Sorghum Milling in Botswana

A Development Impact Case Study

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Sorghum Milling in Botswana: A Development Impact Case Study

CONTENTS

Currency

The analysis in the report is done in Botswana currency:

1.0 Pula = 100 thebe(t) = Can. $1.41

I INTRODUCTION

1. The research and development work on sorghum milling in Botswana that IDRC supported through two projects between 1976 and 1980 has been part of an informal network of projects in Africa and other regions. Table 1 and Figure 1 give a broad picture of the Africa grain milling network, showing cost estimates of the projects and how they have interrelated over the last ten years. The projects have revolved round the perceived need to promote the production and utilization of small grains and grain legumes, particularly sorghum and millet, that are well adapted to the drier parts of Africa and constitute staple food for large rural populations. A major constraint to this development lies in the difficulty of dehulling the grains prior to grinding into flour. Thus the main focus of the projects has been on the development of a simple mechanical dehulling device. As Table 1 shows, the IDRC contribution to the projects which are most directly related to the dehuller totals about $1½ million. This figure only includes estimated project costs and excludes the considerable investment in staff time, travel costs and so on that has been made in the last 10 years. Similarly, the estimated $900,000 recipient contribution in Table 1 significantly understates the overall commitment by people and institutions in Africa and Canada to this development effort. In summary the total resource commitment by IDRC and its partners is significantly higher than the $2.5 million shown in Table 1. As Figure 1 indicates, in recent years the "network" has spread, and the dehuller is now being tested and developed in eight African countries (and also in Thailand and Guatemala). Thus the program is of considerable significance, both in terms of past investment and future commitments and intentions. It is hoped that this case study can contribute to the planning and implementation of the research and development effort.

Table 1: Africa Grain Milling related projects supported by IDRC: estimated costs (project summary data).

Project				Budget Data		
				IDRC	Recipient	Total
					(Can $'000)	
OVERSEAS						
Nigeria	I	72-0003		132	66	198
	II	73-0128		160	35	195
Senegal	I	76-0026		270	400	670
	II	79-0066		114	72	186
Botswana	I	75-0137		125	37	162
	II	78-0023		80	39	119
Ghana		76-0003		180	95	275
Sudan		78-0054		138	109	247
Tanzania		79-0093		122	50	172
Ethiopia[1/]		79-0016	(499)	60	(90) 12	72
		80-0010	(108)		(32)	
Sub-total				1381	915	2296
CANADA						
Guelph		71-0019		15	-	15
Saskatchewan						
PRL		73-0051		26	-	26
PRL		74-0168		44	-	44
PRL		78-0008		72	-	72
University		73-0032		26	-	26
Sub-total				183	-[2/]	183
TOTAL[3/]				1564	915	2479

1/ Dehuller being tested as part of two larger projects on sorghum utilization and breeding. Rough estimate of 10% of project effort related to milling.

2/ Recipient contribution not specified in project summaries, but certainly not zero.

3/ This total excludes some projects related to other components of grain milling systems, e.g. Composite Flour at Manitoba. It also excludes important informal collaborative inputs from such institutions as the University of Alberta, Northern Alberta Institute of Technology, CIDA, ITC, Laval University.

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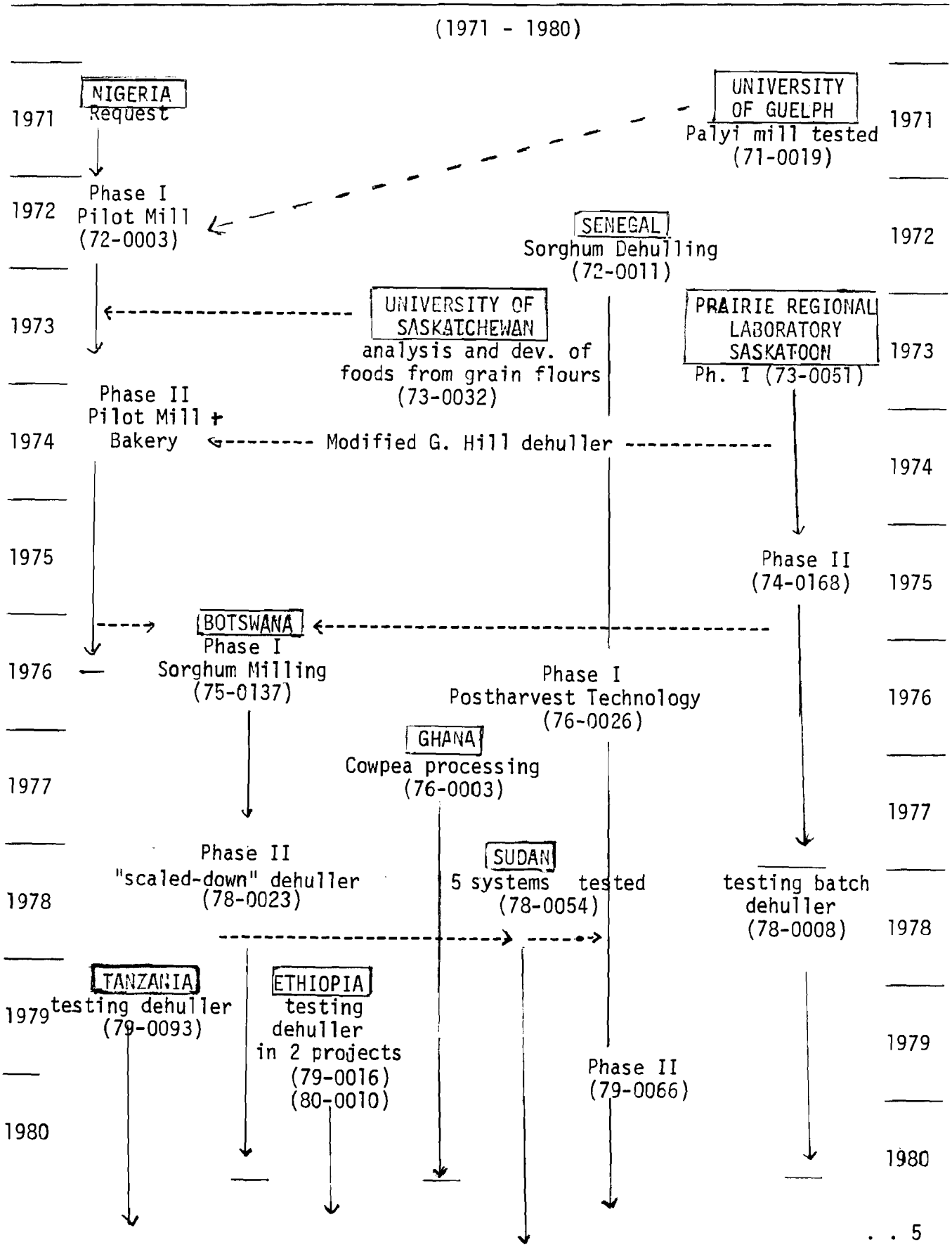
FIGURE 1: Africa grain-milling related products supported by IDRC



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2. Several of the individual projects and the research network as a whole have been the subject of studies and reports, mostly by the Agriculture, Food and Nutrition Sciences (AFNS) Division of IDRC. A sample of some of this literature is given in Annex 1, and it is not intended to reproduce any of it here: rather it will be drawn upon where the information contributes to the study.

