 3 diets.

The initial weight of sheep fed the control diet was higher than sheep fed other diets. The weight gain for sheep fed control was lower than animals fed other diets. Expressed as a percentage of the initial weight, sheep fed either fresh or ensiled bogas gained 13 and 20% respectively compared to those on the control diet (2%). At the end of the experiment the live weights were similar in the three groups. This seems to indicate that sheep accepted, after an acclimatization period, the bogas diets better than the control one.

Lessons Learned

The first Terms of Reference were based on the specifications included in the project Appraisal Report. These were modified during the first year of implementation, which entailed additional work for the PEA and the counterpart. During the revision of the protocol of experiments with ILRI, Kenya, it was recommended to keep all the animals confined in the same environment to avoid the introduction of external factors that could influence the final results. Additional buildings had to be built for sheltering all animals as the original protocol only envisaged to shelter the animals being fed bogas. This caused some delay in the implementation.

Goats and sheep seemed to be more difficult to acclimatize to confined conditions and the feed trial period for those animals should have included an acclimatization period. Difficulties in the identification of the heat period of the dairy cows might have been caused by confinement.

Despite the consultations conducted before and during the implementation of the trials, the protocol of the experiments was often criticized and the reliability of the results achieved raised many reservations. In particular the negative results obtained with goats were discussed; the diets for goats and sheep needed to be improved and a period for acclimatization to adapt to the new diet and to confinement conditions should have been allowed.

The difficulties experienced were beyond the control of the PEA, the counterpart and the subcontractor; and will have to be taken into consideration in the design of future studies. Therefore, it is recommended that during the design and formulation of similar projects/subcomponents special attention be given to the issues mentioned above in the preparation of the protocol of experiments.

The main lessons learned are:

(i) Experiments with dairy cows should include measurements on DM intake and its influence on the health condition and milk production, as well as studies on the influence of the diet composition in the rumen fermentation and nutrient metabolism;
(ii) The cows selected for the experiments should be at the same lactation stage or in a narrow range;
(iii) A period for the acclimatization of the sheep and goats to the new diets/confined condition should be included in the experiments;
(iv) Diets for sheep and goats need careful evaluation in order to reduce the risk of deaths;
(v) Statistical analysis of the results of the feed trials should be included in the protocol of experiments;
(vi) An international expert in animal feed from sisal waste should join the national team of experts in fine-tuning the protocol and the diet and in defining the relevant statistical analysis to be conducted.

The main difficulties in implementation were related to the technical aspects of the experiments. The implementation arrangements and subcomponent management were appropriate despite the difficulties experienced in recovering the revenues from the sale of the milk and the animals. The difficulties were partially due to the fact that the payment of the last installments of the subcontracts was not related to the sale of the animals and of the milk and partially to the fact that project suffered from changes of the PEA project managers.

A preliminary estimation of the amount to be returned to the project (US$ 29,594) was prepared by the PEA and submitted to the management of Kilifi Plantations Ltd., that proposed a different evaluation (US$ 19,142). The offer from Kilifi Plantations was accepted by UNIDO and CFC and Kilifi managers agreed to transfer the money in four installments.

The technical manual (one of the subcomponent outputs) was not prepared. Even though the final report submitted by the subcontractor (Kilifi Plantations Ltd.) includes information and recommendations about the ensilage method and compounding of rations, this information has not been presented as a manual. Drawings of the recovery system, and of the silage pits characteristics were prepared and are included in the sub component report. The complete feasibility study planned in the Appraisal Report was not prepared either. The contractor final report only presents a simplified financial appraisal based on:

(i) The equipment investment;
(ii) Estimates of some operational costs, namely: depreciation, labor, power and feed costs for dairy cows (30 animals), beef steers (36 animals), goats (42 animals) and sheep (42 animals) and purchase costs of animals, except dairy cows;
(iii) Estimates of the revenues accrued from the sales of sheep and goats each year, beef steers in the second year and milk. The calculations were done for five years and within this period the break-even point was not achieved.

Conclusions and recommendations

Conclusions

- Bogas can be used as an additional source of fodder or as a "replacement' to non-existent fodder during the dry season;
- There was no major difference between fresh and ensiled bogas;
- The studies indicate that the sheep and goats took a long time to acclimatize to all the diets probably due to the mode of presentation and confinement. Acclimatization time should be allowed in future experiments and the diet should be reviewed;
- The steers gained one kilogram daily irrespective of the diet offered;
- The mean milk yield was statistically similar for cows fed on the three diets, an indication that bogas can be used to feed dairy cows;
- In many occasions the design of the experiments was questioned and considered unsatisfactory.

The results obtained should be compared with other studies undertaken in other sisal processing countries (Brazil / Tanzania).

Recommendations

- Bogas is bulky and should be fed to animals near the source;
- Bogas should be ensiled during the wet season for use during the dry season;

- Bogas is low in protein and fibre, and it should therefore be fed together with supplements high in protein and other forages;
- Further studies are recommended to verify the results from this study and to establish the effect of bogas on rumen fermentation and nutrient metabolism;
- The economics of drying bogas to reduce cost of transportation should be evaluated for it to be availed to farmers around sisal estates or stored for use during the dry season;
- Further experiments should be conducted following a revised design.

The financial appraisal prepared by Kilifi Plantations assumed that the diets using bogas were suitable for the beef steers, sheep and goats and that the sale price of the animals would be higher than the purchase price due to weight gains. The results of the experiments conducted indicate that this assumption might be true for beef steers, and for sheep that presented some weight gain in the two last months of the trials. While for goats it is still not well defined. Considering the poor execution of the experiments it is suggested to review this financial appraisal in the future.