3. The Botswana case has been chosen for study because it offers an example of an extremely rapid progression from applied research through pilot project to dissemination and adoption of a technology. The purpose of the development impact case study is to document and quantify as far as possible the economic and social costs, benefits and policy implications of the R & D process to date and to examine the determinants of and constraints to progress, drawing out any lessons of experience that could be applicable in other countries.

II DEVELOPMENT IMPACT

(1) What has happened

As illustrated in Figure 1, between 1971 and 1975 a technology for mechanically dehulling small grains was developed and tested in a series of projects, mainly in Nigeria and Canada. Thus the research had already been carried to a fairly advanced stage by the time it reached Botswana.

In the mid 1970's, the Botswana government decided to address its concern about the trend away from locally produced sorghums towards imported maize, mostly from the Republic of South Africa. The Ministry of Agriculture asked the Botswana Agriculture Marketing Board (BAMB) to investigate the possibilities of processing sorghum. The traditional method of milling by hand is lengthy and inefficient. The meal produced has to be eaten quickly, otherwise it becomes rancid on account of the high moisture content - a result of the soaking which is an integral part of the traditional process. Mechanical dehulling and grinding can be done without wetting the grain.

BAMB contacted IDRC, and the General Manager met with the Associate Director of Post-Production Systems at a workshop in Nairobi. The first phase of the project aimed to

> "develop a suitable village level milling system for processing sorghum to produce sorghum flour . . . as acceptable in quality and price as imported maize meal."

The underlying policy objective of contributing to increasing basic food self sufficiency is plainly stated in this project objective.

The outcome of the project has been documented in several reports, (Annex 1: 3, 8, 11). Briefly, a pilot mill was established at Pitsane,

a village with a large BAMB grain storage depot on the railway south of the capital Gaborone. The mill used two dehullers and a hammermill, driven by two diesel engines. The meal produced was sold in bags of various sizes, from 2.5 kg to 60 kg. Table 2 shows the throughput in metric tonnes of grain rising from 85 tonnes in late 1977 to about 1,800 tonnes in 1982. The mill was operated with the assistance of IDRC advisors until June 1978, when local BAMB management took over. The mill has been running since, working about 12 hours a day producing about six tonnes of flour.

Even though it is higher in price, there is a strong demand for the sorghum flour, supporting the results of a previous consumer preference survey. This evidence supports the interpretation that the trend away from sorghum to maize has been a phenomenon of urbanization and availability: quite simply maize meal was on the shelf and sorghum flour was not.

However, more than three-quarters of the Botswana people (Batswana) live in rural areas and consume their own sorghum supplies. The survey also indicated that most people prefer to eat flour from the sorghum they have grown themselves. To meet this need requires modifying the milling system so that it can process smaller amounts in batches, in other words, operate as a service unit as opposed to the commercial system at Pitsane. This then was the aim of the second phase* in Botswana:

> "to determine the technical, operational and economic feasibility of 'scaled-down' models of the Botswana milling system."

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* Strictly speaking they were not phases, but separate projects "Sorghum Milling" (75-0137) and "Rural Industry Promotion" (78-0023).

Table 2 : Estimates and Projection of Sorghum Milled in Botswana

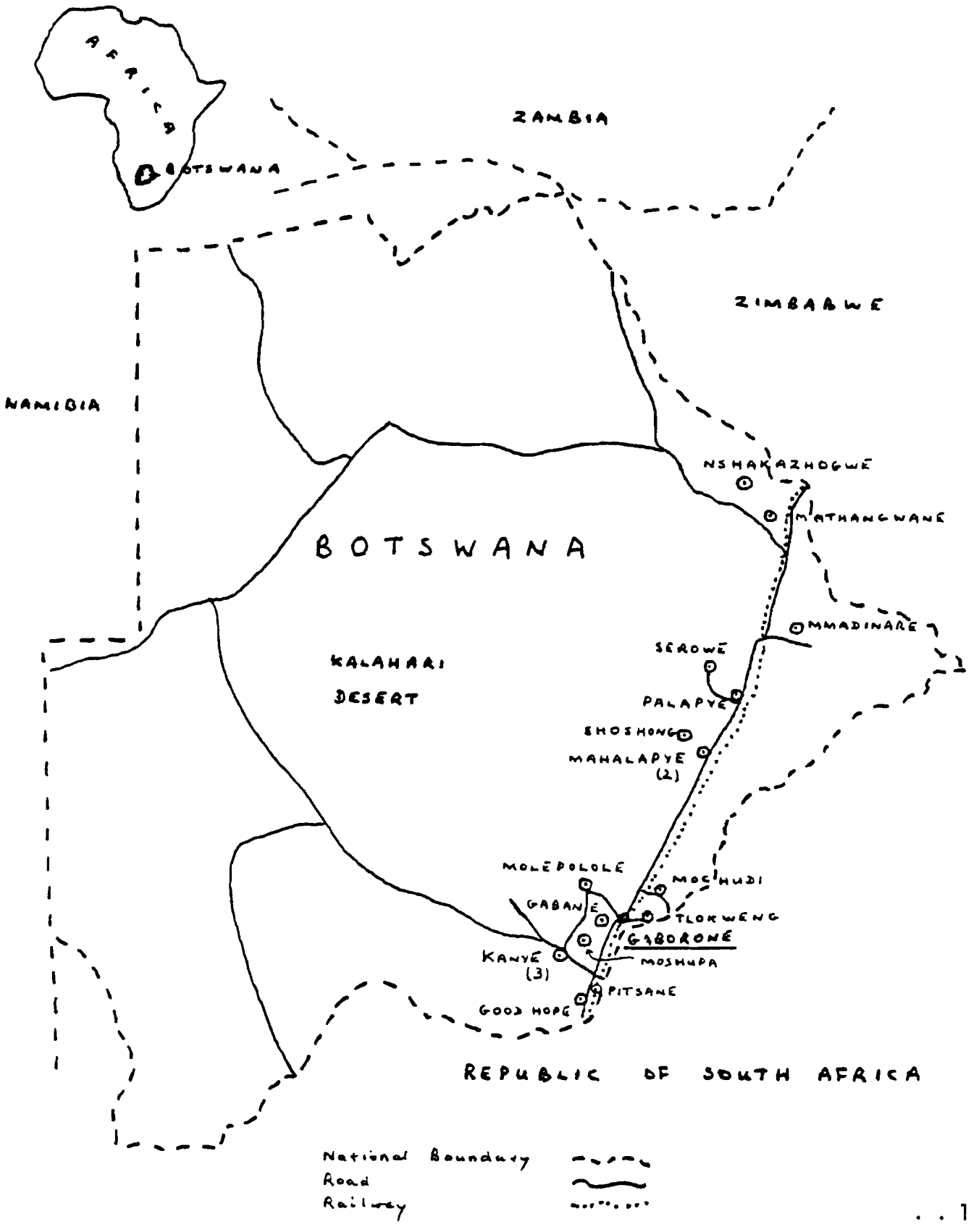
Mill	1977	1978	1979	1980	1981	1982	1983
				(metric tonnes grain)			
*Pitsane (C)	85	1,330	1,923	1,800	1,800	1,800	1,800
*Kanye : RIIC I (S)	-	-	232	700	640	640	640
* " : RIIC II (C)	-	-	-	-	192	768	768
" : SRDA (C)	-	-	-	250	600	600	600
*Gabane (C & S)	-	-	5	572	600	600	600
*Tlokweng (S)	-	-	-	-	440	480	500
Moshupa	-	-	-	-	500	500	500
*Molepolole (S)	-	-	-	-	520	780	780
*Palapye (C & S)	-	-	-	-	170	420	500
Mahalapye I	-	-	-	-	250	500	500
Mahalapye II	-	-	-	-	300	600	600
Mathangwane	-	-	-	-	300	600	600
Mochudi	-	-	-	-	250	500	500
Serowe	-	-	-	-	250	500	500
Shoshong	-	-	-	-	-	500	600
Nshakazhogwe	-	-	-	-	-	500	600
Mmadinare	-	-	-	-	-	500	600
TOTAL grain milled (t)	85	1,330	2,160	3,322	6,812	10,788	11,188