Sub-component B.3: Bio-energy from sisal waste

Objectives of the sub-component

The main objectives of the project were:

- Collect and analyze the available information on sisal waste production and calculate the possible biogas production capability from available sisal waste;
- Evaluate preliminary results achieved with the small experimental biogas plant and analyze the requirements for the demonstration project facility (Facility) design and construction including the presence of the flume tow recovery system and the need for a screen to remove suspended particles from the inflow of the digester;
- Recommend the suitability of the site as Facility location and propose preliminary layout for the plant;
- Prepare a process flow sheet with a tentative mass balance and suggest the optimal solution for the Facility within available budget.

The final objective of the sub-component was to establish, at a pilot level, the technical and economic viability of the production of biogas and fertilizers from sisal waste. The biogas will be used as fuel in a gas engine to produce electrical power and heat. The heat will be used mainly for heating the biogas reactor (digester), while the primary use of the produced electrical power will be at the Estate level. Excess electrical power might eventually be exported to the 11 kV national power distribution network. Optionally, the project will assess the use of biogas for direct delivery to Estate households. The solid and liquid waste from the biogas digester will be utilized as fertilizers in the agriculture activities.

One of the main positive effects of the project will be the considerable reduction of the environmental degradation caused by the uncontrolled disposal of enormous quantities of sisal waste.

Ultimate goal of the project was to prove that currently unused sisal waste from the decortication plant process can be transformed into valuable electrical and thermal energy; the generated savings will lower the costs for fibre extraction. After successful completion, this will be the first demonstration project for the utilization of sisal waste in an economically feasible and environmentally friendly way. The technologies developed and the market information that will be generated shall be disseminated widely to promote commercial adoption.

A project proposal including cost, design and site details was developed and a preliminary Facility and system engineering design, including technical options and alternative plans were summarized in the Technical Report and Annexes, submitted in March 2004.

Proposed site

The following main criteria were considered for Facility site selection:

- Site access;
- Available infrastructure at, or near by selected site;
- Soil conditions;
- Present and future long term feedstock supply (location, availability & supply reliability, quality & quantity);
- Land availability & costs;
- Power and heat requirement for self consumption of miscellaneous consumers located in near vicinity of Facility Site;
- Access to power distribution network;
- Labour availability and skills;
- Water availability and use rights;
- Local environmental impacts;
- Necessary permits;
- Waste disposal restrictions.

The site to be selected should satisfy all requirements as set up in the above list. The road access to the site should fulfil the requirements, and the site should possess the necessary infrastructure for the Facility construction and its later operation. The soil is apparently stable but it will be necessary to perform further soil investigations. There are no other indications about possible underground rocks or soft spots (except present sisal waste dumping area).

It is agreed that Katani will provide the land for the Facility without any cost. Before start-up of any site activities as well as before detailed layout planning, a site level plan was prepared. This will enable the layout planer as well as equipment designer to optimize the Facility design. In other words, this will allow to place the equipment and to size the fluid tanks and other major equipment in such way that, for example, the utilization of natural gravity flow will minimize the amount of pumps.

Conclusions and recommendations

Conclusions

Sisal waste generated and accumulated without being properly disposed, has the potential to cause significant ground- and surface water pollution and also atmospheric pollution through methane generation. The use of sisal waste to generate renewable energy through anaerobic digestion provides a wide range of environmental benefits, in addition to the value of the biogas itself, as it is a waste treatment method that reduces environmental pollution and allows nutrients (fertilizers) to go back to the soil enhancing agriculture activities.

Evaluation of small scale biogas producing and electric power generating plants requires measuring and valuing all above mentioned aspects i.e. the biogas fuel production, the electric power output, the fertilizer output and at last but not least the environment protection. It can be said that the production and utilization of biogas have both direct and indirect economic benefits and social benefits.

The following can be concluded/highlighted:

- Sisal wet decortication process utilizes only the 2% of the sisal leaves and about the 98% of the biomass is considered waste, a mixture of short fibres, green material and processing water.
- The decortication process requires a lot of water and produces a huge amount of biomass waste, which eventually reaches groundwater or rivers causing water oxygen depletion and damaging the ecosystem.
- The anaerobic digestion process is an important alternative to sisal waste disposal and allows electric power generation. The anaerobic digestion is also an important measure to use sisal biomass waste resources efficiently, to improve sisal Estate profitability and long fibres production, to alleviate poverty and facilitate industrialization in rural areas.
- The biogas plant using sisal waste should produce energy to replace fossil fuels, reduce CO_2 emissions, reduce smell and hygiene problems of sisal waste deposits, reduce potential CH_4 emissions from uncontrolled anaerobic degradation of the sisal waste, increase the fraction used as fertilizer and facilitate a more accurate use as fertilizer. Biogas use, replacing conventional fuels like kerosene or firewood, allows for the conservation of the environment. A critical shortage of energy, primarily of electric power, is reflected in high electric power market prices. Self-produced electricity from sisal waste can considerably improve Estate cash flow, production quality and profitability. The direct employment at biogas plants might be estimated to be 40 jobs.
- Biogas production programs, however, should not neglect the argument of improved yield, i.e. increases in Estate production as a result of the use of self-produced bio-fertilizer. Although improved yields through self-produced, biogas based, fertilizers are difficult to capture in a stringent economic calculation and for Estate-to-Estate comparison demonstration, they are very effective. Estates should be encouraged to record harvests on their plots, before and after the introduction of self-produced, biogas based, fertilizers.
- Biogas based fertilizer is a marketable product and existing Tanzanian transportation infrastructure might allow its transport at a reasonable cost.
- Savings from sisal waste controlled disposal costs will be regarded as a benefit of a biogas system as soon as stringent regulations will be issued on sisal waste.
- The production of biogas and utilization of biogas for electric power production creates national wide effects on energy balance.
- The price of supplied energy produced by biogas competes with prices on the national or regional level of the electric power market. Monopolistic practices, which enable energy supplier to sell his energy at a very high price level still dominate the energy market in Tanzania. A decentralized, economically stable and self-sufficient biogas plant therefore - under competitive conditions – could provide its energy without market distortions.
- Furthermore, other benefits arise when comparing on the one hand the benefits of decentralized power generation (mainly reliable and safe power supply, lower power unit price) and the disadvantages of centralized power generation (mainly black-outs and power unit price) from Estate's economic point of view.