* Based on records and interviews. Others are estimates based on the actual performance of those studied.

(C) = Commercial Mill (S) = Service Mill

REPUBLIC OF BOTSWANA

Location of Sorghum Mills as of January, 1982.



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Responsibility for the necessary research, re-designing and testing in village communities was given to the Rural Industries Innovation Centre (RIIC), an enterprise of Rural Industries Promotion (RIP). RIP is a private non-profit company, incorporated in Botswana and governed by a Board of Directors that includes the Director of Botswana Enterprises Development Unit, the Senior Industrial Officer of the Ministry of Commerce and Industry and the Director of the Botswana Technology Centre. It is chaired by the Minister of Commerce and Industry. The RIP has been funded almost exclusively by the Friedrich Ebert Foundation, a German aid agency. Until 1980, the RIIC was the only project of RIP and constituted all its physical assets.

Among its facilities, the RIIC has a prototype development workshop, and a production and repair metal workshop. It also operates an extension program, serving as a direct link with rural communities, fostering problem identification and the adoption of suitable technologies.

Between 1978 and 1980, the RIIC redesigned, developed and tested various prototypes of a scaled-down dehuller. The research had the happy outcome that, because the scaling down allowed the dehuller to be operated at higher speeds, the throughput of the smaller model was no lower than the original larger version. The system established consisted of a dehuller that could operate on a batch (service) or continuous-flow (commercial milling) basis, incorporating a fan and cyclone for collecting the bran; a hammermill; and a water-cooled diesel engine to drive both machines.

One mill was set up at Kanye, where the RIIC is located, and milled 232 tonnes of grain between May and December, 1979. Another mill was established at Gabane in later 1979, operated by the Pelagano Village Industries, a government sponsored development group. It operated as a

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commercial unit in the mornings and as a service mill in the afternoons. Its current throughput is about 600 tonnes per year, (Table 2).

This very brief summary of events omits many elements described in the publications in Annex 1, ranging from technical problems arising and being overcome, to efforts to publicize the system by demonstrations, seminars and publications. These are only left out to avoid repetition, and not because they did not constitute integral parts of the process.

A seminar in September 1979 was held for persons who expected to invest in milling packages, and RIIC accepted orders at that time. A mill operator's handbook was written, to go with an owner's handbook. The first course for mill operators/owners took place in February 1980, and production on three dehullers began early that year, followed by eight more in mid-1980. The phasing of the various units established is given in Table 2, in terms of quantity of sorghum processed in each year. The locations of the mills are shown on the map (page 9). All are in the south and east of the country along the line of rail where most of the population is concentrated. The target for 1982 is for a further 20 units, and RIIC has firm orders for five, plus a list of 19 possibles. However Table 2 only provides information on units actually in place and operating. These 17 systems will process an estimated 10,788 tonnes of grain in 1982, rising to 11,188 tonnes in 1983. Consumption estimates vary widely, but taking a middle estimate of 2 kg per family per day, this amounts to the sorghum requirements of about 15,000 families, already more than 10 percent of the Botswana population (130,000 families).

(2) Social and Economic Effects

Two broad categories of benefits have been anticipated from the adoption of the system:

- to facilitate increased consumption and thereby production of domestic sorghums, thus increasing food security and decreasing (a) dependence on imports and (b) foreign exchange expenditure:

- to release women and childrens' time for more economically and socially rewarding activities.

SERVICE MILLING

By itself, service milling is not likely to have a significant effect on domestic production, since it can be assumed that most of the grain that is machine processed would have been produced and hand-processed even if the mill did not exist. In fact, to the extent that the mill extraction rate is higher and wastage is lower than traditional methods, the amount of grain needed to feed a family in a year will be less. This could have the effect of increasing food reserves if the same amount of grain is produced; and/or of releasing resources for other production activities if subsistence requirements are reduced.

Therefore the benefits of service milling lie mostly in allowing women and children to do other things. Reliable estimates of the amount of time spent on hand-processing are few, varying from 2 to 5 hours per day. Certainly, it is invariably a daily task and certainly it involves a laborious routine of wetting, pounding, winnowing, drying, pounding, and so on. The most recent work is a survey organized by the Chief Extension Officer of RIIC in August, 1981 (Annex 1, 6) to assess the impact of the mills in four rural communities.

In reply to the question "How many hours per day does the mill save you on food processing?" 40 out of 143 women were unable to estimate, but the remaining 103 (72% of the sample) gave an average of 2½ hours/day. Similarly, 64% of the sample responded that an average of 2 hours per day of children's time was saved. From these estimates should be deducted the time spent travelling to the mill, waiting for the grain to be processed, and returning home. The survey did not address this question specifically, although it did find that people used the mill about once a week, and that the average distance was 1.5 kilometres, or a round trip of 3.0 km. From this information and personal observation, it is unlikely that the time spent using the mill is more than ½ hour per day on average, or 3½ hours per week. Thus women and children's net time saved is about 4 hours per day*, (2½ + 2 less ½).

The survey provided some information on how this new found time was spent by women and children. For women, 57% spent it on household activities (washing clothes, cleaning the yard, household work) and 41% said that they spent it on "production activities" such as mixing clay, weeding, knitting, beer brewing. Half of the children were reported to be occupied with studying and reading; 31% with household work; and 19% playing. The reliability of this information is not known, since it would probably be difficult for even the interviewers to judge the extent to which answers were accurate, or were aimed to provide what might be respectable or acceptable, more than truthful.

However, in terms of economic analysis, the reliability is not significant. The important fixed point is that large numbers of

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* Again, from personal observation, very few women in rural Botswana have conventional means for measuring time, and the interview method of determining time spent hand-processing depends on the reliability of their subjective judgement of "an hour."