It is concluded that an anaerobic digestion system in sisal decortication plant is economic when:

- It is economically feasible the replacement of imported expensive electric power by self-generated electric power;
- It can use and/or sell self-produced solid and liquid fertilizer fraction at a reasonable price to other Estates or agricultural producers;
- Fines or levies for improper/illegal waste dumping are paid to the local authorities.
- The produced biogas should cover the base-line Estate's energy demand, while the peaks may be covered with an imported energy from TANESCO distribution network.
- The produced excess biogas or electric power can be sold and/or exported;

Recommendations

Quality and costs are essential to make this pilot demonstration biogas production and power generation program successful and allow for a self-supporting dissemination process, and for the provision of design standards and in production efficiency.

Taking into account the calculated biogas production of anaerobic digestion and related electric power generation, the proposed biogas technology offers a very attractive and the most economic solution for Tanzanian sisal Estates and sisal long fibres production plants and it is recommended for implication.In order to disseminate efficient utilization of sisal waste for biogas production and electric power generation not only nationwide but also in other countries as well as in order to bring this Project to a successful completion, the following recommendations shall be considered:

Optional systems, waste heat utilization for long fibres drying and biogas compression and pressurized biogas storage should be considered for application. If all factors for optimal integration are carefully evaluated, the running costs of an installation will automatically be as low as possible.

For successful and smooth Project implementation and completion it is absolutely necessary to continue and/or establish close co-operation with all responsible Tanzanian Authorities.

Professional technology dissemination, marketing approach, training courses for consultants and engineers, as well as introductory seminars with site visits for politicians should be organized. An international coordination would certainly speed up the process.

The following design features should be implemented:

- The Facility designer and supplier shall aim at carrying out the design and construction of the Facility without any imported materials in the long run. The lower the import content of the total plant costs, the less the external diseconomies which may arise in consequence of sliding exchange rates.
- Whenever possible, sunken digesters should be built. They do not need pumping, either from the inlet tank into the digester, or from the digester into

the storage tank. The investment cost for pumps is low, but their lifetime is very short, and replacement costs are high.

- Before any design concept is initiated, it should be ensured that this concept is satisfactory from a purely technical point of view (which has to be proven in practice) and that the system is optimally integrated into the existing Estate infrastructure.

Sub-component C.1: Screening and selection of technology for production of pulpable fibre

Summary

Over the past decades sisal production has steadily declined as a consequence of the decreasing demand for the traditional sisal products. During project preparation it was recognized that the use of sisal fibre as raw material for pulp provided a good opportunity for substantial increase in the demand of sisal fibre. Sisal pulp could find application in specialty and semi-specialty papers and as reinforcement pulp in recycled papers. However, in order for sisal pulp to make inroads in the pulp markets, an appropriate technology had to be developed to extract the fibre at a competitive price.

The C.1 sub-component activities focused on the identification and selection of technologies to extract sisal fibre suitable for pulping and to conduct pulping and pulp tests on the agricultural trials. The information collected was used in the preparation of a feasibility analysis for a full scale Fibre Extraction (FEX) plant.

After preliminary investigations, two technologies were developed: the roller crusher (mainly to extract fibre from small quantities of chips from the agricultural trials) and the hammer mill. The roller crusher was based on the technology available at the Wageningen University (WAU) in the Netherlands while the hammer mill was manufactured according to the experience of the Brazilian commercial company Companhia da Celulosa da Bahia (CCB). Both technologies were tested, optimized and compared and from the results of different trials the sequence with optimum results consisted of two passes in the hammer mill with water supplied inside the mills. The roller crusher causes fibre damage which results into low pulp yield. As a result of the trials the fibre extraction technology for the FEX demonstration plant was selected.

The operation of the hammer mill from May to September 2004 revealed that it was necessary to perform extended trials with all sub-systems in place to enable determine all hammer mill operational parameters, determine exact yield and quality of the produced fibre and reduce eventual economic risks. For this reason it was proposed to manufacture a second hammer mill and the necessary ancillary equipment with funds from a new CFC (Common Fund for Commodities) fast-track project started in July 2005. The first built hammer mill will be used for the first pass of fibre extraction and the new (second) hammer mill to process the extracted fibre through a second pass. A feeding system to supply the first hammer mill with chopped fibre, and collector and discharge conveyors for the second hammer mill will be included to the system to enable its continuous operation. The data collected from the operation of the system will confirm and consolidate the information used in the preparation of the feasibility analysis.