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people have preferred to pay the going price for service milling than to persist with hand processing. One way of estimating the benefits from the service milling would be to put values on the different activities that are undertaken with the new found time. Empirical evidence to measure this would be extremely difficult to obtain, and according to one approach, is neither necessary nor desirable. There is an appealing economic principle that the consumer is the best judge of the value of a good or service and that this value can be measured by the consumer's willingness to pay (wtp). In terms of the service mill, consumers have been, and continue to be, willing to pay for the service under three broad categories:

- the service itself: charges range from 3t to 5t* per kg of grain, suggesting that many of those who are paying 3t would probably be willing to pay more (since many of their compatriots do pay 4t and 5t);

- transportation : means of transport to and from the mill range from foot, bicycle, donkey cart to truck, all of which have a cost that customers are prepared to incur;

- time : customers are also prepared to spend the time carrying grain, waiting in line and carrying back the flour (and sometimes the bran).

In economic analysis in Annex 2, owing to estimation difficulties, no wtp for transport and time is included and the willingness to pay for the service itself is assumed (conservatively) to be 3.5t per kg grain. Therefore the customers must value the time that they are

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* 1.0 Pula = 100 t
1.0 t = 1.4¢ (Can.)

now able to spend on other things at the equivalent of 3.5t/kg or more otherwise they would keep the money and continue hand processing.

Another category of benefit that can be attributed to service milling is that from the better extraction rate. The best estimate available for hand-processing suggests that about 0.70 kg of flour from 1 kg of grain can be expected by this method. The empirical tests carried out during the research phase at RIIC show that a machine extraction rate of 80% is reasonable to expect under operating conditions. The benefit from the higher yield of flour is estimated at 2.2t/kg.

Using these estimates of the social and economic benefits of service milling, a social benefit-cost analysis of an individual service mill gives the following results:

Internal rate of return	30 percent
Net Present Value @ 12%	27,000 Pula (Can. $38,000).

The assumptions made and the details of the calculations are given in Annex 2. Some of the key assumptions such as life of the equipment, working days lost per month, throughput, and value of service may seem to err on the conservative side. However, they are considered realistic in the light of current teething troubles being experienced by some of the units and the revolutionary character of the technology in the Botswana rural setting. They are also based on actual data obtained from units functioning now in the country, rather than on experimental results.

The above calculation omits an important economic policy consideration which arises from the fact that hand processing involves no importation of materials, whereas mechanical milling results in foreign exchange costs for diesel, oil and most vehicle operating costs, and for the

hammer mill, diesel engine and components and raw materials for the dehuller, all of which have to be imported. In the economic analysis of projects in countries when foreign exchange is a constraint (i.e. most low-income, non oil producing countries in Africa) an attempt is made to favour projects that use local resources more than imports, or produce exports or replace imports, by "penalizing" projects that use a lot of foreign exchange and crediting those that earn or save it. This is done by applying a "shadow foreign exchange rate" to costs and benefits that either use or earn foreign exchange, (F.E.). In the present case, the service provided by the mill is substituting for a local resource, not an imported one, so there are no foreign exchange implications on the benefit side. However, as mentioned, most of the costs except human resources are imported, therefore using a shadow F.E. rate will increase costs without affecting benefits. Therefore, the rate of return is lowered. The limited information available on Botswana's balance of payments and foreign exchange position suggests that F.E. is not a constraint at present. Cattle, diamonds and sundry recreational exports, together with foreign aid, keep reserves high and banks will readily hand over foreign currency in exchange for local cash.

However it is worth noting that using a shadow foreign exchange rate of 25% (i.e. increasing the cost of all imported items by 25%) reduces the Rate of Return from 30% to 18% and the Net Present Value to 8,000 Pula. This implies that even if foreign exchange was a constraint, an additional service mill would still be a socially profitable investment for Botswana, although closer to the margin of acceptability.

COMMERCIAL MILLING

In terms of reducing dependence on imported food, it is clear that commercial milling has a potential role to play. By definition, the

products of commercial milling are exchanged in the cash economy, whereas the service mills operate more in the subsistence sector. In the cash economy, flour from locally grown sorghum can compete with imported flour, although it is hard to find up-to-date data that could indicate the extent to which this has in fact happened. Also, the introduction of commercial milling by itself could not be expected to cause an increase in local production. It does of course provide an essential element, so that when increases in local production do occur they can be transformed into a product that is acceptable to consumers. Another essential element in the development of domestic food production is price. Both BAMB and individual mill owners wishing to secure local supplies for commercial milling have had to increase the producer price for sorghum grain. Currently the government is backing its food security and self-sufficiency objectives in several ways: through development schemes such as ALDEP (Arable Lands Development Program); provision of marketing infrastructure (40 more BAMB storage depots are planned); and increased guaranteed producer prices announced in time to influence planting decisions. Sorghum prices for 1982 are higher than import prices, and this policy has had to be reinforced by a ban on imports from South Africa to avoid profit taking across the border.

These circumstances raise a dilemma in the valuation of benefits from commercial milling. Botswana is a net importer of food grain and food grain products, therefore until self-sufficiency is reached, the economic value of flour from local grain can be based on import parity, since any flour not produced locally would have to be imported. Therefore it could be argued that sorghum flour for which consumers pay 30 to 34+/kg should be valued at about 28+/kg, which is the price of imported maize flour, or flour made from the cheaper imported sorghum (i.e. the import parity price).

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However there are two main arguments against this valuation. First, the local and imported sorghums are different, and produce different flour when milled. The imported grains are hybrid varieties and there is evidence of a consumer preference for the domestic white sorghums*. Although strictly speaking people could be "fed" entirely from imported maize and sorghum, consumer satisfaction would be considerably less. Second, valuing local production at import parity is only useful to point out the economic cost implications of a policy that has many more criteria than the greater satisfaction of Botswana palates. There are political, strategic, social and cultural values attached to locally-produced food, that numerical analysis cannot incorporate, but must be aware of. Therefore it seems reasonable to use the extent to which Botswana society is willing to pay for local sorghum flour as a starting point for its "real" value. The "value-added" benefits of commercial milling can be estimated by deducting the supply price of a tonne of local sorghum from the value of the flour and bran it produces, expressed in terms of "willingness to pay." Following this principle, the net benefits per tonne of grain milled commercially are estimated at 72 Pula per tonne. Using this figure, a social benefit cost-analysis of an individual commercial mill shows an internal rate of return of 26% and a Net Present Value at 12% of 34,000 Pula, (Can. $48,000). Details are provided in Annex 3.

However, using import parity prices for the benefits and a shadow F.E. rate of 25% significantly alters these results. First, assuming that only locally produced grain is commercially milled results in a large increase in value-added. The F.E. component in the production cost of local sorghum is small (10% is generous), whereas the shadow F.E.

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* In fact there are regional preferences within the country: people in the south prefer their white varieties and the further north, the deeper the red colour preferred.

rate can be applied to the total value of the flour. Therefore the value of the grain rises only slightly while the value of the flour rises by the full 25%, and the gap between the two widens. The value-added benefits increase from 72 to 107 Pula per tonne, more than enough to offset the increases on the cost side, and raising the rate of return to 79%. A second calculation considers the case when only imported grain is milled. Then the full cost of the grain is subject to the shadow F.E. rate and the value-added is lowered to 90 Pula per tonne, and the rate of return to 40%.

The absolute value of these estimates is much less important than the direction of change and the difference between service and commercial milling.

Summary of Results

Basis of analysis	Service Milling (rate of return)	Commercial Milling (rate of return)
Local prices (willingness to pay)	30%	26%
Shadow F.E. rate 25%	18%	79% local grain 40% imported grain

The summary shows that in terms of local costs and prices that people are willing to pay, there is not much to choose between service or commercial milling (although the Net Present Value of commercial milling is higher because of much higher gross benefits). Changing the assumption to one of a foreign exchange constraint reduces the rate of return to service milling, but increases the return to commercial operations. In simple terms this is because service milling involves substituting a service that has some F.E. costs (machine-processing) for one that has

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none (hand-processing). Whereas, in the context of a basic food deficit commercial milling involves substituting a product that has some F.E. costs (locally milled grain) for one that has 100 percent F.E. content (imported flour). In the first place there is an addition to F.E. spending with no saving; in the second, there is a considerable saving to offset the increasing F.E. expenditure. Milled local grain has, of course, a much lower F.E. content than milled imported grain and therefore the rate of return is much higher.

Thus when F.E. is an important consideration, commercial milling is more attractive than service milling, and it is much better to mill locally-produced than imported grain.

AGGREGATE EFFECT

An attempt is made in Annex 4 to estimate the overall rate of return to the grain milling R & D effort in Botswana from 1976 to date, using the actual and projected data in Table 2 on grain processed. Costs are assumed to have started in 1976, with the first project, and the accumulated benefits from work done prior to that in Nigeria and Canada are assumed to be costless to Botswana. The lack of data requires some heroic assumptions to be made about the cost of resources used during the research phase that should be charged to the whole program. Similarly, the cost of resources that will be required in terms of administrative and technical support to maintain the development momentum is not easy to estimate. However, the projection of benefits is based only on the information in Table 2, which refers to the 17 mills established and operating as of January, 1982; it does not include an estimate of output from the units that will undoubdtedly be established in 1982 and subsequently, and which will tend to reduce the per unit "overhead" administrative and technical costs. This factor, together with the conservative projections of throughput of existing mills and

value of benefits, lend confidence to the overall results, which are:

Internal rate of return	20%
Net Present Value (12%)	725,000 Pula (Can. $1,021,000)

This analysis supports the general conclusion that the sorghum milling R & D effort in Botswana with which IDRC has been associated has had and is having a positive development effect on society. The principal beneficiaries are the women and children who would otherwise have to process the daily family food by hand, and the Botswana consumer who is able to exercise his or her preference for local produce over imported flour.

This conclusion should not be surprising since the case study was picked deliberately on the basis of previous existing evidence that a development impact had occurred subsequent to the research phase and that the impact was probably positive. In order to extract the maximum benefit from the evaluation it is worth considering the main causal factors, or determinants of the successful progression from research to positive development effect. It is felt that as much can be learnt, and perhaps with greater confidence, from occasions when "things have gone right" as from when they have not, and an identification and discussion of determinants is the subject of the next section.

(3) Determinants

Project origins: As described earlier, the sorghum milling R & D effort in Botswana had its origins in a Botswana government development policy objective of "economic independence" (National Development Plan, 1979-85) and, more specifically, a request from the Ministry of Agriculture to BAMB to investigate sorghum processing possibilities as part of a means to this end. Thus, although it would be an exaggeration to say that

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IDRC "responded" in the sense of remaining inactive until a request for assistance was received, a principal determinant of successful development work was present in the form of strong government commitment and active support. In this context, the technology and the kind of support that the Centre was seeking to offer fitted well.

Also, the local commitment has been comprehensive, and the government has taken steps to remove constraints and facilitate development in all the necessary areas: production, pricing, marketing, trade, and processing.

This tends to illustrate the importance of maintaining the Centre's operating philosophy of avoiding pushing pre-ordained packages of assistance onto recipients. Particularly when a specific item of technology, such as the dehuller, is closely identified with IDRC support, there is a risk that this "solution" begins to look for a problem; consequently there is a need to keep a clear focus on responding to a local commitment to address a particular problem. The Centre must also be fully aware of the dimensions of the problem that need to be examined in order to be sure that the technology has a good chance of making a positive contribution. In some countries, the part of the system in most need of technological advance may be drying and/or storage, and not processing.

Consumer preference: A second key determinant of the positive development effect is the strong local demand for sorghum and especially products derived from local sorghums as opposed to imports. In many parts of Africa, the shift from rural/subsistence to urban/cash economies is associated with a shift in preference away from traditional grains to maize, rice and wheat. In Botswana, it appears that the shift in consumption from sorghum to maize has (at least in part) not been

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accompanied by an irrevocable change in preference. Clearly commercial milling of local produce will have little chance of developing unless the consumers who buy their food rather than producing it genuinely prefer local flour, or unless the local product is cheaper.

The preference of Botswana women not to have to hand-pound their own grain is an obvious determinant of the rapid acceptance of the system. This can be contrasted with Senegal, where women give a much higher priority to grinding millet and will arrive with grain already dehulled by hand for milling: they are more prepared to pay for grinding than dehulling.

Institution: It is hard to put these determinants in order of importance, and perhaps it would be fruitless, since if any one was absent, it is unlikely that anything significant would occur. Certainly, the Rural Industries Innovation Centre (RIIC) is an essential factor. It could have been grouped with the other manifestations of government support but is considered important enough for separate discussion. There are three main aspects of the RIIC that should be mentioned. First, the RIIC has the capacity to conduct research and field testing of various prototypes of small-scale rural technologies and to produce a proven item in sufficient numbers to satisfy potential demand in the country within a relatively short period. If the "D" in R & D stands for development in the sense of manufacture and dissemination of a technology, this means that both the R and D of the dehuller and the system into which it fits are conducted by one organization. This has been critical to the rapid sequence of events in Botswana. Second, the strong government links that the institution has to the Ministry of Commerce and Industry means that the largely expatriate technical staff of RIIC channel their efforts to areas of particular concern to the government. Third, the long term commitment to core support of RIIC by the Friedrich

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Ebert Foundation provided the essential infrastructure for the implementation of the IDRC-supported project, and the training, technical and administrative back-up for the subsequent development work.

Use of expatriates: It should also be noted here that the range of specialist technical and professional skills required to develop and disseminate a technology such as the milling system is not available in Bostwana, and the role of expatriates has been central.

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III CONCLUSIONS

1. The data used in the analysis is incomplete and imperfect but the calculations are based on actual events that have occurred and actual milling systems that are functioning. However, visual evidence and impressions are as important as dry data in making judgements about development, and to support the analysis is a strong impression of interest, enthusiasm and commitment. This supports the conclusion that the net effect of the sorghum milling effort on the social and economic welfare of Botswana has been and will be positive. Insofar as such an effect can be reduced to simple numbers, the Net Present Value of the sum of all research and development investment since 1976 is estimated to be about Can. $1,000,000 (at 12%), with a Rate of Return of 20 percent. Up to the point where local demand is satisfied, the Net Present Value will be increased for each additional mill brought into service*.

   The extent of local demand is hard to ascertain, and there are several conflicting estimates. A UNIDO Feasibility Study on sorghum milling was done in 1980, but is unavailable at the time of writing. The key variables upon which an estimate of the potential demand for the dehulling and milling units depends are:

   - effective demand for service milling of local production
   - extent to which local sorghum flour can replace other products
   - average annual throughput of service and commercial units
   - domestic production capacity of sorghum.