Considering the results of the feasibility analysis study for a fibre extraction (FEX) plant, three hammer mills should be also considered. The foreseen project duration is 11 years. The total investment cost for the 3-hammer mill scenario is estimated to be US$ 1,992,100.

The pulping trials and the tests carried out on the samples confirmed that sisal pulp has a good quality. In particular Hybrid 11648 was generally found to be superior in terms of tensile and tear strength and bleachability, due to low kappa number especially at the planting density of 6400 plants per hectare.

The initial idea of total plant harvesting has been shelved due to difference in leaf and bole fibre characteristics. Selective harvesting over a number of years until sisal stops producing leaves has to be adopted.

Lessons Learned

Operational lessons

1. Technology selection for FEX plant

From the experience gained it can be concluded that:

- The roller crusher did not perform as the one used in the Netherlands because the diamond shape of the roller surface pattern was not achieved; roller crushing is not advisable as the process causes fibre damaging which results in low pulp yield.
- It is not recommended even to combine the roller crusher with the present design of the hammer mill, as it confers no advantage. This is due to the fact that the upper hammers of the hammer mill do the preliminary crushing. The lower hammers do the crushing and parenchyma separation in the hammer mill. The effect in the lower hammers is the same whether the chips are crushed prior to feeding to the hammer mill or not.
- It is not recommended to use water bath washing systems as they require large quantities of water, and separation of mucilage was not clearly confirmed. The flow of parenchyma is facilitated by water; therefore it is important to introduce water inside the hammer mill to attain better quality of the fibre.
- It is recommended to operate two hammer mills in parallel to do the first pass with water injected inside each hammer mill, and one hammer mill in series to do the second pass with water injected before the hammer mill and inside the hammer mill.
- The fibre produced had moisture content of about 71%, which would require squeezing to reduce moisture before it is sent to the drier. After squeezing, two carding units will be required, one before the drier to loosen the fibre to facilitate drying and another one after the drier to brush the fibre to reduce parenchyma content from 5% to about 3%. Industrial drying mechanisms should be further evaluated.

2. Main characteristics of sisal pulp

From the results achieved in the pulping trials, it can be concluded that:

- Visual appearance of uncooked fibre: the fibre extracted using the roller crusher was damaged. The damaged, soft fibre obtained from the roller crusher (three-factor trial samples) has faster delignification during cooking.

This is indicated by the lower kappa number of three-factor trial samples, than undamaged fibre from the hammer mill (e.g., CEPS I, fourth harvest).

- Visual appearance of pulp: the amount of shives in pulp samples from the hammer mill indicated a low level of delignification, probably due to less effect of chemicals due to the presence of a high percentage of residual parenchyma and omission of the use of Anthraquinone. Anthraquinone was originally included in the TOR, but Katani Ltd. did not use it. Samples from the roller crusher showed low shives content probably due to over crushing, which acted more or less as an initial stage of mechanical pulping.
- Pulp yield: the drop in pulp yield at the third harvest of CEPS I may have been be caused by the fibre extraction method used (roller crusher). The fourth harvest was extracted using the hammer mill, which produced undamaged fibre resulting in high yield. There were no significant differences in pulp yield between different varieties.
- Kappa number: the high kappa number of all the samples may have been caused by the high percentage of residual parenchyma. Fibre from hammer mill and roller crusher was found to have 8 to 10% residual parenchyma thus requiring more chemicals in delignification. If used, Anthraquinone would have acted as catalyst during delignification. Although the parenchyma contents were in the same range, fibre from 3-factor trials and extracted by roller crusher produced pulp with relatively low kappa number compared with pulps from hammer mill fibre probably, as mentioned above, due to excessive crushing and cutting caused by the rollers facilitating the penetration of the pulping chemicals in the fibre.
- Breaking length: fibre from the fourth harvest had a relatively high degree of polymerization of the lignin chain, requiring stronger cooking conditions to remove the larger amount of lignin which is more prevalent in older sisal than in younger sisal. In general, tensile strength of pulps from the fourth harvest were lower indicating hard pulp and resulting in low pulp tensile strength, expressed as breaking length. The third harvest was processed using the roller crusher. Due to excessive crushing the fibre is subjected to partly mechanical pulping, making it easy for chemicals to penetrate through the fibre producing soft and flexible pulp. As a result more collapsed individual pulp fibre is obtained during refining and more external bonds are formed, thus generating a higher tensile strength.
- Tear strength: this characteristic depends on the external pulp fibre bonds as well as of the strength of the individual fibre walls. The cellulose fibre from the first harvest appears to be flexible and can cause entangling between, resulting in high tear strength. In the fourth harvest, the fibres have shown high tear strength, probably due to the higher strength of the individual fibre walls.
- Burst strength: the burst strengths of the pulps obtained from the third and fourth harvests are in general low but present less variation between samples than the values observed for the first and second harvests. The 3-factor trials results indicate that the effect of the plant density is positive for the varieties H. 11648 and Mlola, negative for *Agave Sisalana* and practically none for *Agave Hildana*. This last variety presents the highest values.
- Bole fibre and leaf fibre cannot be mixed, as the pulping conditions and the quality of the pulp obtained are very different.

3. The feasibility analysis study for a FEX plant

It is recommend by Katani Ltd. that the three-hammer mill scenario be adopted and implemented as it is, within the original appraisal loan amount. Despite the fact that both scenarios have an IRR higher than the 10% discount rate used in the financial analysis, the results indicate that the scenario with three hammer mills is the more profitable one.