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* Any sales of milling systems to other countries will not bring significant benefits to the Botswana economy but will provide useful revenue for RIIC. Interest has been expressed by Sudan, Malawi, Tanzania and Zimbabwe.

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At the moment, the distribution of units is not following any formal master plan, but purchasers are advised of existing local milling capacity in the area where they intend to establish a mill. The basic investment decision is left mainly to the purchaser. As the limit of local potential is approached, it may be necessary to substantiate the advice given to would-be investors with more reliable information on production, consumption and throughput of existing mills in specific locations.

The cost-benefit analysis serves to illustrate the sensitivity of the milling development to two main variables: foreign exchange and time.

As already mentioned, there are no foreign exchange (F.E.) savings associated with service milling, whereas both capital and operating costs contain imported elements. Also, commercial milling by itself cannot be expected to save foreign exchange, and the import cost elements of storage, transport, and packaging are significant. Therefore in circumstances where foreign exchange is a serious problem, policy-makers need to be aware of the implications of widespread adoption of this technology. Belief in the non-monetary benefits of service milling would need to be strong; and the promotion of commercial milling would need to be part of an integrated package of appropriate production, marketing, pricing and trade policies, so that there are good prospects of F.E. savings from increased production and processing of local grains to offset the F.E. costs of milling.

The Botswana experience has been one of a very rapid transition from research to adoption: the first project began in 1976 and by 1981, 14 milling units were in operation. One of the main determinants that made this possible was the capacity of RIIC to do research on, to manufacture, and to extend the technology. If these functions had had to be carried out by different organizations, or if for some reason there had been a lag of, say five years between prototype testing and

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adoption on the scale that now prevails, the overall rate of return drops to about 10 percent and the Net Present Value at 12% becomes negative. The Botswana case might be said to be exceptional and these rough calculations should not lead to the conclusion that any project with a slower rate of transition will not have positive effects. However, they do support the contention that time is the essence of development. For highly specific technology R & D, such as that required to adapt and promote the adoption of the dehuller, a rapid transition from problem-oriented research to implementation of the solution is important.

2. Just as the transition in time has been rapid, so has the transition in technology been revolutionary: from wooden mortar and pestle to diesel engines driving complex hardware. As might be expected there have been teething problems in the field; e.g. the drive shaft, the rubber lining and the carborundum stones of the dehuller, have worn out at unexpectedly fast rates. The difficulties are partly due to inadequate operation and maintenance skills and partly design faults, although the balance between the two is uncertain. Unquestionably, for development momentum to be sustained, intensive operator training; adherence to maintenance schedules; and regular technical back-up services are essential. At present, the capacity of RIIC to provide the latter is stretched to the limit. To the extent that the design of the dehuller could be modified to eliminate teething troubles and decrease its sensitivity to inexperienced operators, the possibility of more research and therefore of further IDRC support is raised. If not for this specific project, it is an important general policy question for the Centre: how to recognize when to back out and leave local resources to cope, and when to maintain support in order to consolidate a development path?

3. Much of the previous discussion illustrates an important point about the role of research in development and the utilization of the results of IDRC-supported projects. It is clear from this case that, even with

an identifiable item of technology, development does not "happen" along a simple, single track from research project to widespread adoption. Nor does a single research project cause a development effect. Many elements have to coincide, some in the category of political, physical or cultural environment; some under the headings of public policy and private decisions; and some related to the application of existing knowledge together with new knowledge generated by research. The best that any one research project can hope for is to provide a missing element and to be associated with, rather than cause, a positive development.

In order to increase the possibility of such positive associations occurring, the lessons from this particular case would seem to be:

(a) to be confident about the significance of the problem and the appropriateness of the solution, and specifically that

- dehulling is a limiting constraint and that it is perceived as such by rural people as well as policy-makers,
- there is a strong preference for local flour,
- there is sufficient local production in sufficient concentrations to make machine processing feasible, especially in cases where F.E. is limiting;

(b) the presence of the other determinants of positive development, principally

- local government commitment and active support where appropriate in production, marketing, pricing and trade policy,
- the right institutional infrastructure for research adaptation, manufacture and distribution, and
- operator training and technical back-up services.

Clearly no recipient could offer guarantees on all of the above, nor could a development research donor insist on them before offering support. However, detailed consideration of such issues, with preliminary investigation work as necessary should be an integral component of the dialogue preceding assistance.

Postscript on Methodology

The method used in this report to analyse the development effect is a simplified form of "social benefit-cost analysis." The term "social" is traditionally used to signify that the values of costs and benefits are based on estimates of "real" value to society, which may or may not be the same as money prices currently paid. The classic illustration of this is the case of unskilled labour in a setting of chronic unemployment. A new project using previously unemployed labour will have to pay the going wage, but that may be an overstatement of the cost to society of doing so: if idle labour is drawn into productive employment, the "real" cost to society in terms of lost output may be close to zero. Decision-makers wishing to select projects that tend to reduce unemployment, may require that they are favoured by costing labour at lower than the cash wage (i.e. by using a "shadow" wage rate).

The merits and deficiencies of this technique are covered by an extensive literature, but a few comments on this particular case are in order.

(a) With the exception of some benefits and foreign exchange sensitivity tests, current market prices have been used in the analysis. Therefore the financial rates of return should not be significantly different from the social rates. However, some financial analyses of mill units do not show the level of profitability that would be suggested by social rates of return of 30 percent. There are two main reasons: first, the financial analyses include both depreciation, interest and loan repayment on the cost side, thereby double-counting capital to an extent that is not done in cost-benefit analysis. Second, insofar as the valuation of benefits in the social benefit-cost analysis is higher than the market price, e.g. 3.5 t per kg for service milling compared with a charge of 3.0t at most mills, the lower financial rates

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of return indicate that most of the social benefits are being captured by the consumers and not by the owner-operators.

(b) It is potentially misleading to let the judgement of a complex operation rest on a single figure, such as a Net Present Value. Many assumptions have to be made on the way to arriving at such a figure, most of them about future events, and any one of which could significantly change the end result. Therefore these criteria should not be used to make absolute judgements about the desirability or otherwise of projects. Apart from data problems, the criteria are of little value in isolation and in an ideal world would be used to select out a set of the most socially profitable projects. The technique is most useful for making comparisons, e.g. between a service mill and a commercial mill, and for testing the sensitivity of the social profitability to changes in key variables, such as foreign exchange costs or rates of throughput. Also, the framework and concepts of the social benefit-cost "model" necessitate a disciplined and comprehensive consideration of what really are the costs and benefits of a particular activity to the society in question. This often leads to identification of the most critical policy decisions that must be made in order to secure the potential benefits.

(c) Further caveats are needed on the overall rate of return to sorghum milling R & D, although not on the general conclusions to which the analysis contributed. The literature is liberally endowed with work showing high rates of return to agricultural research, particularly to plant breeding research. A great deal of the analysis is conceptually unsound, weakly documented and of minimal assistance to decision-making. First, the results have rarely been used to compare the desirability of different avenues of research, either within agriculture, or between agriculture and other sectors. They have perhaps tended to be employed

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to support the notion that agricultural research per se is "a good thing," which may be generally true but is not especially helpful to research planning and management. It tends to generate and perpetuate unrealistic expectations about the powers of agricultural scientists, as if they alone can solve food problems and therefore have somehow failed when the problems remain unsolved. The eminent agricultural scientist A.H. Bunting, has written recently on this subject*

> "Agricultural research is the only area of applied science known to me in which a practitioner is not only trusted but expected to improve the output of a system without finding out first how it actually works now."

Second, the published works reveal sufficiently little of their detailed analysis to support the suspicion that too few of the extra non-research resources that are necessary to produce the production and consumption benefits are included in the calculations. All of the benefits tend to be credited to R & D. Also, many of the studies, like the present one, are of known success stories and therefore show high marginal rates of return without studying the composition of the average rate of return. One of the pioneers of this work, Z. Griliches, uses an oil exploration analogy to make this point**:

> "What is the point of calculating the rate of return on one of the outstanding technological successes of the century (hybrid corn)? Obviously it will be high. What we would like to have is an estimate that would also include the cost of all the "dry holes" that were drilled before hybrid corn was struck."

However, it is suggested that to follow such a proposal in this case would yield little benefit. To analyse all rural technology R & D in Botswana, or all sorghum milling projects funded by IDRC, and to arrive at a single magic number would be extremely costly (apart from

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* Journal of Agricultural Economists 1981, Vol. 32, (3) p. 297.

** Journal of Political Economy 1958, Vol. 66, p. 426.

some considerable conceptual difficulties). It would only be of real value if it threw up insights into how to plan and organize all research in order to maximize the number of strikes and minimize the dry holes. Suggestions have already been offered in the conclusions on this area, and scarce evaluation resources would perhaps be better employed implementing them, supported by further case study work as appropriate.

Some key documents with overview and evaluative content on Africa grain milling projects supported by IDRC.

1. Grain Milling and Utilization (Nigeria): An Evaluation, W.D. Daniels, AFNS, 1978.

2. Feasibility Study on Food Grain Processing in Nigeria, by Study Group on Nigerian Grain Processing, June 1978.

3. Sorghum Milling - a New Agro-Industry for Botswana, R.S. Forrest and G. Yaciuk (IDRC - MR30) 1980.

4. Consumer preference study in grain utilization, J. Steckle and L. Ewanyk (IDRC - 022e), 1974.

5. Final Report, Sorghum Milling Botswana II (IDRC 3-P-78-0023), 1980.

6. The Impact of Sorghum Mills on Four Rural Communities in Botswana, D. Narayan-Parker, RIIC, 1981.

7. Food Systems: an account of the post production systems program supported by IDRC (IDRC 146e), 1979.

8. An End to Pounding, Paul Eastman (IDRC 152e), 1980.

9. Post-Harvest Technology in Senegal: Current Practices and Future Needs, G. and A.D. Yaciuk (1978).

10. The Post-Harvest Food Grain Industry in Semi-Arid Africa, R.S. Forrest, T.A. Peterson, J.J. Hogue, J. Steckle, IDRC 1975.

11. A Decade of Learning. AFNS: The First Ten Years (IDRC 170e) 1981.

12. "tlhobolo letshilo ya mabele" - the machine that dehulls and grinds sorghum for us. RIIC, Kanye, December 1979.

Plus: Trip reports, progress reports and final reports on each project contain important evaluative information.

Cost-benefit analysis of a service mill

COSTS

		Life(years)	Pula	F.E.%
Capital:	Dehuller, Mill, Lister engine	8	9,177	86
	Building	16	4,000	50
	Vehicle (second-hand)	4	15,000	100

Fixed operating:	Pula per year
Management resources (P 400/month)	4,800
Administrative support, supplies, etc. (P 50/month)	600
3 operators/assistants (P 70/month each)	2,520
Insurance, electricity, clothing, miscellaneous	500
Vehicle (P 100/month)	1,200
Spare parts, supplies	1,500
Labour cost: maintenance and repairs	750
	11,870

Variable operating:

Diesel: 1 litre/110 kg grain @ 55t/litre — Pula 5.00/tonne

THROUGHPUT

year	1	2	3 onwards
Down time (days/month)	3	3	2
Total working days/year	102	204	216
Daily throughput (tonnes)	1.5	2.0	2.2
Annual throughput(tonnes)	153	408	475

BENEFITS

(1) Willingness to pay for service: 3.5t per kg grain.

Note: This is a minimum figure for this category of benefits since customers are also willing to pay for transport costs to and from the mill, and the time that the whole process takes.

(2) Better extraction rate than traditional hand method:

Traditional

1.0 kg grain yields	0.70 kg flour @ 31t/kg	=	21.7t
	+0.30 kg bran @ 7t/kg*	=	2.1t
	Total value of products		23.8t

Mechanical

1.0 kg grain yields	0.80 kg flour @ 31t/kg	=	24.8t
	+0.20 kg bran @ 6t/kg	=	.12t
	Total value of products		26.0t

Difference in total value of products = 2.2t/kg

* The bran produced by the traditional method carries more of the pericarp with it and is assumed to have a higher nutritional value. It is valued at 1.0t/kg more than the bran from mechanical dehulling.

Total Benefits:	(1) willingness to pay	3.5
	(2) better extraction rate	2.2
		5.7t/kg

The following table lays out a projection of costs and benefits over a 16-year period, which is assumed to be the life of the longest lived asset - the building. During that time, the milling equipment is assumed to be replaced once and the vehicle three times. It is also assumed that two-thirds of the total annual fixed operating costs are incurred in Year 1 when the mill is set up.

With these assumptions, the Net Present Value is 27,000 Pula or Can $38,000 and the Rate of Return is 30 percent.

Table 1: Cost-benefit analysis (values as above)

Year	Costs				Benefits	Net Benefits	Present Value at	
	Capital	Fixed	Variable	Total			12%	30%
				('000 pula)				
1	28	8	1	37	9	(28)	(25)	(22)
2		12	2	14	23	9	7	5
3		12	3	15	27	12	9	5
4		12	3	15	27	12	8	4
5	15	12	3	30	27	(3)	(2)	(1)
6		12	3	15	27	12	6	2
7		12	3	15	27	12	5	2
8		12	3	15	27	12	5	2
9	24	12	3	39	27	(12)	(4)	(-)
10		12	3	15	27	12	4	1
11		12	3	15	27	12	3	1
12		12	3	15	27	12	3	1
13	15	12	3	30	27	(3)	(1)	(-)
14		12	3	15	27	12	2	-
15		12	3	15	27	12	2	-
16		12	3	15	27	12	2	-
					Net Present Value		+24	0
					Rate of Return		-	30%

Table 2: Cost-benefit analysis : shadow foreign exchange rate 1.25.