Development Lessons

The activities implemented met the overall sub-component objectives. In particular technologies for the extraction of sisal fibre suitable for pulping at competitive costs were evaluated and the results used to propose the layout of a FEX plant. The trials conducted confirmed that hammer milling is the most suitable technique to produce fibre for pulp and paper applications and proved that two passes in the hammer mill are needed to reduce parenchyma to the satisfactory level of less than 5%.

The results achieved and the information collected allowed the preparation of a feasibility analysis study for a FEX plant. Nevertheless Katani Ltd. found that the data available is insufficient and inadequate for the production of a bankable document. This is because the prototype hammer mill was designed to benchmark alternative technologies for fibre extraction and not to perform industrial operations, therefore the system allows only for batch runs and single passes. These are not sufficient to properly measure and estimate the costs involved in the management and operation of the plant.

During the Project Coordinating Committee Meeting held in November 2004, it was recommended that the project sub-component be further funded. The proposal was endorsed, in principle, by the Food and Agriculture Organization (FAO) Intergovernmental Group on Hard Fibres (17 December 2004) and a new "fast-track" project ("Operationalization of a pilot facility for a continuous sisal fibre extraction/production process") was funded by CFC.

The new activities to be carried out include: the construction, erection, and testing of a second hammer mill in series with the existing one and of an upgraded washing system at the existing experimental hammer mill site, the system operation and the preparation of a new feasibility study for a FEX plant, which will take into consideration the new parameters and the data collected.

Altogether the pulping tests can be considered as successful, even though clear indications of the performance of different varieties, densities and harvesting periods cannot be drawn. Yet Hybrid 11648 was probably the best variety. An important finding of the sub-component is certainly the evidence that boles and leaves cannot be pulped together because of the different pulping conditions required and the different quality of the pulp. As a consequence the initial idea of whole plant harvesting had to be disregarded. The characteristics of sisal pulp were investigated further as part of sub-component C.2 "Pulp Pilot Production". Despite the specifications included in the Terms of Reference Anthraquinone was not used due to difficulties in weighing.

Despite the many delays experienced, partly due to the fact that the equipment developed was a prototype and partly to the fact that the activities conducted were experimental, the implementation arrangements proved to be adequate.

TATC proved to be a satisfactory contractor; despite some delivery delays the activities were carried out professionally and met the specifications included in the Terms of Reference.

The implementation of pulping and selection of technology activities suffered from the unfortunate loss of one member of the national project staff.

Conclusions and Recommendations

1. Sisal fibre produced using hammer mill and roller crusher have high percent of residual parenchyma, about 10% by weight, which affects the pulp characteristics. The white amorphous parenchyma adhering to the fibre cannot be removed by further washing. Fibre extraction technology selection should take into account these observations to ensure the production of fibre of commercial grade with residual parenchyma around 3% to attain high strength and low kappa number.
2. It is recommended to use the hammer mill for fibre extraction due to its extraction efficiency. Roller crusher causes fibre damaging which results in low pulp yield.
3. Total plant harvesting has been shelved due to difference in leaf and bole fibre characteristics. Selective harvesting over a number of years until sisal stops producing leaves has been adopted. This means harvesting will continue beyond the fourth harvest.
4. Hybrid 11648 was generally found to be superior in terms of tensile and tear strength and bleachability, due to its low kappa number especially at the planting density of 6400 plants per hectare.
5. The hammer mill could be operated continuously for only 15 minutes while it is necessary to perform two passes and to run the mill continuously at full load for one shift/day of about eight hours and over a longer period (from one to two months) to confirm reliability of the equipment and establish wear and tear of running parts, power consumption, water consumption and labour requirements. This information is needed to enable the project counterpart to submit a bankable feasibility analysis for a fibre extraction plant to access the CFC loan.
6. Considering the results of the feasibility analysis study for a FEX plant, it is advisable to consider the 3-hammer mill scenario, as it is more profitable. Investment and production costs, derived from the A.3, C.1 and C.2 activities, are specified in the feasibility study

Sub component C.2: Production of sisal fibre and pulp for market trials

Background

Sub-component C.2 was conceived as the link between sub-components C.1 and D.1. In sub-component C.1 the possible fibre extraction technologies were evaluated and the quality of fibre and pulp extracted from the agricultural trials assessed. The aim of the C.2 activities was to produce enough fibre and pulp on the bases of the results achieved and the recommendations made in C.1. The fibre and the pulp were then to be used to provide samples to be sent to commercial mills to perform the market trials foreseen as part of sub-component D.1.

The hammer mill proved to extract sisal fibre efficiently and in order to obtain feedback from the pulp and paper market, samples of sisal fibre and pulp were produced and then dispatched to interested mills. The market study conducted indicated that a total of 45 mills in specialty business would be interested in receiving samples of sisal fibre and pulp between 1 kg and 25 kg totaling 120 kg. A total of 29 mills in reinforcement pulp indicated interest in samples but did not indicate the quantities required. Further contacts will be made to establish their requirements and to reconfirm the amounts requested, but it can be estimated that about 300 kg of fibre and 120 kg of pulp will be sent to the mills.

In order to have a significant example of the quality of the fibre extracted by the hammer mill and therefore allow for a full-load test of the fibre extraction equipment, about 3.3 metric tones (MT) of dry fibre were produced. The source of raw material for pilot pulp production was the CEPS-II plantation at Hale (about 1750 plants from CEPS-II a) and about 1750 plants from CEPS-II b). Pulping was done in the industrial digester of Kibo Match pulp mill (Moshi).

In addition, part of the pulp produced was bleached, on a laboratory scale, in order to make available relevant information on the quality achievable and on the bleaching sequence most suitable for sisal pulp. The results of the bleaching tests were also made available to interested mills as part of the market trials. The original idea was to run a paper machine and produce paper samples. This was not possible with the available resources and no commercial mill showed interest in pulping and producing paper from the project sisal fibre at its facilities.

Lessons learned

The objectives identified in the Appraisal Report were broadly met. Even though the large quantities of pulp originally foreseen were not produced the planned semi-commercial production of pulp was carried out. Enough quantities of pulp were generated for the market trials, as foreseen, and confirmatory laboratory tests were also performed.

Commercial mills and research institutions were contacted by UNIDO in August 2003 to bleach a large quantity (five tonnes) of pulp, but only a few responses were received and the proposed costs were too high. It was therefore decided to perform laboratory trials only.

Ideally it would have been interesting to produce paper from bleached sisal pulp, but the costs of such trials would not have had a technical benefit as each commercial mill uses its own blends and procedures. The quality of sisal fibre and pulp can be assessed by the mills against their own needs with the samples provided.

The Project Coordinating Committee (PCC) decided not to prepare a feasibility study for a pulp mill based on sisal, as the main interest of the industry is to produce and sell fibre, and not pulp.

The implementation of sub-component C.2 suffered from the delays accrued in the development of the other sub-components. Thanks to the project extension granted by CFC, the activities were conducted in 2004. Unfortunately further delays were caused by the necessity of additional equipment for the hammer mill and by the poor quality of the first pulping at Kibo Pulp and Paper Mill. This affected the preparation of the fibre and pulp samples (sub-component D.1) and delayed the activities of the institute that conducted the bleaching trials.

The Ljubljana Pulp and Paper Institute proved to be professional and reliable.

Conclusions and recommendations

From the activities performed it can be concluded that the hammer mill provides suitable technology for fibre extraction and that sisal pulp has competitive properties.

The differences in the quality of the pulp produced at Kibo Pulp and Paper Mill in Tanzania and the pulp produced at the Ljubljana Pulp and Paper Institute in Slovenia confirmed that adjustments in the pulping conditions are always required depending on the equipment used. Nevertheless, the fibre and pulp samples and the bleached pulp sheets sent to commercial mills provide the necessary information for the companies to assess the quality of the final product achievable at their facilities.

Sub-component D.1: Market Study and Trials

Summary

The design and formulation phases of the project concluded that, in order for sisal pulp to make inroads into the reinforcement market and to increase its share in the specialty pulp market, a number of important issues would have to be addressed: (a) lack of good estimation of world demand for the types and qualities of pulp with which sisal pulp would have to compete and the price at which this competition would take place; (b) cost of produced sisal fibre in order to enable competition in most market segments with other fibres, the factory-gate cost for sisal fibre would have to be substantially lower than the prices for line fibre. To lower the costs of sisal fibre better agricultural practices and specific fibre extraction technologies are needed, together with measures to recover the waste to add value to the crop and at the same time reduce environmental hazard.

Sub-component D.1 **"Market study and trials"** was conceived to address the need for a good estimation of the world demand for reinforcement pulp and for specialty pulps as well as market development and promotion of those pulps for specialty and commodities paper. It was originally designed to be implemented in three phases.

The specific objectives of the first phase are as follows: (1) to estimate as realistically as possible demand potential for sisal pulp in different sectors (specialty, semi-specialty and reinforcement); (2) to estimate a realistic market premium price for sisal pulp; and (3) to establish market contacts for future operations.

The output of the first phase was a comprehensive market study establishing market demand for sisal pulp and its use in different sectors of paper production and a list of pulp and paper mills with interest in further participation in the following phases. The second phase was very limited and somehow condensed into the third and last phase, the market trials.

The terms of reference (TOR) for the market study subcontract were prepared by UNIDO based on the appraisal report and submitted to the Common Fund for Commodities (CFC) for approval in 1997. The TOR included the services to be provided for the three phases of the subcontract and a request for a separate quotation and time schedule for each phase. The monitoring and supervision was carried out by UNIDO.

The subcontract was awarded to the consulting company Sevenhuijsen Associates, Netherlands and signed in April 1998. The first draft final report and annexes was submitted to UNIDO in June 1999. It was not considered satisfactory by the counterparts and UNIDO. The subcontractor was requested to revise the report and to identify the pulp and paper mills that have replied to the questionnaires and that were interested in receiving information, data, and sisal fibre and pulp samples. The revised report including the list of mills was submitted to UNIDO in the middle of 2001.

The main conclusions of the study are:

a) The pulp properties of bleached sisal pulp are suitable for its use in the specialty pulp market. Compared with Abaca pulp, sisal pulp properties such as porosity, tensile and tear are lower but its price is about 60% higher than sisal (averages abaca U$ 2,600 and sisal U$ 1,600). Properties and prices for flax, hem and jute pulps are in the same range as sisal.