Year	Costs				Benefits	Net Benefits	Present Value at	
	Capital	Fixed	Variable	Total			12%	18%
				('000 pula)				
1	34	8	1	43	9	(34)	(30)	(29)
2		13	3	16	23	7	6	5
3		13	3	16	27	11	8	7
4		13	3	16	27	11	7	6
5	19	13	3	35	27	(8)	(5)	(3)
6		13	3	16	27	11	6	4
7		13	3	16	27	11	5	3
8		13	3	16	27	11	4	3
9	30	13	3	46	27	(19)	(7)	(4)
10		13	3	16	27	11	4	2
11		13	3	16	27	11	3	2
12		13	3	16	27	11	3	2
13	19	13	3	35	27	(8)	(2)	(1)
14		13	3	16	27	11	2	1
15		13	3	16	27	11	2	1
16		13	3	16	27	11	2	1
					Net Present Value		+8	0
					Rate of Return			18%

Cost-benefit analysis of a commercial mill

COSTS: as for a service mill, plus the following

			Pula
Capital	:	Storage	4,000
		Transport	15,000
		Packaging unit	2,000
Fixed operating	:	Administration	1,200
		Mechanic (replaces an operator)	720
		Extra labour	840
		Transport	1,200
			3,960

Variable operating:	Bags for grain	3.50	Pula/tonne
	Packaging supplies	19.20	Pula/tonne
	Insecticide, miscellaneous	10.00	Pula/tonne
		32.70	Pula/tonne

THROUGHPUT

Year:	1	2	3
Down time (days/month)	3	2	2
Working days per year	102	216	216
Daily throughput (tonnes)	3	4	5
Annual throughput (Tonnes)	306	864	1080

BENEFITS

1.0 tonne of grain @ 180 Pula:	800 kg flour @ 30t	=	240 Pula
	200 kg bran @ 6t	=	12 Pula
			252 Pula

Value added per tonne of grain = 72 Pula.

Table 1: Cost-benefit analysis (values as above)

Year	Costs				Benefits	Net Benefits	Present Value at	
	Capital	Fixed	Variable	Total			12%	26%
				('000 pula)				
1	49	11	12	72	22	(50)	(45)	(40)
2		16	33	49	62	13	10	8
3		16	41	57	78	21	15	10
4		16	41	57	78	21	13	8
5	32	16	41	89	78	(11)	(6)	(3)
6		16	41	57	78	21	11	5
7		16	41	57	78	21	9	4
8		16	41	57	78	21	8	3
9	41	16	41	98	78	(20)	(7)	(3)
10		16	41	57	78	21	7	2
11		16	41	57	78	21	6	2
12		16	41	57	78	21	5	1
13	32	16	41	89	78	(11)	(3)	(1)
14		16	41	57	78	21	4	1
15		16	41	57	78	21	4	1
16		16	41	57	78	21	3	-
					Net Present Value		+34	0
					Rate of Return			26%

2. BENEFITS : Assuming a shadow foreign exchange (F.E.) rate of 1.25.

Import parity price for sorghum flour is 28t/kg. Therefore every kilo of locally-produced flour is worth 35t (28 x 1.25) at the shadow F.E. rate. The supply price at factor cost of local grain is assumed to have a 10% F.E. component and is valued at 185 Pula per tonne, (assumed only locally produced grain is milled).

1.0 tonne of grain	: 800 kg. flour @ 35t =	280 pula
@ 185 Pula	: 200 kg. bran @ 6t =	12
		292 pula

Value added per tonne of grain = 107 Pula

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Table 2: Cost-benefit analysis : shadow foreign exchange rate 1.25

Year	Costs				Benefits	Net Benefits	Present Value at	
	Capital	Fixed	Variable	Total			12%	79%
				('000 pula)				
1	60	11	14	85	33	(52)	(46)	(29)
2		17	41	58	92	34	27	11
3		17	51	68	116	48	34	8
4		17	51	68	116	48	31	5
5	38	17	51	89	116	27	15	2
6		17	51	68	116	48	24	1
7		17	51	68	116	48	22	1
8		17	51	68	116	48	19	1
9	50	17	51	118	116	(2)	(1)	-
10		17	51	68	116	48	15	
11		17	51	68	116	48	14	
12		17	51	68	116	48	12	
13	38	17	51	89	116	27	6	
14		17	51	68	116	48	10	
15		17	51	68	116	48	9	
16		17	51	68	116	48	8	
					Net Present Value		+199	0
					Rate of Return			79%

3. BENEFITS

This analysis assumes that only locally-produced sorghum is milled. If imported grain is used, the picture changes radically. Then the full cost of the grain (163.50 Pula/tonne) is subject to the shadow F.E. rate, (instead of only 10% of the cost of production in the case of local grain). In this case the value of benefits drops to 90 Pula per tonne.

1.0 tonne of grain @ 204 Pula → :800 kg. flour @ 35t = 280 Pula
:200 kg. bran @ 6t = 12 Pula
294 Pula

Value added per tonne of grain = 90 Pula

Under these assumptions, the Net Present Value (12%) is 85,000 Pula, and the Rate of Return is 40%.

Cost-benefit analysis of sorghum milling R&D in Botswana

Assumptions

Capital and operating costs for each unit established are taken from the service and commercial mill models in the two previous annexes. The capital costs of Pitsane, Gabane and Kanye (RIIC) are included in the total project costs from 1976 to 1979.

Throughput

The total throughput as given in Table 2 in the main text is assumed to be divided between commercial and service milling, as follows:

(tonnes of grain)	1977	1978	1979	1980	1981	1982	1983 onwards
milled commercially*	85	1330	1923	2479	3127	3828	3868
service milled	-	-	237	843	3685	6960	7320
	85	1330	2160	3322	6812	10788	11188

* Pitsane, Kanye, Gabane, Palapye.

Overhead Support

An estimate of 50,000 Pula per year is included for 1976 to 1983 inclusive to cover inputs from RIIC, Rural Industries Promotion and the government. Subsequently, the 17 units in operation are costed at a total of 120,000 Pula per year for management, administration and technical input for maintenance and repairs.

Table 1: Cost-benefit analysis of sorghum milling R&D Since 1976

Year	R&D	Over-head	Costs				Benefits			Net Benefits	
			Capital	Fixed	Variable	Total	Commercial	Service	Total	Current	P.V.12%
						('000 pula)					
1976	76	50				126	-	-	-	(126)	(249)
1977	40	50		3	3	96	6	-	6	(90)	(159)
1978	58	50		18	50	176	96	-	96	(80)	(126)
1979	26	50		38	73	187	138	14	152	(35)	(49)
1980		50	49	69	97	265	178	48	226	(39)	(49)
1981		50	273	153	136	612	225	210	435	(177)	(198)
1982		50	84	222	179	535	276	397	673	138	138
1983		50		222	183	455	278	417	695	240	214
1984			80	222	183	485	278	417	695	210	167
1985			91	222	183	496	278	417	695	199	142
1986			80	222	183	485	278	417	695	210	133
1987			98	222	183	503	278	417	695	192	109
1988			91	222	183	496	278	417	695	199	101
1989			174	222	183	579	278	417	695	116	52
1990			107	222	183	512	278	417	695	183	78
1991			80	222	183	485	278	417	695	210	
1992			80	222	183	485	278	417	695	210	
1993			80	222	183	485	278	417	695	210	
1994			80	222	183	485	278	417	695	210	421
1995			80	222	183	485	278	417	695	210	
1996			80	222	183	485	278	417	695	210	
1997			80	222	183	485	278	417	695	210	
1998			80	222	183	485	278	417	695	210	

Net Present Value = + 725

Rate of Return 20%