The tear - tensile relations, which are key properties for reinforcement pulps are better for sisal than for softwood pulp. The current market price of sisal pulp produced from line fibre, however, is too high to make it competitive with bleached softwood. In order for sisal pulp to make inroads in the reinforcement pulp market, the sisal pulpable fibre production costs and prices will have to be reduced without compromising the final pulp quality. To compete with bleached kraft softwood (BKS) at U$ 600/ADMT at paper mill gate, the price of sisal pulpable fibre produced in East Africa could not be higher than about US$ 180 - US$ 185/ADMT at mill gate of pulp mills in Europe. To be able to achieve these levels of price the following issues will have to be addressed:

- Development of new varieties
- Improved agricultural practices and management
- Development of new technologies for extraction of pulpable fibre

b) The potential market for specialty pulp is about 284,000 and 336,000 ADMT in 2005 and 2010, respectively and it includes all types of pulps as abaca, flax, hemp, jute, cotton, wood pulp and sisal. The potential market for sisal specialty only is about 48,000 and 59,000 ADMT in 2005 and 2010, respectively. Therefore, the sisal fibre market for specialty pulp is about 80,000 and 98,000 ADMT in 2005 and 2010 assuming a pulp yield of 60%. The prices for bleached and unbleached sisal pulp are in the ranges of US$ 1,500 - US$ 1,700/AD and US$ 1,400 – US$ 1,600/ADMT, CIF Europe, respectively.

The market for BKS as reinforcement pulp is estimated at about 17 and 20 million ADMT in 2005 and 2010 respectively. The market potential for reinforcement sisal fibre was estimated based on the answer to the questionnaires and including only paper mills that are producing printing and tissue papers that are the main paper grades using reinforcement pulp. This estimate only included the mills willing to pay 10% premium price for sisal pulp. The average demands for sisal bleached pulp are 223,000 and 262,000 tonnes in 2005 and 2010, respectively. These market potentials are about 4.5 times the sisal specialty market and 1.3% of the market for BKS. At a paper mill gate premium price of US$ 660/ADMT of pulp, the price of sisal pulpable fibre from East Africa could be around US$ 210-220/ADMT at the pulp mill gate in Europe.

c) The questionnaires sent to mills using reinforcement pulp were answered by 175 mills out of which 147 were in Europe, five in Asia, four in South America and 26 in North America. The survey identified 16 mills interested in receiving fibre and 29 pulp samples. Those mills are the potential partners for the next phases of the market study.

The total number of replies to the questionnaires on specialty paper was 160, out of which 112 from Europe, five from Asia, four from South America and 39 from North America. The number of mills interested in receiving fibre and pulp samples was 15 and 45 respectively. Those mills are also potential partners for the next phases.

Despite the delays in the implementation, the objectives were of this subcomponent D1- Phase 1 and the envisaged outputs were produced as planned.

Lessons learned

The objectives identified in the Appraisal Report were broadly met, even though phase 2 and phase 3 were to a certain extent merged. Despite the many critics the market study was performed following the agreed Terms of Reference. A need for a more intensive market survey of China, South East Asia, Middle East and Africa was identified towards the end of the project, after the market trials.

The properties of sisal and its potential use in specialty paper production are broadly recognized, even though it emerged clearly that it is difficult to attract the interest of commercial mills if no constant supply can be guaranteed. Therefore at the project level satisfactory results were achieved, which should be confirmed once commercial operations are possible.

Preliminary indications on the price that the market would pay for sisal were also obtained; these were used in the feasibility analysis study for a FEX plant prepared by Katani Ltd. The production and trade in specialty pulp and paper is very secretive and figures given by the mills visited are only general indicators.

Ideally it would have been important to work with a commercial mill in the bleaching trials and therefore strengthen the contacts between the project and the mills. As mentioned in Addendum C.2, this was not possible.

The time lag between the preparation of the market study and the market trials was longer than expected because of the many delays in the selection of the extraction technology and therefore in the preparation of the material for the trials. As pointed out in the introductory note to this report, the negative consequence of these delays is that the projections prepared at the time of the market study were out-of-date at the time of the market trials and of the preparation of the feasibility study. Nevertheless it should be stressed once again that the overview of the market and the contacts developed were the bases on which the trials developed.

Conclusions and recommendations

The main conclusions and lessons learned are:

- The properties of bleached sisal pulp are suitable for use in the specialty pulp market. Sisal properties of porosity, tensile and tear are lower than abaca but sisal prices are about 60% lower than abaca (averages abaca US$ 2,600 and sisal US$ 1,600). In general, properties and prices for sisal, flax, hemp and jute pulps are similar and only differ slightly depending on their preparation and customer requirements.

- There are numerous specialty utilizations for sisal pulp in bank notes, electrolyte paper, oil and fuel filters, coffee filters, tea bags, cigarette papers, stencil paper, etc. Many paper makers use a blend of various pulps to take advantage of the properties of each fibre and their respective prices.

- The production and trade in specialty pulp and paper is very secretive and figures given are only general indicators. In some of the productions like bank notes and security paper, the mills are very security conscious and in most cases information is not given at all. In some instances, verbal information was given on the understanding that it will not be reported in a public paper. There are virtually no worldwide projections available and therefore future market potential for specialty pulp is normally an extrapolation of the past production/consumption. It is estimated that the current market is about 250,000 ADMT and has been growing at the rate of 5%-6% per annum in the last four years. This includes all types of pulps going into specialty uses - abaca, flax, hemp, jute, cotton, wood pulp and sisal. Of these, the current production of sisal pulp is 45,000 tonnes and growing at the same rate mentioned above. The fibre needed to produce this pulp is around 90,000 tonnes.

- The prices for unbleached and bleached sisal pulp are in the ranges of US$ 1,200 – US$ 2,300 per ADMT, CIF Europe depending on quality and source.

- The current market for BKS as reinforcement pulp is about 15 million ADMT per annum and growing at times by up to 9% per annum in the last seven years. The market potential for sisal reinforcement pulp is very high but prohibitive because of the price and the [un]reliable availability of large quantities of fibre. The aspect ratio and tear and tensile index, which are key properties for reinforcement pulps, are better for sisal than for softwood pulp. Mills indicated that they would pay a premium of a maximum of 12% over BKS. In order for sisal pulp to make inroads in the reinforcement pulp market, the price of sisal pulpable fiber will have to be reduced without compromising the final pulp quality. The current market price for BKS is around US$ 650 per ADMT delivered to the paper mill. To compete, it is estimated that the price of sisal pulp has to be around US$ 750 per ADMT.

- Investment in small pulp mills is possible if the target is a niche specialty pulp market. These mills can be as small as five ADMT per day and still be profitable. Any investment targeting the reinforcement pulp market has to be of much larger tonnage because potential buyers need assurance of supply and economies of scale become critical in reducing the cost.

- China, India and South East Asia are becoming increasingly important both as major markets and as producers of pulp. Some mills in Europe are contemplating relocation to areas of sources of fibre and where the costs of energy and labour are more favorable than in Europe.

- There is a need to conduct a more intensive market survey of China, South East Asia, Middle East and Africa. These are emerging markets and their needs for paper products are expanding at a faster rate than the traditional European or North American markets. There is scant published market information on these markets.

- A number of contacts were established with potential customers for sisal pulpable fibre and sisal pulp. There is a demand for sisal pulpable fibre, sisal pulp and paper products. To meet this demand, producers need to develop market linkages in the various markets. Contacts were also established with pulp equipment suppliers for possible future development of pulping operations.

Sub-component F.2: Dissemination Workshop

Summary

The scope of sub-component F.2 was to disseminate as widely as possible the results achieved by the project, and to exchange experiences with representatives of other countries were sisal is produced. A first workshop was held in Tanga in February 2003.

The final dissemination workshop was organized in Tanga, Tanzania, at the Mkonge Hotel from 16 to 19 November 2004. An organizing committee, with seven sub-committees) was formed to organize the event.

The countries represented included: Brazil, Cuba, China, Kenya, Mexico, and South Africa. The event was officially opened by the Vice President of the United Republic of Tanzania, H.E. Dr. Ali M. Shein and blessed by the presence of representatives from the Government and from international organizations. In particular the following guests participated:

Dr. A. Rwendeire (UNIDO Divisional Managing Director)
H.E. Ambassador A. Mchumo (CFC Managing Director)
Hon. Capt. (Rtd.) J. Mwambi, (Tanga Regional Commissioner)
Hon. Mr. M. Mwandoro (MP), (Chairman Tanzania Sisal Board)
Mr. J. Cheluget, (Kenya Ministry of Agriculture, Head of Kenya Delegation)
Mr. S. Mbabaali (FAO)
Hon. Dr. J. Ngasongwa (MP), (Minister for Industries and Trade)
Mr. D.D. Ruhinda, (Chairman Sisal Association of Tanzania).

Implementation and results achieved

On the first day, participants had the opportunity to visit the project sites: from the Agricultural Research Institution (ARI), at Mlingano to the demonstration areas of the smallholder scheme agricultural trials at Hale. The foundation stone of the biogas project was laid during a formal ceremony and the prototype hammer mill was formally inaugurated.

On the second day the meeting was officially opened and speeches and statements delivered. On the third day the presentation of the project main features started and continued on the next and last day. The different sessions covered the following topics: "Enhancing and Improving Sisal Production", "Alternative Uses and Markets for Sisal", "Market Demand for Sisal", "Industrialization of Sisal, Way Forward". The presenters were the project national and international experts.

During the second session (Market demand for sisal), the experiences of participants from Brazil, China, Cuba, Mexico and South Africa were presented and a contribution to the discussion was given by Mrs. P. Brazier (from Wigglesworth, UK) on the demand for sisal products in Europe, North America and Asia.

All the presentations were followed by active participation in the discussion sessions. Criticisms were raised on the demand projections produced as part of the market study. As specified in the report for sub-component D.1, the study was carried out at the end of the 1990s and there were no additional resources allocated in the project to bring it up-to-date. Therefore the results of the market study should be evaluated cautiously.

The presentations given at the workshop are summarized in the proceedings of the Workshop (Addendum F.2). The content of the presentations reflects the views of the presenters, and not of the PEA, the donor or of the organizers of the event.

Lessons learned

The workshop was well attended and participants provided enthusiastic comments. The spirit of the workshop was very positive and the views of the participants and of the guests on the sisal industry highly optimistic. The workshop raised a lot of interest in the country. The overall goal of disseminating the project results was therefore met.

The participants underlined that dissemination should have been done more homogeneously throughout the implementation of the project and noted as being rather poor especially during the first years of project implementation. After the first workshop (February 2003) more efforts were made to communicate the project activities to a wider audience.

Conclusions and recommendations

In the future more attention should be given to disseminate the project from the beginning and to facilitate a more participatory approach. This applies to both smallholder growers and to sisal estates. The role of the Tanzania Sisal Board should be instrumental in reaching all the sisal industry.

The participants showed a lot of interest, in particular for the Meristematic Tissue Culture (MTC) activities initiated at ARI Mlingano. Action should be taken to make the laboratory more efficient and ensure delivery. The future of the sisal industry seems very promising and there is a need to prove the efficiency of biogas generation from decortication waste and the opportunities of alternative markets (pulp and paper, composite materials).

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